

The EGRBAC Model for Smart Home IoT

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Abstract—The Internet of Things (IoT) is enabling smart houses, where multiple users with complex social relationships interact with smart devices. This requires sophisticated access control specification and enforcement models, that are currently lacking. In this paper, we introduce the extended generalized role based access control (EGRBAC) model for smart home IoT. We provide a formal definition for EGRBAC and illustrate its features with a use case. A proof-of-concept demonstration utilizing AWS-IoT Greengrass is discussed in the appendix. EGRBAC is a first step in developing a comprehensive family of access control models for smart home IoT.

Index Terms—Access Control, Smart home IoT, RBAC

I. INTRODUCTION AND MOTIVATION

The smart home is one of the most popular domains for deploying the Internet of Things (IoT), envisioned as a global network of machines and devices capable of interacting with each other [1]. Nevertheless, surprisingly little attention has been paid to access control policy specification and enforcement in home IoT [2].

Authorization issues in home IoT are significantly different from traditional domains in three main aspects. First, we have many users who use the same device, for example a smart door lock. Second, house occupants usually have complex social relationships, which introduces a new threat model, such as an annoying child trying to control the smart light in a sibling's room, or a current or ex-partner trying to abuse one or all house residents [2], [3]. Another major characteristic of IoT devices is that the majority lack a screen and keyboard making them hands free for convenience while making access control more challenging. These characteristics suggest the need for a dynamic and fine-grained access control model for smart home IoT, where users and resources are constrained [4].

In this paper we describe our first access control model for smart home IoT. Why focus on the home rather than general IoT? We believe that smart homes provide a rich yet

scoped environment where we have a limited number of users who want to access a limited number of shared constrained smart things with different privileges. Such scoping is useful to develop an initial set of models. In future these scoped models can be adapted and evolved to address the access control requirements of other IoT domains, such as a smart office, a smart classroom or a smart city.

Our model is inspired by the early work of Covington et al [5] who extended role-based access control (RBAC) to the smart home environment in a model called Generalized RBAC (GRBAC). We call our model the extended GRBAC (EGRBAC) model. EGRBAC, like GRBAC, focuses on user to device (U-D) interaction, leaving device to device (D-D) for future work. One goal of EGRBAC is to investigate the limitations of applying RBAC concepts in home IoT. In future work we plan to develop models that incorporate concepts of attribute-based access control (ABAC) and demonstrate their benefits relative to EGRBAC.

The paper is organized as follows. Section II identifies desirable criteria for smart home IoT access control models. An analysis and review of related work is given in Section III. Section IV provides an overview of GRBAC [5] and of the architecture that we adopt to enforce EGRBAC. Section V describes our threat model. In Section VI, we introduce EGRBAC along with a use case scenario, analyze EGRBAC against our proposed criteria and discuss the limitations of EGRBAC. A proof-of-concept demonstration is discussed in Section A. Section VIII concludes the paper.

II. CRITERIA FOR HOME IoT ACCESS CONTROL

We begin by proposing at least the following criteria for home IoT access control models (whether U-D, D-D or both), based in part on He et al [2] and Ouddah et al [4].

- 1) The model should be dynamic so as to capture environment and object contextual information.
- 2) The model should be fine-grained so that a subset of the

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TABLE I: Characteristics of IoT Access Control Models

Model Type	Model	U-D or D-D	Dynamic	Fine Grained	Suitable for constrained home environment	Designed or interpreted for smart home IoT	Implemented	Provides a formal Access Control Model
RBAC Model	EGRBAC, this paper	U-D	yes	yes	yes	yes	yes	yes
RBAC Model	GRBAC, Covington et al [5]	U-D	yes	no	yes	yes	no	no
RBAC Model	Zhang et al [6]	U-D and D-D	yes	yes	yes	no	no	yes
RBAC Model	Barka et al [7]	U-D and D-D	no	yes	no	no	no	utilizes RBAC [8]
RBAC Model	Jindou et al [9]	U-D	no	yes	no	no	yes	yes
RBAC Model	Kaiwen et al [10]	U-D	yes	yes	yes	no	no	yes
RBAC Model	Lin et al [11]	U-D	no	yes	yes	no	no	no
ABAC Model	Ye et al [12]	U-D and D-D	yes	no	no	no	no	yes
TABAC Model	Bandara et al [13]	U-D	no	yes	yes	no	yes	utilizes XACML [14]
ABAC Model	Mutsivangwa et al [15]	U-D	N/A	N/A	no	no	no	no
ABAC Model	Xie et al [16]	U-D and D-D	N/A	N/A	no	no	no	no
UCON Model	Martincelli et al [17]	U-D	yes	yes	yes	no	yes	utilizes U-XACML [18], [19]
CapBAC Model	A survey is provided in [4]	Not adequate for the constrained environment of smart homes as explained in Section III.						

functionality of a device can be authorized rather than all-or-nothing access to the device.

- 3) Smart things in homes are usually limited in term of computational power, and storage. Furthermore, a generic interoperability standard among IoT devices is still missing. Accordingly, the model should be suitable for constrained smart home devices. In other words, it should not require extensive computation or communication by those constrained devices.
- 4) The model should be constructed specifically for smart home IoT, or otherwise be interpreted for the smart home domain such as by appropriate use cases, to ensure that the model is suitable for smart home different specifications such as, social relationships between house members, cost effectiveness, usability, and so on.
- 5) The model should be demonstrated in a proof-of-concept to be credible using commercially available technology with necessary enhancements.
- 6) The model should have a formal definition, so that there is a precise and rigorous specification of the intended behavior.

We analyzed IoT access control models proposed in the literature based on these six characteristics. A summary of the analysis is provided in Table I. In this table we only included access control models that govern user to device access, since this is the scope of our model. From the table we can notice that except for our model (summarized in the first row), no model satisfies all desired characteristics. Furthermore, surprisingly, except for EGRBAC and GRBAC, no model was designed or interpreted explicitly for smart home environment. In Section VI we justify the evaluation of EGRBAC according to the characteristics in this table.

III. RELATED WORK

Smart home IoT has been extensively studied by security experts. Many researchers have focused on identifying IoT security and privacy vulnerabilities [20]–[27]. Moreover, to analyze IoT security challenges and security design issues in particular, many researchers have conducted studies of IoT

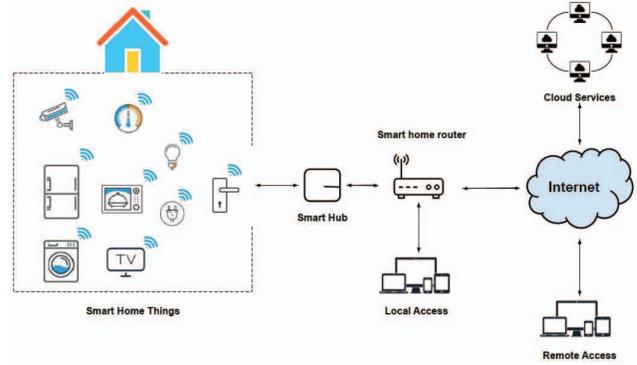


Fig. 1: EGRBAC Architecture (adapted from [42])

frameworks (e.g. [20], [24], [28]–[30]). One of the critical security services in IoT that mostly all researchers agree upon is access control. Ouaddah et al [4] have extensively investigated access control in IoT environments. The IoT access control models in Table I are based on RBAC [31]–[33], ABAC [34], [35], UCON [36] or CapBAC [4]. Our assessment of these models with respect to the above criteria is summarized in the table. Going beyond the models in this table, some approaches based on blockchain technology have been proposed (e.g. [37]–[39]). However, as [38] described, the blockchain technology has some technical characteristics that could limit its applicability such as, cryptocurrency fees and slow processing time. The authors in [4], [40], [41] provide surveys on additional models beyond Table I such as focussed on D-D only. However, none of them meet all the criteria of the table.

IV. BACKGROUND

A. The GRBAC Model

Covington et al introduced the Generalized Role-Based Access Control (GRBAC) model [5]. In addition to the usual concept of *User Roles*, GRBAC incorporates the notion of *Object Roles* and *Environment Roles*. A user role is analogous to the traditional RBAC role. An object role is defined as the properties of the resources in the system, such as images, source code, streaming videos, devices. An environment role is defined as the environment state during access. Covington et al [43] subsequently described an architecture to support environment roles activation according to the current environment conditions. They also provided a high level but incomplete formal definition of environment role based access control model, building upon [8]. They did not formalize the object role part of GRBAC. In this paper, we provide a more fine grained model with a detailed formalization. However, we used devices instead of objects since it is more appropriate to smart homes.

B. IOT Based Smart Home Architecture

The smart home IoT architecture that we adopted for EGRBAC enforcement was introduced by Geneiatakis et al [42]. It is illustrated in Fig. 1. The IoT devices are connected to a corresponding hub and are not directly accessed by other devices or by users. The intermediate hub is responsible for

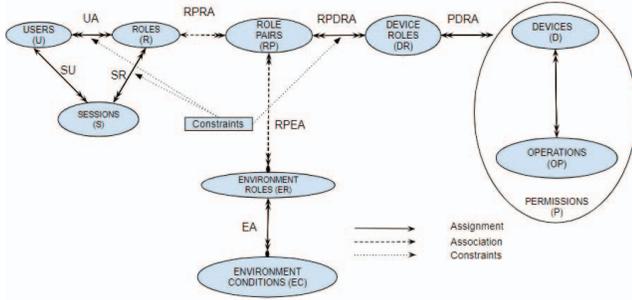


Fig. 2: EGRBAC Model Components

providing Internet connectivity, since the majority of commercial sensors do not provide direct Internet connectivity. The communication between the smart hub and the IoT devices is usually wireless, through different protocols such as Zigbee, Z-Wave and WiFi. In order to connect the smart IoT devices optionally, to the outside world, the hub is connected to the home's routers via an Ethernet or a Wi-Fi interface. In general there are two types of access. In local access users directly interact with the IoT devices through the connectivity services provided by the hub. In remote access users access IoT devices via cloud services, which in turn communicate with the smart hub via the Internet to access these devices.

V. THREAT MODEL

In smart houses we recognize two types of adversaries [2]. First, an outside hacker who is trying to get digital or physical access to the house by exploiting system vulnerabilities. Second the household members themselves. These are insiders who have legitimate digital and physical access to the house, such as family members, guests, and workers. The motivation for legitimate users to break down the access control system of the smart home may vary from curiosity (e.g. a kid playing with oven setting), disturbing other family members (e.g. a kid locking his brothers outside the house), to disobedience (e.g. a kid is watching TV and he is not allowed to), or robbery (e.g. a worker trying to adjust the camera setting). Making sure that those legitimate users get access only to what they are authorized to by the house owner, is the central focus of our paper. We emphasize that authorized insiders who try to hack the access control system, or to break the IoT devices to get an unauthorized access to the system are outside the scope of our threat model.

VI. EGRBAC MODEL FOR SMART HOME IOT

In this section we define the EGRBAC (Extended Generalized Role-Based Access Control) model.

A. EGRBAC Formal Definition

Fig. 2 depicts the components of EGRBAC, and Table II formally defines these. Sets are shown as ovals in Fig. 2, while the binary relations amongst them are shown as directed arrows with the single arrow indicating “one” and the double arrow “many.” An arrow ending in a dot indicates a subset rather a single element of that set (as in one end of EA and RPEA). A solid arrow represents assignment, a dashed arrow indicates an

TABLE II: EGRBAC Model Formalization

Users, Roles and Sessions

- U, R and S are sets of users, roles and sessions respectively
- $UA \subseteq U \times R$, many to many users to role assignment (home owner specified)
- $SU \subseteq S \times U$, many to one sessions to user relation that assigns each session to a single user who controls the session
- $SR \subseteq S \times R$, many to many session to roles relation that assigns each session to a set of roles that can change under user control, where $(s_i, r_j) \in SR \Rightarrow (\exists u_k \in U)[(s_i, u_k) \in SU \wedge (u_k, r_j) \in UA]$; by definition of SU , u_k must be unique

Devices, Operations, Permissions and Device Roles

- D, OP, P and DR are sets of devices, operations, permissions and device roles respectively
- $P \subseteq D \times OP$, every permission is a device, operation pair (device manufacturer specified)
- $PDRA \subseteq P \times DR$, a many to many permissions to device roles assignment (home owner specified)

Environment Roles and Environment Conditions

- ER and EC are sets of environment roles and environment conditions respectively
- $EA \subseteq 2^{EC} \times ER$, many to many subsets of environment conditions to environment roles assignment (home owner specified)

Role Pairs

- $RP \subseteq R \times 2^{ER}$, a set of role pairs specifying all permissible combinations of a user role and subsets of environment roles (home owner specified); for every $rp = (r_i, ER_j) \in RP$, let $rp.r = r_i$ and $rp.ER = ER_j$
- $RPRA \subseteq RP \times R$, many to one role pairs to role association induced by RP , where $RPRA = \{(rp_m, r_n) \mid rp_m \in RP \wedge rp_m.r = r_n\}$
- $RPEA \subseteq RP \times 2^{ER}$, many to one environment roles to role pairs association induced by RP , where $RPEA = \{(rp_m, ER_n) \mid rp_m \in RP \wedge ER_n = rp_m.ER\}$

Role Pair Assignment

- $RPDRA \subseteq RP \times DR$, many to many role pairs to device roles assignment (home owner specified)

Constraints

Constraints are discussed in Section VI-C

Authorization Predicate

- The authorization predicate takes 4 inputs: session s_i , device d_j , operation op_k and set of active environment conditions EC_l ; a session s_i can access device d_j with operation op_k when the set of environment conditions EC_l is active iff the following predicate is true:

$$\begin{aligned}
 & (\exists (rp_m, dr_n) \in RPDRA) \\
 & [((d_j, op_k), dr_n) \in PDRA \wedge \\
 & (s_i, rp_m.r) \in SR \wedge \\
 & rp_m.ER \subseteq \{er \in ER \mid (\exists EC'_l \subseteq EC_l) \\
 & [(EC'_l, er) \in EA]\}]
 \end{aligned}$$

association via mathematical definitions, for example, RPRA and RPEA relations are determined by definition from RP and hence are associations rather than independent assignments. A dotted arrow represents constraints.

Users (U), Roles (R), and Sessions (S) are familiar sets in RBAC systems. A user is a human being who interacts with smart home devices as authorized. In context of smart homes, a role specifically represents the relationship between the user and the family, which encompasses parents, kids, neighbors and such [2]. The many-to-many UA relation specifies the assignment of users to roles. An example of a user with two different roles is a neighbor who is assigned the neighbor role, but also happens to be a plumber who needs temporary access to repair an appliance and so should have different set of privileges for that purpose in a worker role. Users establish sessions during which they may activate a subset of the roles they assigned to. A user might have multiple sessions active simultaneously. SU is a many to one relation that maps each session to its unique controlling user. SR is a many to many relations that maps each session to the set of roles associated with it.

A Device (D) is a smart home device such as a smart TV. Operations (OP) represent actions on devices as specified by device manufacturers. A permission is an approval to perform an operation on one device, i.e. it is a device, operation pair. The set of permissions P is a subset of $D \times OP$. In EGRBAC, Device Roles (DR) are means of categorizing permissions of different devices (different from GRBAC where Device Roles categorize devices including all their permissions). For example, we can categorize the dangerous permissions of various smart devices by creating a device role called dangerous devices and assign dangerous permissions (such as, turning on the oven, turning on the mower, and opening and closing the front door lock) to it. The many-to-many PDRA relation specifies this assignment.

Environment Roles (ER) are a GRBAC innovation representing environmental contexts, such as daytime/nighttime, and winter/summer. Environment roles are turned on/off (i.e., triggered) by Environment Conditions (EC) such as daylight, or weather. EA maps each environment role to a subset of EC. Suppose *Entertainment_Time* should be active on weekend evenings. We can use *weekends*, active during weekends, and *evenings*, active during evenings, and assign $(\{weekends, evenings\}, Entertainment_Time)$ to EA. Each role pair is a combination of a role and currently active environment roles. A role pair *rp* has a role part *rp.r* that is the single role associated with *rp*, and an environment role part *rp.ER* that is the subset of environment roles associated with *rp*. The permissible role pairs RP are specified as a subset of $R \times 2^{ER}$, since some ER subsets may not be meaningful. RPRA associates each role to one or more role pairs. RPEA associates each role pair to a subset of ER. RPDRA brings all these components together by assigning device roles to role pairs, and hence, for each role pair *rp*, the single role associated to it through RPRA can get access to all device roles assigned to it through RPDRA, when the set of environment

$$\begin{aligned}
U &= \{alex, bob, susan, james, julia\} \\
R &= \{kids, parents, babySitters, guests, neighbors\} \\
UA &= \{(alex, kids), (bob, parents), (susan, babySitters), \\
&\quad (james, guests), (julia, neighbors)\} \\
D &= \{TV, DVD, PlayStation, DoorLock, Oven\} \\
OP &= \{On, Off, PG, R, Lock, Unlock, On_{oven}, Off_{oven}\} \\
P_1 &= \{TV, DVD, PlayStation\} \times \{On, Off, PG, R\} \\
P_2 &= \{TV, DVD, PlayStation\} \times \{On, Off, PG\} \\
P_3 &= \{DoorLock\} \times \{Lock, Unlock\} \\
P_4 &= \{Oven\} \times \{On_{oven}, Off_{oven}\} \\
P &= P_1 \cup P_2 \cup P_3 \cup P_4 \\
DR &= \{Dangerous_Devices, Entertainment_Devices, \\
&\quad Kids_Friendly_Content\} \\
PDRA &= P_1 \times \{Entertainment_Devices\} \cup \\
&\quad P_2 \times \{Kids_Friendly_Content\} \\
&\quad (P_3 \cup P_4) \times \{Dangerous_Devices\} \\
EC &= \{weekends, evenings, TRUE\} \\
ER &= \{Entertainment_Time, Any_Time\} \\
EA &= \{(\{weekends, evenings\}, Entertainment_Time), \\
&\quad (TRUE, Any_Time)\} \\
RP &= \{(kids, \{Entertainment_Time\}), \\
&\quad (parents, \{Any_Time\}), \\
&\quad (babySitters, \{Any_Time\}), \\
&\quad (guests, \{Any_Time\}), \\
&\quad (neighbors, \{Any_Time\})\} \\
RPDRA &= \{((parents, \{Any_Time\}), Dangerous_Devices), \\
&\quad ((kids, \{Entertainment_Time\}), Kids_Friendly_Contents), \\
&\quad ((parents, \{Any_Time\}), Entertainment_Devices), \\
&\quad ((babySitters, \{Any_Time\}), Entertainment_Devices), \\
&\quad ((guests, \{Any_Time\}), Entertainment_Devices), \\
&\quad ((neighbors, \{Any_Time\}), Entertainment_Devices)\}
\end{aligned}$$

Fig. 3: Use Case 1 Configuration in EGRBAC

roles which are associated to *rp* through RPEA are active.

The main idea in EGRBAC as a whole is that a user is assigned a subset of roles and, according to the current active roles in a session and active environment roles, some role pairs will be active, whereby the user will get access to the permissions (not devices as in GRBAC) assigned to the device roles which are assigned to the current active role pairs.

The bottom part of Table II formalizes the authorization function of EGRBAC. Consider a session s_i which attempts to perform operation op_k on device d_j when the subset of environment conditions EC_l is active. This operation will succeed if and only if there is a role pair rp_m and device role dr_n assigned to each other in RPDRA such that the following conditions are true. (i) dr_n is assigned the permission (d_j, op_k) in PDRA. (ii) $rp_m.r$ is one of the active roles of s_i (as given in SR). (iii) Each environment role $er \in rp_m.ER$ is active because it is activated by a subset of the currently active environment conditions EC_l .

B. EGRBAC Use Case

We present a use case to illustrate the components and configurations of EGRBAC. The objective is as follows. (a) Allow kids access to a subset of capabilities (On, Off, PG, but not R) in entertainment devices (TV, DVD, and PlayStation) during weekend evenings only. (b) Authorize parents to use dangerous capabilities of dangerous devices (i.e lock and unlock the door lock, switch on and off the oven) at any time. (c) Authorize parents, babysitter, guests, and neighbors to use entertainment devices any time unconditionally.

EGRBAC can be configured as shown in Fig. 3 to achieve

this objective. The five users *alex*, *bob*, *susan*, *james*, and *julia*, are respectively assigned to roles *kids*, *parents*, *babysitters*, *guests* and *neighbors*. The devices comprise *DoorLock*, *Oven*, *TV*, *DVD* and *PlayStation*. Each device has different permissions as indicated in P_1 , P_3 and P_4 . Also P_2 is a subset of P_1 , restricted to *PG* content.

We have three device roles with *PDRA* assigning P_1 permissions to *Entertainment_Devices*, P_2 to *Kids_Friendly_Content*, and P_3 and P_4 to *Dangerous_Devices*. Three environment conditions, *weekends*, *evenings* and *TRUE* are defined to be respectively active on weekends, evenings and always. *EA* specifies that the environment role *Entertainment_Time* is active when both environment conditions *weekends* and *evenings* are active while *Any_Time* is always active.

RPDRA has the following assignments. The role pair (*parents*, {*Any_Time*}) is assigned to the device role *Dangerous_Devices*, whereby parents can use permissions P_3 and P_4 without environmental restrictions. The role pair (*kids*, {*Entertainment_Time*}) is assigned to the device role *Kids_Friendly_Content*, so that kids are restricted to P_2 permissions and only when the environment role *Entertainment_Time* is active. The role pairs (*parents*, {*Any_Time*}), (*babySitters*, {*Any_Time*}), (*guests*, {*Any_Time*}), (*neighbors*, {*Any_Time*}) are assigned to the device role *Entertainment_Devices* so that users with these roles can use all permissions on *Entertainment_Devices* at any time.

C. EGRBAC Constraints

An important component in EGRBAC is Constraints. A constraint is an invariant that must be maintained at all times. Constraints are an integral part of RBAC and ABAC models [8], [31], [44]. in EGRBAC, we define three types of constraints, as follows.

Permission-role constraint. These constraints prevent specific roles from access to specific permissions. In the use case above, the permissions embodied in the *Dangerous_Devices* role are assigned to the (*parents*, {*Any_Time*}) role pair in *RPDRA*. However, this does not prevent assignment of *Dangerous_Devices* to other role pairs, perhaps even to (*kids*, {*Any_Time*}). The latter assignment could happen inadvertently or maliciously. Permission-role constraints prevent such situations.

Formally, *PRConstraints* $\subseteq 2^P \times 2^R$ constitute a many to many subset of permissions to subset of roles relation. Each *prc* = (P_i, R_j) \in *PRConstraints* specifies the following invariant for every $p_m \in P_i$ and every $r_n \in R_j$:

$$\begin{aligned} & (\forall (rp_p, dr_q) \in RPDRA) \\ & [(p_m, dr_q) \notin PDRA \vee rp_p.r \neq r_n] \end{aligned}$$

Thus, it is forbidden to assign any device role that p_m is assigned to, to any role pair with r_n as the role part. Use case 1 can be augmented with the constraint shown below.

$$PRConstraints = \{(P_3 \cup P_4), R \setminus \{parents\}\}$$

This will prevent the assignment of any permissions in P_3 or

P_4 to role pairs with the role part being any role except for *parents*.

Static Separation of Duty (SSD). This is the familiar SSD in RBAC. It enforces constraints on the assignment of users to roles. In other words, if a user is authorized as a member of one role, the user is prohibited from being a member of a second conflicting role [45].

Formally, *SSDCConstraints* $\subseteq R \times 2^R$ constitute a many to many role to a subset of mutually exclusive roles relation. Each *ssdc* = (r_i, R_j) \in *SSDCConstraints* specifies the following invariant:

$$(\forall u_m \in U)(\forall r_n \in R_j)[(u_m, r_n) \in UA \Rightarrow (u_m, r_i) \notin UA]$$

Thus, it is forbidden to assign any role that is in R_j to any user to whom r_i is assigned.

Dynamic Separation of Duty (DSD). This is the familiar DSD in RBAC. With DSD it is permissible for a user to be authorized as a member of a set of roles which do not constitute a conflict of interest when acted in independently, but produce policy concerns when allowed to be acted simultaneously [45] in the same session.

Formally, *DSDConstraints* $\subseteq R \times 2^R$ constitute a many to many role to a subset of active mutually exclusive roles relation. Each *dsc* = (r_i, R_j) \in *DSDConstraints* specifies the following invariant:

$$(\forall s \in S)(\forall r_n \in R_j)[(s, r_n) \in SR \Rightarrow (s, r_i) \notin SR]$$

Thus, it is forbidden for any session that has role r_i active to also have any role $r_n \in R_j$ active.

D. EGRBAC Assessment

We now show that EGRBAC meets our criteria for smart home IoT which proposed in Section II. Our model is dynamic since it can capture different environment conditions through environment roles. Moreover, through device roles EGRBAC enables users to give access to subsets permissions of different devices instead of giving them access to the entire devices. Thereby, EGRBAC is a fine grained model. EGRBAC is suitable for constrained home environment, since it doesn't require smart devices to implement a computational heavy logic. The enforcement architecture that we adopt (see Section IV) includes the component smart hub, which facilitates transferring the policy decision engine to a more capable local device. This enables devices to collect and analyze data externally, but closer to the source of information, react autonomously to local events, and communicate securely with each other on local networks. Moreover, mediating each request through smart hub solves the heterogeneity problem of IoT devices. EGRBAC is designed to fit smart home IoT access control challenges. EGRBAC is demonstrated with one illustrative use case, and an AWS implementation that captures local, and remote access for smart home devices as described in Section A, with accompanying performance analysis.

Limitations Except for relationships, our model doesn't capture other user attributes. It does not handle device to device communication. Finally, it doesn't consider continuous

verification for access control authorized policies, where the authorization predicate is only examined at the time of request.

Policy Conflicts Conflicting policies may occur when you have negative policies, where you prevent specific roles from accessing specific permissions. In EGRBAC model our policies are positive policies where you give roles access to specific permissions. Instead of negative policies, EGRBAC uses constraints to prevent a specific role r_n from accessing a specific permission p_m .

VII. PROOF-OF-CONCEPT IMPLEMENTATION

In this section we describe a proof-of-concept implementation of EGRBAC. We simulated the use case provided in Fig. 3 using AWS (Amazon Web Services) IoT service [46]. The simulation illustrates how the access control model and policies can be configured to establish the applicability of our model utilizing commercially available systems. Moreover, we executed multiple test cases to measure the processing time in different scenarios. The details of this section are provided in the appendix which can be accessed in the following url: https://profsandhu.com/conference_papers.htm

VIII. CONCLUSION AND FUTURE DIRECTIONS

In this paper, we propose EGRBAC access control model for smart home IoT. Our model fills the gap in the area of access control model for smart home IoT. It is a dynamic, fine-grained model that grants access based on the specific permission required rather than at device granularity. We demonstrated our model with a use case scenario and a proof-of-concept implementation in AWS. We also conducted a performance test to depict how our system responds in different scenarios with different loads, the results show that our model is functional, and applicable. Our model still needs some further work as discussed in Section VI. In the future we are planning, to develop a family (or series) of models ranging from relatively simple and complete to incorporating increasingly sophisticated and comprehensive features.

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