An Attribute-Based-Delegation-Model and Its Extension

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Abstract. In existing delegation models, delegation security entirely depends on delegators and security administrators, for delegation constraint in these models is only a prerequisite condition. This paper proposes an Attribute-Based-Delegation-Model (ABDM) with an extended delegation constraint consists of both delegation attribute expression (DAE) and delegation prerequisite condition (CR). In ABDM, A delegatee must satisfy delegation constraint (especially DAE) when assigned to a delegation role. With delegation constraint, a delegator can restrict the delegatee candidates more strictly. ABDM relieves delegators and security administrators of security management work in delegation. In ABDM, a delegator is not allowed to temporarily delegate his permissions to a person who does not satisfy the delegation constraint. To guarantee its flexibility and security, an extension of ABDM named ABDM$_X$ is proposed. In ABDM$_X$, a delegator can delegate some high level permissions to low level delegatee candidates temporarily, but not permanently.

1 Introduction

Access control is one of the most important security technologies in information systems. As an alternative to DAC and MAC, Role-Based Access Control (RBAC) [1] security technology has gained considerable attentions [2] recently.

Delegation means a delegator can assign his /her permissions to a delegatee. There are three types of situations in which delegation takes place: backup of roles, decentralization of authority and collaboration of work [3]. Many studies have been done in delegation [4] [5] [6], and considerable attentions are paid to human-to-human delegation [3] [7] [8].

But there are still some problems in delegation need to be solved:

1. Because delegation is controlled by delegator itself, a malicious user can delegate some important permissions to low level delegatees.
2. The Delegation security relies heavily on system administrator.
3. Delegation prerequisite condition cannot restrict the scope of delegatees more strictly.
4. It is difficult for a delegator to select qualified delegatees.

In this paper we first propose a new delegation model named Attribute-Based-Delegation-Model (ABDM). Delegation constraint in ABDM consists of both

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delegation prerequisite condition (*CR*) and delegation attribute expression (*DAE*). Only those delegatees whose prerequisite roles and *DAE* satisfy *CR* and *DAE* of delegation constraint can be assigned to a delegation role. In ABDM, *DAE* and *CR* form a strict delegation constraint in delegation. ABDM is a strict and secure delegation model both in temporary and permanent delegation.

But sometimes we need a less strict delegation model in temporary delegation, such as high level permissions temporarily be delegated to low level users. Since ABDM does not support this kind of delegation, we propose a delegation model named ABDM$_X$ to solve this problem, which is an extension of ABDM.

The rest of this paper is organized as follows. Section 2 presents related work. In section 3, we introduce ABDM model. Section 4 presents the ABDM$_X$ model. Section 5 is a discussion among ABMD, ABDM$_X$ and some existing delegation models. Conclusions and future works are presented in section 6.

2 Related Works

RBDM [7] [8] is the first delegation model based on role. In RBDM, a user can delegate his/her role to another user. A rule-based declarative language has been proposed in RDM2000 [9] to specify and enforce policies in delegation. The delegation unit in RBDM and RDM2000 is “role”. In RPRDM [10], a delegator can delegate part of his/her permissions to a delegatee by a “mask”.

PBDM [3] is a flexible delegation model that supports multi-step delegation and revocation in role and permission level. In PBDM0, a user can delegate all or part of his permissions to delegatees. In PBDM1 and PBDM2, the permission flow is managed by a security administrator with delegeatable role (DBR). RDM2000 and RBDM can be seen as special cases of PBDM.

In most cases, a delegator cannot delegate all of his/her permissions to delegatees. Therefore, a low level user cannot be assigned to high level permissions. In some delegation models, delegation is managed by the delegator himself. RPRDM only addresses repeated and partial delegation, and delegation in RPRDM is also controlled by the delegators. So is the delegation in PBDM0. In PBDM1 and PBDM2, delegation is managed by system administrators or organization security administrators, and a delegator cannot delegate high level permissions to low level users.

RDM2000 and PBDM use can-delegate condition with prerequisite condition to restrict delegates, but the prerequisite condition in these models consisits only of prerequisite role or organization unit [11] [12] [13]. RBAC and other delegation models overlook the differences between users who have the same roles. They are all on the assumption that users who satisfy the prerequisite condition of a delegation permission can be assigned to the delegation permissions, but in some cases this is not true.

Role and user attribute has been proposed recently [14] [15] [16]. In RB-RBAC [15] [16], users who have attribute expression will be assigned to roles dynamically and automatically. Attribute expression in [17] indicates the user’s qualification or ability required by a role.

3 ABDM Model

Delegations in ABDM are divided into two types: decided-delegatees and undecided-delegatees. For example, when a finance manager (*FM*) is out of work, part of the *FM*'s permissions can be delegated to a person, say *Tom*, if *Tom* has the required qualifications or abilities. This is a decided-delegatee delegation. In other case, the *FM* may want to delegate some permissions to a user who has the required qualifications or abilities, but he does not know who has the required qualifications or abilities. If the system can generate qualified delegatee candidates automatically, the *FM* can choose one of the candidates as a delegatee. This is an undecided-delegatee delegation. ABDM can solve these problems mentioned in section 1 and make delegation securer and easier by decided-delegatee and undecided-delegatee delegation.

The delegation in ABDM is similar to that in PBDM. In ABDM, a delegator must first create a temporary delegation role, say *tdr*, and then assigns his/her permissions to *tdr*. Finally, he/she can assign users to *tdr*. In delegation, the temporary delegation role has the same function as that of *DTR* in PBDM. With temporary delegation role, ABDM supports partial delegation. Unlike PBDM1 and PBDM2, there is no *DBR* in ABDM, for its function in delegation can be replaced by temporary delegation role.

The delegation prerequisite condition in our delegation model consists of both prerequisite condition (*CR*) [9] and delegation attributes expression (*DAE*). Only the persons who satisfy both *CR* and *DAE* can be assigned to a temporary delegation role. Users with different *DAE*s can be assigned to different delegation roles temporarily. With *DAE* and *CR*, ABDM has a stricter constraint in delegation.

3.1 Concepts

Definition 1 An attribute expression, *uae*, is of the form *ua roprt uav*, where *ua* is an attribute specified by system, *roprt* is an operator in {<, ≤ ,>, ≥ , =, ≠ } and *uav* is an attribute value specified by system.

For examples, *level*=4, *type*='S', and *total*≥ 33 are *uae*s.

Definition 2 uae_i and uae_j are said to have identical structures if and only if they have the same *ua*s and *roprt*s. uae_i and uae_j are said comparable if they have identical structures, otherwise they are incomparable.

For example, *level*=4 and *level*=5 are comparable, while *level*=4 and *level*≥ 5 are incomparable.

Similar to recent studies [15] [16], we use the symbol '≥' to denote the dominance relations between two *uae*s. Here we also propose a method which is an extension of those in recent studies [15] [16] to judge the dominance relation between two comparable *uae*s:

- suppose two *uae*s have the form of *ua* ≥*uav* or *ua* > *uav*:
  - If *uav* is a numeric value, then the relation of '≥' automatically follows the normal order of *uav*s.
  - If *uav* is not a numeric value, then the relation of '≥' must be manually specified.

- suppose two *uae*s have the form of $ua \leq uav$ or $ua < uav$
  - If *uav* is a numeric value, then the relation of '$\geq$' goes in reverse order of *uav*s.
  - If *uav* is not a numeric value, then the relation of '$\geq$' must be manually specified.
- Suppose two *uae*s have the form of $ua = uav$ or $ua \neq uav$, the relation of '$\geq$' must be manually specified.

For example, we can say uae_1 (*level*>5) $\geq$ uae_2 (*level*>4) and uae_3 (total≤ 20) $\geq$ uae_4 (*total*≤ 20). The dominance relations between uae_5 (*type*='*S*') and uae_6 (*type*='*J*') must be manually specified.

We can say uae_i dominates uae_j if $uae_i \geq uae_j$. In this case, uae_i is the dominant *uae* and uae_j is the non-dominant one.

Definition 3 A *DAE* is a delegation attribute expression using *AND* on terms of the form *uae* where *AND* is the logic operator 'and' and *uae* is an attribute expression.

For examples, *level*=4, *type*='S', and *total*≥ 20 *AND type*='S' are *DAE*s.

In some of the existing models [15] [16], only users can have attribute expression. The substantial improvement on it made by our work is that both users and permissions in ABDM have DAEs. User's DAE indicates a user's status, ability and qualification, while permission's DAE indicates a delegatee's ability or qualification required by this permission in delegation.

For convenience of understanding, we use *u.DAE*, *p.DAE* and *tdr.DAE* to denote the *DAE* of a user *u*, a permission *p* and a temporary delegation role *tdr* respectively.

A temporary delegation role *tdr* has its own *DAE*, which is a combination of *DAE*s of its permissions. *tdr.DAE* can be automatically generated by the system. Permissions' *DAE* will only be used to generate a temporary delegation role's *DAE* in delegation. So, dominance relation can only be tested between a user's *DAE* and a temporary delegation role's *DAE*.

For convenience of understanding, we use *UAE* to denote a *uae* set of a *DAE*. For example, the *UAE* of *level*>5 *AND total*≤ 20 is {*level*>5, *total*≤ 20}.

We use '$\triangleright$' to denote the dominance relation between two *DAE*s:

Definition 4 We say $DAE_1 \triangleright DAE_2$, if $\forall\ uae_j \in UAE_2$, $\exists\ uae_i \in UAE_1$, s.t. $uae_i \geq uae_j$, where UAE_1 and UAE_2 are *uae* set of DAE_1 and DAE_2 respectively.

In this case, DAE_1 is the dominant *DAE* and DAE_2 is the non-dominant one.

For example, we can say DAE_1 (*level*>5 *AND total*≤ 20) $\triangleright$ DAE_2 (*level*>4 *AND total*≤ 30) for *level*>5 $\geq$ *level*>4 and *total*≤ 20 $\geq$ *total*≤ 30. We can also say DAE_3 (*level*>5 *AND total*≤ 20) $\triangleright$ DAE_4 (*level*>4) according to definition 4.

We can say a user is a qualified delegatee of *tdr* if his/her *DAE* $\triangleright$ *tdr.DAE* in delegation.

Here we introduce a *DAE* generation algorithm named *DG* algorithm as below:

DG (*DAE* Generation) Algorithm:

```
Input: $p_1 \ldots p_n \in P$, where P is the permission set of tdr.
Output: DAE of tdr
Begin
UAE=$\Phi$;
for i=1 to n
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    $UAE=UAE \cup UAE_i$, where $UAE_i$ is the $uae$ set of $p_i.DAE$
for i=1 to $|UAE|$
    for j=1 to $|UAE|$
    if $uae_i \neq uae_j$ and $uae_i \geq uae_j$ then delete $uae_j$ from $UAE$
Return $DAE = uae_1$ AND…AND $uae_n$, where $uae_1 … uae_n \in UAE$, n=$|UAE|$
End
```

In *DG* algorithm, comparable *uae*s are tested for dominance relation one by one, and the non-dominant ones are discarded. In the end, only incomparable *uae*s remain in *UAE* and these *uae*s can form the *tdr.DAE*. Each *uae* in *tdr.DAE* has its own restriction on user's corresponding *uae*. Because *uae*s in *tdr.DAE* have the strictest restrictions on users, a delegator cannot delegate high level permissions to unqualified users. So, *tdr.DAE* generated by *DG* algorithm can reflect the comprehensive requirements of users' *DAEs* required by delegation permissions and thus grantee the security of delegation.

3.2 ABDM

Definition 5 the following is a list of ABDM components:

- *R*, *RR*, *TDR*, *S*, *P*, *U*, *Ude*, and *Uee* are set of roles, regular roles, temporary delegation roles, sessions, permissions, users, decided-delegatee candidates and undecided-delegatee candidates respectively.
- $RH \subseteq RR \times RR$ is a regular role hierarchy
- $TDRH_u \subseteq TDR \times TDR$ is a temporary delegation role hierarchy owned by a user *u*
- $R=RR \cup TDR$
- $RR \cap TDR=\Phi$
- $URA \subseteq U \times RR$ is a user to regular role assignment relation
- $UDA \subseteq Ude \times TDR$ is a decided-delegatee to temporary delegation role assignment relation
- $UEA \subseteq Uee \times TDR$ is a undecided-delegatee to temporary delegation role assignment relation
- $UA=URA \cup UDA \cup UEA$
- $PRA \subseteq P \times RR$ is a permission to regular role assignment relation
- $PDA \subseteq P \times TDR$ is a permission to temporary delegation role assignment relation
- *roles*: $U \rightarrow 2^R$ is a function mapping a user to a set of roles

  $roles\ (u) = \{r |\ (u, r) \in UA\}$
- *per_r:* $RR \rightarrow 2^P$ is a function mapping a regular role to a set of permissions

  $per\_r(r) = \{p | (\exists r' \leq r)\ (p, r') \in PRA\}$
- *per_d:* $U \cup TDR \rightarrow 2^P$ is a function mapping a temporary delegation role to a set of permissions

$per\_d(u,tdr)=\{p|(\exists\, tdr' \leq tdr)((p,\, tdr') \in PDA) \wedge\ tdr \in\ roles(u)\}$

- $per\_u{:}U \rightarrow 2^P$ is a function mapping a user to a set of permissions

$per\_u(u)=\{p|(\exists\, r\in\ RR)((u,r)\ \in\ URA \wedge\ (p,\ r)\ \in\ PRA)\} \cup\ \{p|(\exists\, r\in\ TDR)((u,r)\ \in\ UDA \wedge\ (p,r)\ \in\ PDA)\} \cup\ \{p|(\exists\, r\in\ TDR)((u,r)\ \in\ UEA \wedge\ (p,r)\ \in\ PDA)\}$

- $Ude{:}\ TDR \rightarrow 2^u$ is a function mapping a temporary delegation role to a set of users that assigned to this role

  $Ude(tdr)=\ \{u|(\forall\, p\in\ per\_d(u,\ tdr))(\ p \notin per\_u(u)) \wedge\ (u,tdr)\ \in\ UDA\}$

- Uee: $TDR \rightarrow\ 2^u$ is a function mapping a temporary delegation role to a set of qualified users

  $Uee(tdr)=\{u|u.DAE \rhd\ tdr.DAE \wedge\ (\forall\, p\in\ per\_d(tdr))(\ p \notin per\_u(u))\}$

- $can\text{-}delegateD \subseteq R \times CR \times DAE \times TDR$ is a delegation constraint on UDA
- $can\text{-}delegateU \subseteq R \times CR \times Uee \times TDR$ is a delegation constraint on UEA.

For example, *can-delegateD* {*ST*, *TR*, *level*=4 *and type*='S' *and total*=35, *tdr*} means that a delegator who has *ST* can assign a delegatee who must has role *TR* and his *DAE* satisfies *level*=4 *and type*='S' *and total*=35 to *tdr*. *can-delegateU*{*ST*, *TR*, *Alex*, *tdr*} means that a delegator who has role *ST* can assign *Alex* to *tdr* if *Alex* is a member of qualified delegatees set of *tdr* and *alex* has role *TR*.

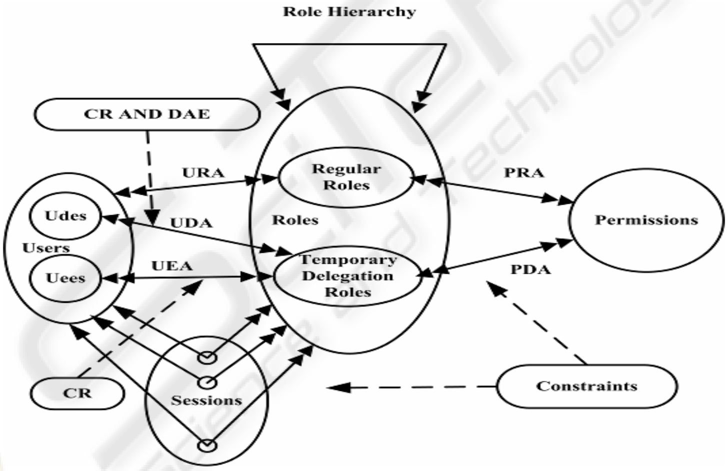


Fig. 1. ABDM model

Here some examples are given to show how ABDM works. Let us discuss the case in figure 2. For convenience of understanding, we suppose delegatees do not have the same permissions as those of *tdr* before delegation. Figure 2 also gives a example of role hierarchy, user's *DAE* and its roles, and permission's *DAE*. *Tom* with a role *ST* is supposed to want to delegate his permissions {*Borrow_in_S*, *Read_in_S*, *5_books_one_time*} to someone. First, he must create a temporary delegation role *tdr*. Second, he can assign permissions {*Borrow_in_S*, *Read_in_S*, 5*_books_one_time*} to *tdr*. The *tdr*'s *DAE* now is generated by *DG* algorithm with the input of *DAE*s of *Borrow_in_S*, *Read_in_S* and 5*_books_one_time*.

In ABDM, the system can automatically generate a *Uee*(*tdr*) with qualified delegatee candidates after the second step. *Tom* can perform either decided-delegatee or undecided-delegatee delegation.

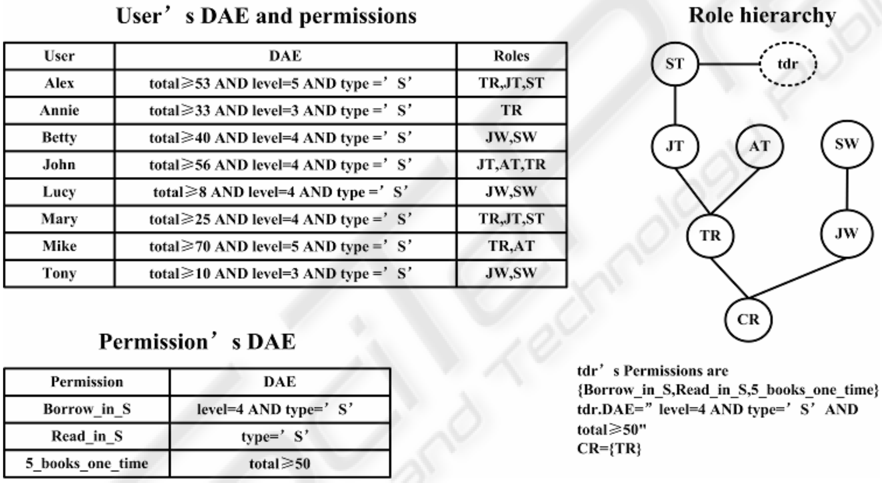
Tom can perform a decided-delegatee delegation according to the following steps:

1. *Tom* selects *Annie* and *Lucy* from user set;
2. *Tom* assigns *Annie* and *Lucy* to *tdr*. Delegation failed for neither *Annie* nor *Lucy* is a qualified delegate.

Tom can perform an undecided-delegatee delegation according to the following steps:

1. *Tom* selects a user, *Alex*, from *Uee*(*tdr*) which is generated by system. This time, *Uee*(*tdr*)= {*Alex*, *John*, *Mike*}.
2. *Tom* assigns *Alex* to *tdr*. Delegation is successful if *Alex* has role *TR*, otherwise delegation failed.

Delegation revocation in ABDM is similar to that in PBDM. We believe that delegation revocation with *DAE* is an interesting topic for further study.



User' s DAE and permissions

User	DAE	Roles
Alex	total≥53 AND level=5 AND type =' S'	TR,JT,ST
Annie	total≥33 AND level=3 AND type =' S'	TR
Betty	total≥40 AND level=4 AND type =' S'	JW,SW
John	total≥56 AND level=4 AND type =' S'	JT,AT,TR
Lucy	total≥8 AND level=4 AND type =' S'	JW,SW
Mary	total≥25 AND level=4 AND type =' S'	TR,JT,ST
Mike	total≥70 AND level=5 AND type =' S'	TR,AT
Tony	total≥10 AND level=3 AND type =' S'	JW,SW

Permission' s DAE

Permission	DAE
Borrow_in_S	level=4 AND type=' S'
Read_in_S	type=' S'
5_books_one_time	total≥50

Role hierarchy

tdr' s Permissions are
{Borrow_in_S,Read_in_S,5_books_one_time}
tdr.DAE=" level=4 AND type=' S' AND
total≥50"
CR={TR}

Fig. 2. Example of ABDM

4 ABDMX model

Although a securer delegation model, ABDM still has its shortcoming:

There are two types of delegations: temporary and permanent. ABDM is a delegation model dealing with both types of delegations, and the delegation constraint of a temporary delegation role in these two delegations is identical. But in real world, delegation constraint of a temporary delegation role in a temporary delegation is always less strict than that in a permanent delegation. So, with permanent delegation constraint, a delegator sometimes cannot temporarily delegate his permissions to a delegatee.

In the case in table 1, for example, if a teacher *t* (*t* has the role *teacher*) wants to delegate *p*1 and *p*2 to a student *s*, he/she must first create a temporary delegation role *tdr*, and then assigns *p*1, *p*2 to it. Now, *tdr.DAE* is *type*=’*T*’. In this case, suppose *DAE*: *type*=’*T*’ ⊳ *DAE*: *type*=’*S*’ and all students have the same *DAE*: *type*=’*S’*. *t* cannot perform a decided-delegatee delegation, for *s* is not a qualified delegate of *tdr*. Then *t* tries to perform an undecided-delegatee delegation. Because none of the students satisfy *tdr*, he/she cannot delegate *p*1, *p*2 to a student in an undecided-delegatee delegation either.

Table 1: Permissions and permissions’ DAE

permissions of *teacher*	permission’s *DAE*
*p*1:reading in the teacher’s reading room	*Type*=’*T*’
*p*2:borrow books from teacher’s reading room	*Type*=’*T*’
*p*3:crete exams	*Type*=’*T*’
*p*4:record results	*Type*=’*T*’

In fact, there are some differences between *p*1, *p*2 and *p*3, *p*4: *p*1, *p*2 can be temporarily delegated to a person who has not the required abilities or qualifications. It will not cause any security problems. But they cannot be permanently delegated to an unqualified person, for that will go against security policy. *P*3 and *p*4 can be delegated to a person if he/she has the required abilities or qualifications both in a temporary and permanent delegation. So, a person with a role *teacher* can delegate his/her permissions *p*1 and *p*2 to a person temporarily but he/she cannot temporarily delegate his/her permissions *p*3 and *p*4 to a person in any cases. That is, *p*1 and *p*2 can be delegated to a low level person temporarily but not permanently.

4.1 ABDMX

To overcome this shortcoming, we introduce a model named ABDM$_X$, which is an extension of ABDM. In this model, there are two different types of permissions: monotonous permission (*MP*) and non-monotonous permission (*NMP*). *MP* can be temporarily or permanently delegated to a qualified person, while *NMP* can only be temporarily delegated. So the delegator can temporarily delegate *NMP* to a low level delegatee candidate.

Definition 6 a permission *p* is a *MP* if it has an identical restriction on delegatee’s *DAE* both in a temporary and a permanent delegation. *p* is a *NMP* if it has restriction on delegatee’s *DAE* only in a permanent delegation. *MN* (*p*) is a function defined as follows:

$$MN(p) \quad = \begin{cases} True & p \text{ is a } MP \\ False & p \text{ is a } NMP \end{cases}$$

A *NMP* menas it has no restriction on delegatee’s *DAE* in a temporary delegation. Permission’s monotony must be specified by the system administrator or security administrator in advance.

Definition 7 a user *u*'s temporary delegation role *tdr* is a monotonous role if it has an identical restriction on delegatee's *DAE* both in a temporary and a permanent delegation. *tdr* is a non-monotonous role if it has restriction on delegatee's *DAE* only in a permanent delegation.. *MN* (*tdr*) is a function defined as follows:

$$MN(u, tdr) = \begin{cases} True & \exists p \in per\_d(u, tdr), \\ & MN(p) = True \\ False & \forall p \in per\_d(u, tdr), \\ & MN(p) = False \end{cases}$$

That is, a non-monotonous role has no restriction on delegatee's *DAE* in a temporary delegation.

Because ABDM does not support delegation with *NMP*s, we must modify it to meet this requirement.

Definition 8 the following is a list of ABDM$_X$ components:

- R, RR, TDR, S, P, P_M, P_N, U, Ude, Uee, TDR_M,TDR_N and TDR are sets of roles, regular roles, temporary delegation roles, sessions, permissions, *MP*s, *NMP*s, users, decided-delegatee candidates, undecided-delegatee candidates, monotonous temporary delegation roles , non-monotonous temporary delegation roles and temporary delegation roles respectively.
- $RH \subseteq RR \times RR$ is a regular role hierarchy
- $TDRH_u \subseteq TDR \times TDR$ is a temporary delegation role hierarchy owned by a user u
- $TDR = TDR_M \cup TDR_N$
- $TDR_M \cap TDR_N = \Phi$
- $R = RR \cup TDR$
- $RR \cap TDR = \Phi$
- $P = P_M \cup P_N$
- $P_M \cap P_N = \Phi$
- $URA \subseteq U \times RR$ is a user to regular role assignment
- $UDAM \subseteq Ude \times TDR_M$ is a decided-delegatee to monotonous temporary delegation role assignment
- $UDAN \subseteq Ude \times TDR_N$ is a decided-delegatee to non-monotonous temporary delegation role assignment
- $UEA \subseteq Uee \times TDR$ is a undecided-delegatee to temporary delegation role assignment
- $UDA = UDAM \cup UDAN$
- $UA = URA \cup UDA \cup UEA$
- $PRA \subseteq P \times RR$ is a permission to regular role assignment
- $PDA \subseteq P \times TDR$ is a permission to temporary delegation role assignment
- *roles*: $U \rightarrow 2^R$ is a function mapping a user to a set of roles

  $roles(u) = \{r \mid (u,r) \in UA\}$
- *per_r*: $RR \rightarrow 2^P$ is a function mapping a regular role to a set of permissions

$per\_r(r) = \{p|(\exists r' \leq)(p, r') \in PRA\}$

- per_d: $U \cup TDR \rightarrow 2^P$ is a function mapping a temporary delegation role to a set of permissions

  $per\_d(u,tdr)=\{p|(\exists tdr' \leq tdr)((p, tdr') \in PDA) \wedge tdr \in roles(u)\}$

- per_u:$U \rightarrow 2^P$ is a function mapping a user to a set of permissions

  $per\_u(u)=\{p|(\exists r \in RR)((u,r) \in URA \wedge (p, r) \in PRA)\} \cup \{p|(\exists r \in TDR)((u,r) \in UDA \wedge (p, r) \in PDA)\} \cup \{p|(\exists r \in TDR)((u,r) \in UEA \wedge (p, r) \in PDA)\}$

- Ude:$TDR \rightarrow 2^u$ is a function mapping a temporary delegation role to a set of users that assigned to this role

  $Ude(tdr)= \{u|(\forall p \in per\_d(u, tdr))(p \notin per\_u(u)) \wedge (u,tdr) \in UDA\}$

- Uee: $TDR \rightarrow 2^u$ is a function mapping a temporary delegation role to a set of qualified users

  $Uee(tdr)=\{u|MN(tdr)=True \wedge u.DAE \rhd tdr.DAE \wedge (\forall p \in per\_d(tdr)) (p \notin per\_u(u))\}$

- $can\text{-}delegateM \subseteq R \times CR \times DAE \times TDR_M$ is a constraint on $UDAM$
- $can\text{-}delegateN \subseteq R \times CR \times TDR_N$ is a constraint on $UDAN$
- $can\text{-}delegateU \subseteq R \times CR \times Uee \times TDR_M$ is a delegation constraint on UEA

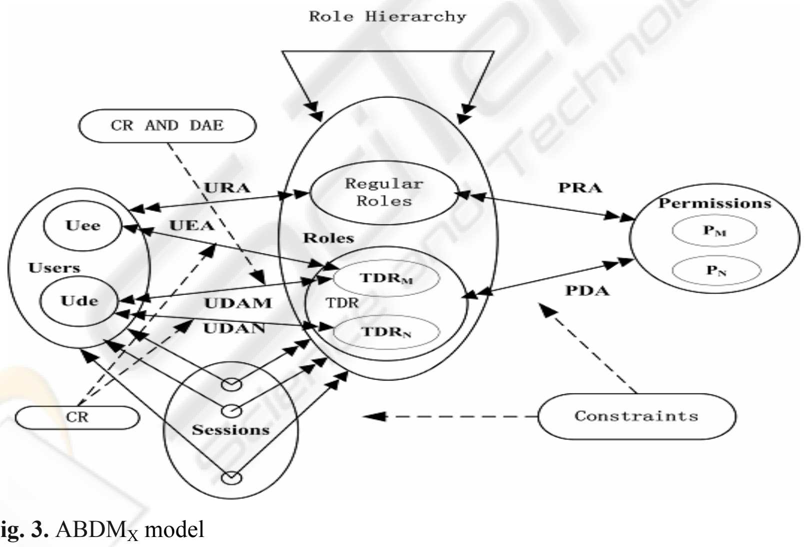


Fig. 3. ABDM$_X$ model

can-delegateN(r,cr,tdr) means a delegator with role *r* can delegate a non-monotonous temporary delegation role *tdr* to a delegatee who has role *cr*.

can-delegateM can restrict delegatees with temporary delegation role's *DAE* and delegation permission's monotony need not to be considered, on the contrary it must be considered in *can-delegateN* for it cannot restrict delegatee with temporary delegation roles' *DAE*. That is, *can-delegateN* only be used in a delegation with *NMP*s while *can-delegateM* can be used in a delegation with both *MP*s and *NMP*s. Because a *NMP* has no restriction on a delegatee's *DAE* in delegation, ABDM$_X$ does not support undecided-delegatee delegation with *NMP*s. We can prevent ABDM$_X$ from generating *Uee* (*tdr*) for *NMP*s by adding a constraint: *MN* (*tdr*) *=True* to the definition of it.

Let us discuss the example presented in section 4 again to show how this extended model works. In one case, teacher *t* wants to delegate his permissions *p*1, *p*2 to a student *s*. He/she can delegate them according to the following steps (in table 1, *p*3, *p*4 are *MP*s and *p*1, *p*2 are *NMP*s):

1. *t* creates a temporary delegation role *tdr*.
2. *t* assigns *p*1, *p*2 to *tdr*. That is, *MN* (*tdr*) *=False* for *MN* (*p*1) *=False* and *MN* (*p*2) *=False*.
3. *t* must perform delegation by *UDAN* for *tdr*∈ *TDR*$_N$.
4. Delegation is successful for *UDAN* (*s*, *tdr*) satisfies *can-delegateN*(*teacher*, *student*, *tdr*) constraint.

In the other case, *t* wants to delegate his/her permissions *p*2, *p*3 to *s*:

1. *t* creates a temporary delegation role *tdr*.
2. *t* assigns *p*2, *p*3 to *tdr*.
   That is, *MN* (*tdr*) *=True* for *MN* (*p*1) *=False* and *MN* (*p*2) *=True* and *tdr*'s *DAE* is *type*='*T*'.
3. Delegator must perform delegation by *UDAM* for *tdr*∈ *TDRM*.
4. Delegation failed because *UDAN* (*s*, *tdr*) does not satisfy *can-delegateN* (*teacher*, *student*, *tdr*) constraint.

Undecided-delegatee delegation with *MP*s and delegation evocation in ABDM$_X$ are similar to those in ABDM. Revocation in ABDM$_X$ is similar to that in ABDM.

4.2 Delegation security in ABDMX

We now discuss delegation security in ABDM$_X$ according to a temporary delegation role *tdr*'s monotony

1. *MN* (*tdr*) *=True*

In this case, *tdr* has *MP*s and the delegator can perform delegation by *UDAM*. Because *can-delegateM* is the delegation constraint on *UDAM*, a delegatee must be a qualified one when assigned to *tdr*.

A delegator can delegate some *NMP*s to delegatees by *UDAM*. That means a delegatee has those prerequisite roles and *DAE* which are required by *can-delegateM* when assigned to *tdr*. This will not cause any security problems.

2. *MN (tdr) =False*

In this case, *tdr* has *NMP*s and the delegator can perform delegation with *UDAN*. Although *can-delegateN* cannot restrict delegatees with *DAE*, there will be no security problem in the delegation. The reason is that in fact *NMP*s have no restrictions on delegatees in this type of delegation.

A delegator cannot delegate *MP*s to delegatees by *UDAN*. In ABDM$_X$, *can-delegateN* constraint means only *NMP*s can be delegated to delegatees by *UDAN* (*tdr* ∈ *TDR*$_N$). This will not cause any security problems in delegation either

5 Discussion

In some existing delegation models, such as RBDM and RDM2000, delegation is controlled by a delegator or a system administrator. There are no restrictions on delegatee candidates except prerequisite role. These models have the highest flexibility but lowest security in delegation. In PBDM, a delegator cannot delegate some high level permissions to low level delegatees under the supervision of the system administrator. PBDM has a medium flexibility and security in delegation. ABDM has a strict delegation constraint consisting of prerequisite roles (*CR*) and temporary delegation role's attribute expression (*DAE*). A delegatee's prerequisite roles and *DAE* must satisfy *CR* and *DAE* of delegation constraint simultaneously when he/she is assigned to a temporary delegation role. A delegator cannot delegate high level permissions to an unqualified user in any case. Because delegatee candidates are limited by delegation constraint, ABDM is believed to have the lowest flexibility but highest security in delegation. In ABDM$_X$, a delegator can temporarily delegate *NMP*s to an unqualified low level user but cannot temporarily delegate *MP*s to an unqualified delegatee in any case. In fact ABDM$_X$ does not cause any security problems in temporary delegation for *NMP*s have no restrictions on delegatee candidates' *DAE*s. So, ABDM$_X$ has a medium flexibility but the same security level as that of ABDM in delegation.

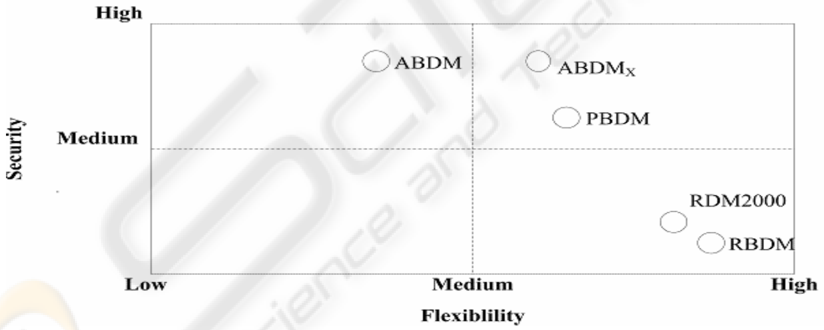


Fig. 4. Security and Flexibility of ABDM, ABDM$_X$, PBDM, RDM2000 and RBDM.

6 Conclusion and Future Work

We propose a novel delegation model ABDM and its extension ABDM$_X$. As a delegation model based on permission and user's attribute, the main feature of it is that it uses user and permission attribute expression as a part of delegation constraint.

ABDM is a securer delegation model for it can restrict delegatee candidates more strictly. ABDM_X is more flexible than ABDM in delegation. For in ABDM_X, a delegator can temporarily delegate *NMP*s to low level users without causing any security problems. Both ABDM and ABDM_X can be used in temporary and permanent delegation and make delegation securer and more flexible.

Further work includes supporting more constraints in ABDM and ABDM_X, such as separation of duty and cardinality, and revocation with *DAE* in them.

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