



Towards a More Complete Model of Role

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In order to manage the use of roles for the purpose of access control, it is important to look at attributes beyond the consideration of capability assignment. Fundamentally, a generic attribute description using a constraint-based approach will allow many of the important aspects of role, such as scope, activation and deactivation, to be included. Furthermore, the commonly accepted concept of role hierarchy is challenged from the point of view of subsidiarity in real organisations, with the suggestion that role hierarchy has limited usefulness that does not seem to apply widely.

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Towards a more Complete Model of Role

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Abstract: *In order to manage the use of roles for the purpose of access control, it is important to look at attributes beyond the consideration of capability assignment. Fundamentally, a generic attribute description using a constraint-based approach will allow many of the important aspects of role, such as scope, activation and deactivation, to be included. Furthermore, the commonly accepted concept of role hierarchy is challenged from the point of view of subsidiarity in real organisations, with the suggestion that role hierarchy has limited usefulness that does not seem to apply widely.*

Keywords: *Role-based, access control, RBAC, management, constraint-based, subsidiarity.*

1 Introduction

Recent interest in role-based access control (RBAC) has grown from attempts to understand its relationship with other types of access control such as the traditional DAC and the military grade MAC, to the management of roles with respect to users and capabilities. The definitions of roles are varied, but are mostly associated with a set of responsibility-capability pairs. Closer examination reveals that there are many attributes which are useful and are needed to form a more complete description of role within the context of RBAC. More specifically, many of these attributes are useful for the management of the way roles should behave, and allow a more powerful means of ensuring flexible and effective access control. The purpose of this discussion is to highlight aspects of role which has so far been ignored in most of the discussion of RBAC. We propose the use of constraint-based descriptions for a number of these attributes, and draw heavily from the idea of applying a constraint-based approach for policy description as discussed in [Goh97].

Questions are also raised to challenge the commonly accepted concept of role hierarchy. This is done with the aim of exposing the need to balance practical role-based concepts with interesting theoretical exposition, to achieve a better understanding of role and its significance in the access control area.

2 Types of Role

In general, roles can be considered from several different angles: organisation, relative relationship, grouping of convenience and grouping through selection. Throughout this section roles associated with a software development project, Figure 1, are used to illustrate various concepts.

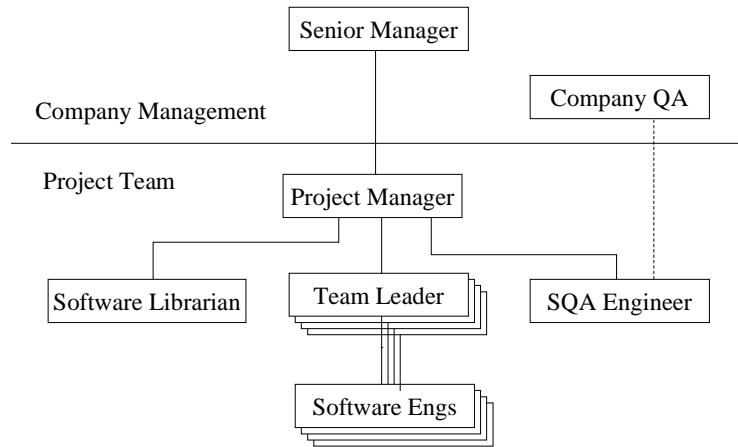


Figure 1 Example organisation for a software project.

2.1 Organisational role

Organisational role has been created as a way to assign responsibility and capability within organisational units. An organisation provides the environment within which a role is meaningful. Suppose we regard role as object, then its environment of validity— sometimes also known as the *domain* in which the role is meaningful— can be considered as an object instance variable [Lupu97]. Accompanying an organisational role is the responsibility of a person with that role towards that *environment*.

Encapsulation decisions can be used to control which roles are exported outside the immediate environment. The role of a research engineer, for example, is usually hidden from the customers' view of the environment called a "company". Customers are, generally, familiar with the "marketing manager", the "sales representative" and the "customer support engineer". In terms of security requirements, it is conceivable that meaningful role within an environment should only be exposed to another environment on a "need to know" basis. This raises many familiar security issues which should be solved as part of role management solutions.

Consider the organisation of a software project shown in figure 1; here roles are identified within the environment of a company, a project and individual teams. Within each of these environments each role has a responsibility and also a visibility such that the team leader will be responsible for a particular work package and will be visible to the project manager but not the senior manager. It is important to note that the organisation diagram defines reporting relationships and is not a role hierarchy; role capabilities are assigned according to the processes performed within a particular environment.

2.2 Object specific role

When the responsibility and capability of a subject interacts with that of another, there is the concept of role interaction. This has been amply discussed in [Lupu98], under both the concept of role relationships and relationship classes. Apart from this significant concept, there is a need to recognise the relative nature of roles with respect to role owner. For example, the concept of "manager" may often be understood in two ways: the manager of a project, and the manager of specific objects within that project. In the software project organisation the team leader will have an organisational role as a manager of a particular work package and a object specific role relative to the staff in the project. This object specific

role is meaningful in the same environment but a lot more specific because it relates to another person, or persons with a certain role. Each team leader may have the same personnel management capabilities but these would be relative to the staff they manage. If some of the team's software engineers could be contractors and the team leader would not perform this relative person management role whilst they will still hold the organisational role.

Modern organisations that try to be flexible in order to optimise their operation often employ what is known as a lattice structure or matrix management, whereby a specialist may have a direct "line" manager deciding her salary, a "reporting" manager in whose project she works, and a "technical" manager to whom technical matters are reported. In this case, role relativity provides distinct views according to the role owner, and adds clarity to the notion of role, something that eludes the definitions given in [Lupu98]. The single most important application of this concept is in enforcing RBAC related to personal data privacy laws, where role owner's identity must be taken into account.

2.3 Grouping as role

Often roles are created simply for easy of reference. "Company employee" is a simple way of referring to a group of people and the associated responsibilities and privileges. All company employees would inherit from this role or have this as a secondary role, however, their specific job related capabilities are derived from their primary role representing their ability and responsibility within the organisation. Equally if a team has both contractors and company employees as software engineers both may have equal capabilities as software engineers within the team but each will inherit different capabilities according to their employment status.

The validity of regarding grouping of convenience as role is due to the experience of practically dealing with organisations in which set privileges can be spoken of and manipulated flexibly. This is somewhat a construction that is directly opposite to grouping by capability as role.

2.4 Unspecific role

Role has its associated capabilities and responsibilities. The relationship between each pair of capability and responsibility is often static and appears as a direct mapping. Capabilities are assigned to a role when that role is being defined and clearly different roles may share a number of common capabilities. Also, it is possible to establish a role that requires specific *qualifications* (see section 3.4).

Accordingly, RBAC can sometimes be modified into access control based on capability: *access will be given for any role that has capability ϕ* . One commonly used example is in the workflow environment: a task can be performed at a particular stage by, not so much as a role, but by anybody with a role that has some qualifier. The qualifier is usually a set of constraints such as "the ability to approve a cheque for up to \$2000.00". When a qualifier is used for access control instead of a role, role plays a secondary part in the access control mechanism, very much like how user ID is relative to RBAC.

Clearly the identity of user and the role that is active at the moment of permitting or denying access are both important for audit trail purposes. Nonetheless, the approach of capability based control points out the way RBAC can be extended practically.

3 Role Attributes

The attributes associated with a role has variously been discussed in [Chen96, Lupu98]. A more sophisticated approach than that taken in [Chen96] is needed as soon as the elemen-

tary model is to be extended. The attributes highlighted below, lack of explicit mention so far in the literature, are mainly for their usefulness..

Why do we need more sophisticated role attributes? In the internet-maniac world, RBAC is finding its usefulness extended far beyond the world of database security, which has helped demonstrate the needs of different access control paradigms. Once a well-understood environment ceases to be guaranteed, in the world of information, it is necessary to create common semantics for different organisations, entities and domains to interact meaningfully. As much work has gone into standardising information and system representation such as DMTF's Common Information Model (CIM) [DMTF-CIM], it is practical to seek role definition commonality by specifying role attributes through standard descriptions, rather than attempting a standardisation of role definitions.

Attention is drawn to the similarity between the concept raised in the RBAC models in [Sandhu96] and the description in the following subsections. The distinction is vital, in that the concept of "constraints" in [Sandhu96] applies to the RBAC components and the relationship between different components, and may in principle be summarised simply as a set of policies [Goh97]. Role attributes are, however, meant to describe the inherent aspects of a role without explicit reference to other objects. The fact that constraints will be mentioned as a convenient way to describe attribute is coincidental and is really an extension of an earlier concept in [Lawrence93]. Role attributes are, therefore, orthogonal to, but interact with, the "constraints" governing RBAC in [Sandhu96].

3.1 Scope

The consideration of role is often done within an assumed domain. This is convenient in making the principles of RBAC clear and in making comparisons with other types of access control such as DAC and MAC. The assumption of a pre-set domain should be removed when we begin to consider roles in a more general way. A burgeoning idea along this line can be found in [Moffett94]. The approach taken in [Lupu97] clearly offers a solution to dealing with the reality that, for example, the role of a nurse in hospital X is not the same as that in hospital Y, and the role of a nurse in ward A is not the same as that in ward B. The instantiation of the "nurse role" object allows the instant variable representing the scope to be defined where necessary.

An extension of this object oriented approach is needed when we consider dynamic role creation and assignment. When can an instance of a role be established? Can a role be assigned to a user in a given environment, apart from by the RBAC policy? The answers to these questions become the scope of a role. The answers themselves can be established through the use of constraints as part of the role attribute. A relevant set of constraints as part of a role will enable the role manager to determine the appropriateness of the application domain and potential automation of role to user assignment. For example, when creating a software project the manager will look for users with a software engineering role who can therefore be assigned to a particular role in the project. This is a generic approach similar to that taken for the description of policy [Goh97] and of RBAC model [Sandhu96]. Note that it is not always obvious which constraints are best regarded as role attributes, and which as RBAC policy.

3.2 Activation Criteria

Once a role is established, it can be made to be intrinsically relevant only under certain conditions within the pre-defined scope. These conditions constitute the constraints that are separate from the RBAC policy constraints. Apart from the "where", "when" and "what" mentioned in [Lawrence93], the most common additional activation considerations include:

- ◆ **Event-triggered condition.** The role of "fire marshal" would only be activated when there is a fire alarm in a building. From this point of view, the trigger

must be well defined, otherwise it will not be possible to have the correct level of access control because the role is usually not activated. Clearly it is possible to include time-based condition as an event trigger, but this separation provides a convenient view mainly for ease of management.

- ◆ **Composite condition.** The constraints that need to be satisfied in order for a role to become active are not always limited to event triggers. An event is at best a trigger, and if the state of the system is such that a constraint is satisfied, then a role becomes active. This is very similar to role scope establishment which is orthogonal to the activation requirements.

In the literature, role has been regarded as a collection of policies in [Sloman94]. This treatment will subsume the requirements mentioned in this section, provided that the way policies are described is sufficiently generic, with descriptive power at least as encompassing as that proposed in [Goh97].

3.3 De-activation Criteria

For how long would a role be valid from the time of its activation? Roles may remain active for a pre-set period of time, indicated as a role attribute, or it may also become inactive based on certain other constraints. In the simplest cases, a time-to-live (TTL) specified in terms of duration or event count is sufficient. More generally a full constraint-based approach, in a fashion similar to role activation, would be needed.

3.4 Qualification

Another dimension in the attributes of role is qualification. When can a person be considered for taking up the role of a security officer? The absence of criminal record could be one of the fundamental requirements. Another qualification may be that the person has relevant experience for more than a number of years. In the software project example the capability of accepting test results may only be performed by an qualified test engineer, and such conditions may even be a contractual requirement. The fulfilment of a role requires the satisfactory discharge of the associated responsibility as well as the access right. A computer playing the role of access controller must have sufficient memory, computing power, and the appropriate software to effect quick control, which may rule out, say, an Intel 286 machine that survived from one's younger days!

The advantage of having qualification as an attribute is the potential to ease or automate role assignment. The process of selecting the qualified candidate as potential owner of a role is greatly simplified, allowing the role assignment manager to make decisions quickly.

3.5 Delegation and Transfer

One of the most interesting features of role is the possibility of delegating or transferring its associated capability. The distinction between delegation and transfer made in the context of database access control [Bertiino97] is, clearly, equally applicable for roles, such that when a role is delegated from one person to another, the delegator retains the capabilities, whereas if a role is transferred from one person to another, the transferor will no longer retain the capabilities. How delegable and transferable a role is could be an attribute of the role itself. Previous discussion on this area can be found in [Yialelis96] which looks at relatively simple scenarios.

For convenience, we coin the phrase "role empowerment" to mean either role delegation or role transfer. A more complete approach to role empowerment necessarily include, but not limited to, the following considerations:

- ◆ **Empowerment qualification.** In the same way that a role should only be assigned to a person with the necessary qualification, the empowerment of capabilities to a delegatee or transferee must be conditioned upon the possession of certain qualification. The role of a nuclear power station operator, for example, cannot be delegated most of the time because there are not many people trained to shut down a nuclear boiler!
- ◆ **Empowerment conditions.** When may a role be delegated and when may it be transferred, if role empowerment is permitted? In addition to empowerment recipient's qualification, there could be conditions for the empowerment to take place, such as when the existing role owner is no longer fit to discharge a responsibility. Again, a constraints-based approach would potentially capture all the necessary information to make a decision.
- ◆ **Delegability and transferability set.** What are the capabilities that can be delegated or transferred, and under what condition?
- ◆ **Degree of delegability.** This is about the number of times a role can be assigned to someone else by the present owner of that role. If the degree is zero, it can be used as an indication that the role should never be handed over to another person by the owner, while degree of one can be used to represent a single delegation or transfer and no more, as in the case of "signatory power holder" in many organisations. Infinite degree of delegability or transferability implies that a role can be handed from one owner to another without any limit in terms of counts.
- ◆ **Degree of transferability.** This is similar to delegation, except that the transfer will lead to the original role owner to relinquish all capabilities and responsibility.
- ◆ **Delegation and transfer relationship.** Can a role delegated to a user be transferred, or can a transferred role be delegated? Can the original owner of a transferred role be the recipient of a delegation or transfer of the same role? How can the constraints governing these two be accurately and adequately described?
- ◆ **Delegation/transfer count.** How many times has the delegation or transfer been carried out?

A large part of this attribute can be implemented at the policy level with no loss of generality. Where the constraint description should be lodged depends entirely on the convenience and ease of management.

4 Subsidiarity in Roles

The word *subsidiarity* is defined as "*the principle of devolving political decisions to the lowest practical level.*" in the Collins Concise Dictionary. We use this word to mean that tasks should be done by the appropriate role holder with suitable responsibility-capability, *independent* of the structural authority in the organisation. This is a very important requirement in many organisations. Theoretically, role hierarchy, which is commonly favoured by most researchers in this area, is a wonderful structured construct. It seems that creating a role hierarchy tends to help organise roles according to their shared capabilities (permissions). Unfortunately, subsidiarity has a disruptive influence on this theory.

Often subsidiarity creates counter examples that will show the ungainliness of inheritance orientated construct. While this is not surprising because things don't always fall into a structure, it is surprising how uncommon a useful role hierarchy is in actual organisations, in terms of the concept of inheritance being neatly applicable as suggested in [Sandhu96]. Practical cases we have encountered also have the inconvenient trait of creating a hierarchy

in which a role inherits the capabilities of another, only to also have a large number of exclusions due to subsidiarity.

Take the software project example, each role has their own responsibilities that determine their capabilities. The project manager would not expect to have capabilities that allow them to alter designs, code or test specs. They would, instead, have different capabilities relating to project management tasks. It is not a good idea for the project manager to change code; they probably lack the necessary qualifications. A supervising engineer would not even expect to inherit all the capabilities of the engineers they are supervising unless their supervisory role is additional to the standard software engineers role. The supervising engineer would be expected to read code, design, and test results to ensure the correct quality and functionality; they would get the software engineers they supervise to change the code when necessary.

While there are areas in which the collection of capabilities under a single role allows some form of extraction to form a hierarchy, this facility is not the most obvious and convenient approach, as shown in [Bartholdt98]. Another area from which we should be able to draw some real requirements are international standards, such as ISO 9000. A company following these standards should aim to identify the processes along with those roles that are responsible for each stage in the process. Within a project, such as a software project [Mazza96] the project manager would create a project plan including role definitions, the relationships between the roles and the qualifications of the staff to fulfil their role. The software procedures will often determine the capabilities required by a each role. For example, a software engineer (but not the project manager) may have the capability to sign a test acceptance form for other engineers in the team. Only the team leader would have the capability to authorise major design changes.

If role hierarchy is not used, how would RBAC develop? Perhaps there is no impact at all. We believe that further investigation in this area by collecting a large number of practical operational cases will help further understanding in this aspect.

5 Discussion and Summary

A large number of concepts brought out in this paper can, at first glance, be thought of as a policy matter. For example, the condition for the activation of a role may be regarded as one that pertains to the policy governing the role. However, as we have seen, the role of fire marshal, for example, is dependent on the event of a fire, or the sounding of the fire alarm. To relegate such intrinsic attributes to a policy outside the definition of role does not seem natural. In cases where the role and policy administrators are different it is essential to keep role related attributes in the domain of the role administrator. The use of constraints that specify a relevant state that is important to a role, rather than simple primitives such as strings and integers, is a much more powerful and flexible way to fully describe roles. This is shown in a number of items in section 3 and we believe that incorporation of this approach can also enable a closer integration with RBAC management as well as the enforcement of other system level policy.

Finally, it is our belief that the concept of hierarchy should be used with caution in the discussion of roles, given that very often this translates badly into practical application, as has been outlined in section 4. It is hoped that with increased understanding, the judicious application, or abstinence of its application, will enable better use and management of RBAC.

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