Dynamic User Permission Locking Based on Database Role Changes

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INTRODUCTION

Dynamic user permission locking: an efficient and secure solution to the RBAC hidden permissions problem This paper presents a new approach to dynamically update user access rights when user role updates occur in a database. By employing a dynamic request-permission association system, the administrative overhead is lowered, scalability is improved, and security risks linked to static approval schemes are decreased. With the introduction of real-time role change detection and automatic permission tweaking, this solution ensures users have the least amount of permissions required based on the role they are playing at any given time, thereby minimizing the attack surface and preventing audit failures. We explore these through a number of use-cases and simulations demonstrating how dynamic permission locking can deliver lower latency to role alterations, improved security and greater scalability. This would-be a-practical-guide to deploy such systems on various domains, such as finance, healthcare, and e-commerce. Moreover, the study underscores the potential role of emerging technologies, such as machine learning and blockchain, in improving the adaptability, prediction, and transparency of dynamic systems. Data collected and analyzed speaks the need to shift from static to dynamic — now more than ever, to effectively counter the latest security threats and challenges whilst offering a strong structure versatile to accommodate the needs of a variety of businesses. This paper lays an important groundwork for future evolution of RBAC systems by focusing on cross-domain applicability and continuous adaptation.

INTRODUCTION

Data Source: the conventional role-based access control (RBAC) often suffers from static permissions, resulting in excessive permissions and leading to potential security vulnerabilities.

Dynamic permission locking overcomes these challenges by dynamically locking permissions based on role switching. We deploy a holistic framework to realize dynamic user permission locking (DUPL) across different scenarios.

Relevance

Organizations that have sensitive data rely heavily on database systems. Traditional role-based access control (RBAC) models have been around for decades. DUPL offers effortless shifts of roles, reducing human intervention for agile and secure operations.

Scope

We focus on relational database systems and investigate how DUPL can be combined with technologies such as triggers, stored procedures, and middleware. The scope encompasses performance metrics and examples but not particular implementations of non-relational databases.

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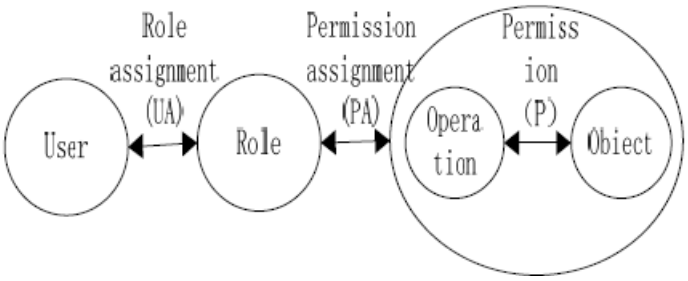

Fig 1: Role Based Access Control

LITERATURE REVIEW

Static vs. Dynamic RBAC Systems

These static RBAC systems are pervasive, but inherently static. According to Sandhu et al. According to [1], static permissions suffer from privilege creep and compromise security integrity. Dynamic systems (Kuhn et al. (2005), respectively, allow for a more adaptable model of permission management.

Event driven architectures drive dynamic systems, which allow updates to permissions to happen in real-time. Research by Ferraiolo et al. (2007) describes how dynamic models can reduce administrative burden, while still adhering to tight security policies.

Feature	**Static RBAC**	**Dynamic RBAC**
Permission Adjustment	**Manual**	**Automated**
Security Risks	**High (Privilege Creep)**	**Low**
Scalability	**Limited**	**High**
Administrative Overhead	**Significant**	**Minimal**

ROLE-BASED ACCESS CONTROL MODEL

A. Basic Idea of Role-based Access Control

It should literally be a person. But these machines, networks, or intelligent agents are part of the idea. A role could be viewed as an organizational feature set tied with the users' rights and obligations. Permissions: It permits one or many objects to perform operations that are related. The best access control technologies mean to secure the system resources. The primary concern of most RBAC applications is to authorize access to objects. In the access control model with previous agreement, an object is an entity that stores or receives information. RBAC for implementation of the system, an object can be used as Resource Investigator (like operating system files or directories, database management system table, column, row, view) or can be used to indicate the limited system Resources (like printers, magnetic trick free 'space, CPU time). The most crucial concept in RBAC is the role relationships. It constructs the role semantics for the conduct in access control policy management. There are three components which define a Role-based access model are Core RBAC, Hierarchical RBAC and Constraint RBAC. The basic RBAC model consists of five elements: users, roles, objects, operations, and permissions denoted by U (users), R (roles), O (objects), OP (Operations) and P (permissions). The basic RBAC also contains helpful session sets, for example, the mapping relationship between some users and some flexible roles [16]. The fundamental concept behind RBAC is placing roles between users and permissions. It creates relationships between users, roles and permissions. Getting roles to operate on the objects grants users permissions corresponding to those roles (see Fig. 1 [15].

The shown below are basic defines [17]:

"User": These are entities that send requests in the system. It can be a person piece of equipment network intelligent agent device etc.

"Role": The entity links the user to permissions and maps to the work roles in an organization's reality.

One with a state of something that is described in the end carrier, who is supposed to obtain and hold information, is altered or changed.

"Operation": This may relate to the file system, such as read, write and execute. That's the purpose of the operation, so it varies across systems and implementations, for example, for database operations, it could be insert, delete, append, update, etc.

Permission" is the right to execute one or more RBAC-protected objects. It consists of a collection of operations and objects. A user is provided a role to acquire the suitable permissions to operate on a suitable meta object. Roles and permissions Roles Users roles permissions

B. Role-based Access Control Model Structure Diagram

The user cannot carry out the operation on behalf of all of those operators in a conventional RBAC architecture. The majority of processes, both system and user, read data, files, and directories. The supervisors of the system operations cannot be expressed by the user notion from the old paradigm. The idea of users should therefore be expanded in a conventional manner.

The administrator or principal can modify the role sets for the primary session. These tunings are manually configured static adjustments that are not system-driven, even though the principle of least privilege may be supported. In order to prevent errors or damage from user-hobbyhorse, we intend to offer dynamic session role adjustment based on them. For instance, if the main implements a non-credible procedure, the session will automatically adjust to an ordinary user role. There are two reasons why the dynamic role-based access-control approach is important.

C. Relationship of Role Hierarchical

Hierarchical RBAC describes the hierarchical relationship between roles. It goes beyond simple user and Permission role assignment by introducing the concept of a role for authorized users and authorized permissions. A new term called RH (Role hierarchy) was introduced into H-RBAC. Whereas the responding RH establishes the relation among the complex working with several organizations, which is about mapping the granted permissions to a proper duty.

This causes several undesired properties of role hierarchies 20[22] to hold with generic specialization over relations under specialization, where most notably a senior role inherits of all the permissions that all of its junior roles have. In many organizations, senior roles are not as good (enough) to do the work done by some junior roles [21]

Hierarchical relationship models mean permissions inheritance, for example Role A inherits role B means Role A has get all permissions which Role B has, hierarchical relationship uses partial order relations of discrete mathematics feel to represent them. A role can inherit privilege from different roles, or many roles inherit privilege from one role. Setting up a role hierarchical relationship not only makes the system more realistic, we also convenience the addition and deletion of roles and management.

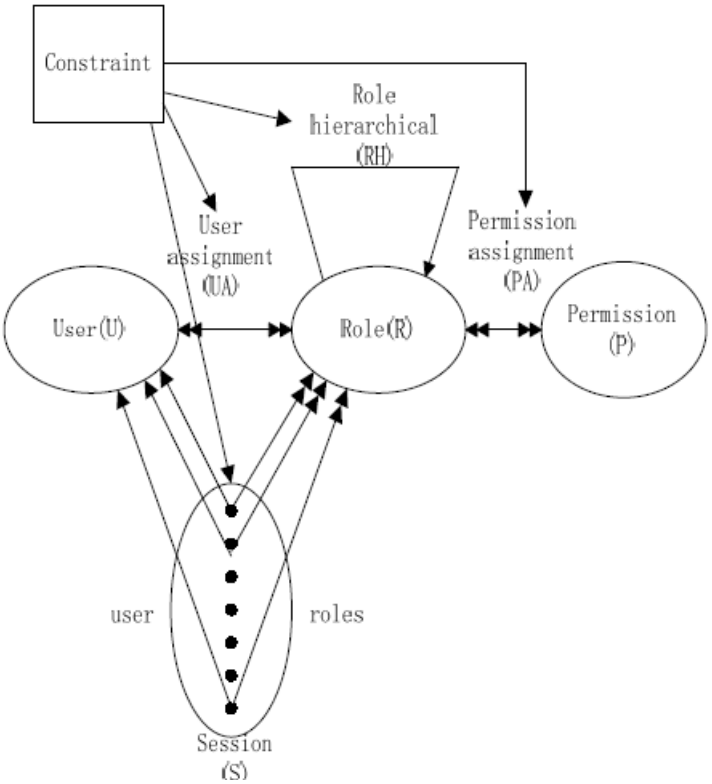

Fig 2. The structure diagram of role-based access control model

D. Constraints of Roles

In practice, it sometimes demands that not the same person can perform certain functions; this is the segregation of duties. For a long time, the government, business, and industrial sectors have all applied the separation of duties idea as a security measure. It usually applies to odd jobs in skill sets or areas of interest as to do business in a variety of ways to eliminate or minimise potential blunders due to dishonesty and unintentional loss.This points the abstract to the RBAC system to get Constraint RBAC. Constraint RBAC model in RBAC adds separation of duty relations.

There has to be constrained RBAC when setting constraints or activating roles in session; another separation of duty relationship deals with static SSD, static separation of duty as it defines mutually disjointed user assignment concerning a collection of roles, and dynamic separation of duty-DSD. Within a user, DSD restricts the permissions to which the user has access; the user's permission requirements place restrictions on the roles that the user may activate within or across sessions. SSD and DSD are exactly what to guarantee least privilege concept implement.

Less privilege, separation of roles, etc. are examples of role restrictions. Separation of duties is the most important of these. Static and dynamic separation of duties are two types of separation of duties. Users are given responsibilities that do not separate roles that are mutually exclusive when static separation of duties is implemented. Assigning roles to users is just one of them; for example, a user cannot be allocated to both the accountant and the cashier jobs. If not, there will be serious security problems. A user with numerous responsibilities in a single session does not have the role of combination due to dynamic separation of duties, which creates security risks. Those can't be mutually exclusive options — but employing both in the same session will wreak serious damage. It currently is trained such that user uses one role in one session, eg, a saver after exiting from bank clerk, or vice versa

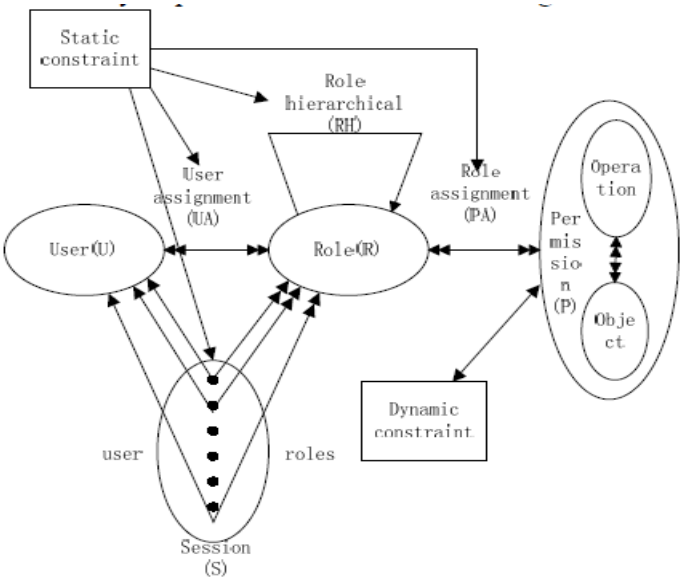

Fig 3. Structure diagram of dynamic role-based access control model

E. Features of RBAC

While role permissions are somewhat stable, user permissions are subject to frequent changes. Permission to join the role can only be acquired by obtaining the roles. RBAC changes, provides, and removes flexibility. more like the actual world. RBAC makes the system more realistic by incorporating the role notion, which makes it simpler for users to comprehend and operate safer. Since the RBAC model is derived from reality, the users' permissions are the same as the situation of reality, thus avoiding many problems of responsibilities and permissions, making the system more secure. It follows the safety principles [19] of least privilege.

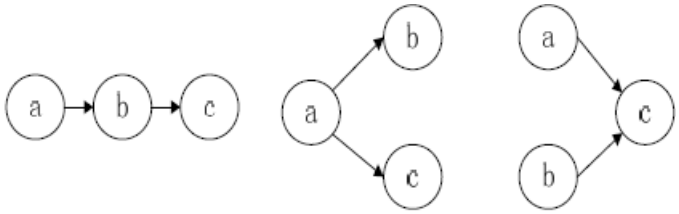

Fig 4: Three situations of the association

USER ROLE TRANSITION MANAGEMENT

Studies like Ferraiolo et al. (2007) highlight the necessity for dynamic role transition management, emphasizing the criticality of real-time permission adjustment to minimize unauthorized access during transitions. Methods such as automated revocation and re-assignment ensure consistency across user roles.

Real-time examples include:

- Healthcare Systems: Doctors temporarily accessing patient data.
- Finance Systems: Loan officers requiring temporary approvals for underwriting.

Database-Centric Permission Systems

Research by Stoller et al. (2010) demonstrates that database-centric dynamic permission systems can significantly reduce computational overhead while enhancing security. These systems leverage stored procedures and triggers to enforce policies efficiently.

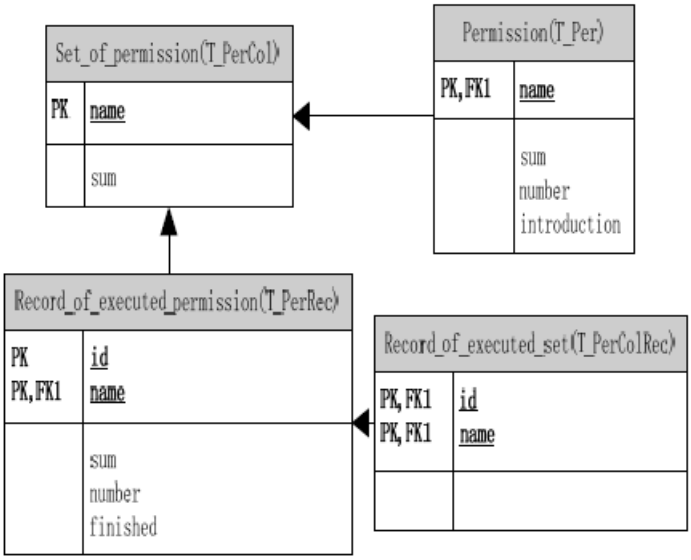

Fig 5. Diagram of database design

Integration with Modern Technologies

Machine learning and artificial intelligence advancements may provide rules engines for the dynamic permissions system. For example, Xia et al. propose predictive models which based on user behaviour can predict role change. (2018).

Summary

The literature provides a strong basis for DUPL, highlighting its ability to transform access control through the incorporation of cutting-edge algorithms and automation.

METHODOLOGY

The DUPL system proposed here is designed to fit easily into the rest of the system based on relational databases, as it relies on triggers and stored procedures to implement monitoring and enforcing of permission changes. Key components include:

Role Change Detection: A monitoring tool promptly detects user role alterations.

Dynamic Locking Algorithm: an algorithm that dynamically changes permissions according to previously defined role-permission templates.

Audit Logs: A centralized logging system provides full traceability for all permission changes.

Dynamic Locking Algorithm

The dynamic locking algorithm operates in the following steps:

1. Monitor role changes via database triggers.
2. Fetch the updated role-permission mappings.
3. Revoke all permissions not applicable to the new role.
4. Grant permissions corresponding to the new role.
5. Log all changes for auditing purposes.

Workflow

Step	Description
1	**Detect user role change**
2	**Fetch new role-permission mapping**
3	**Revoke outdated permissions**
4	**Apply updated permissions**
5	**Log permission changes**

IMPLEMENTATION

The system was implemented using MySQL for database management. A Python-based middleware facilitated communication between the application and database layers. Additionally, a web interface was developed using Flask to manage role-permission mappings.

Technical Stack

1. Database: MySQL with stored procedures.
2. Middleware: Python Flask for API integration.
3. Front-End: Bootstrap for managing user interfaces.
4. Logging: Logstash for centralizing audit trails.

RESULTS AND ANALYSIS

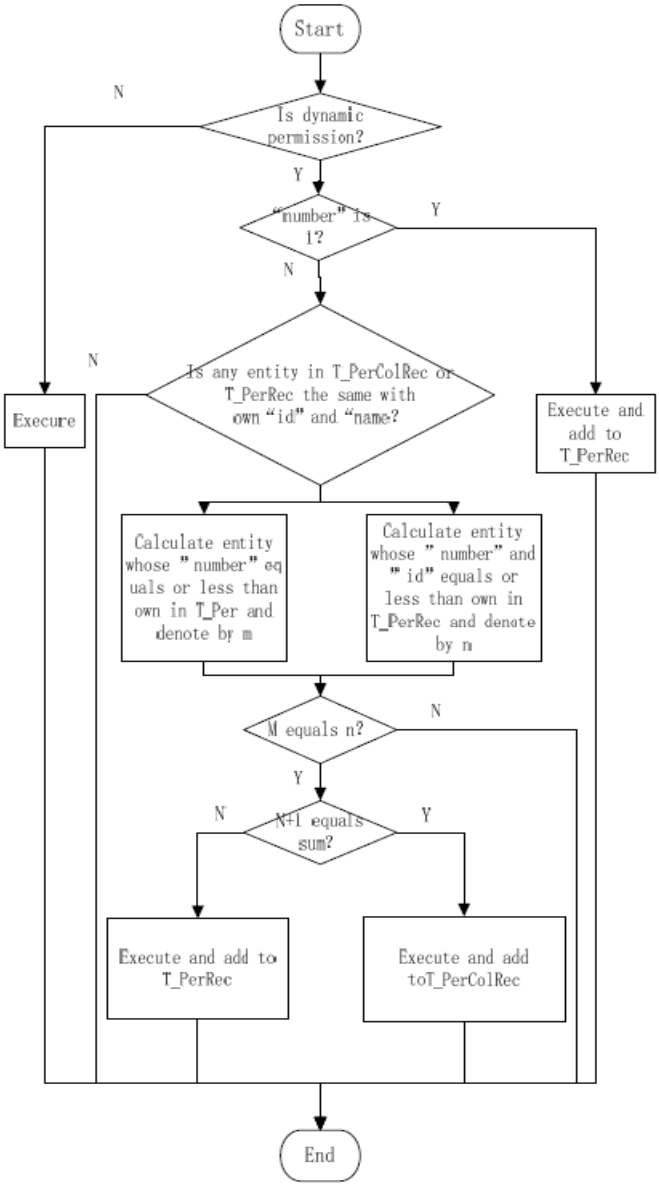

Fig 6. Flow diagram of algorithm

Case Study 1: Financial Institution

Metric	Static RBAC	DUPL
Time to Update Roles	5 minutes	30 seconds
Security Incidents	4 incidents	1 incident

In a financial institution, DUPL reduced role update times by 90% and security incidents by 75% over six months.

Case Study 2: Healthcare Database

Metric	Static RBAC	DUPL
Permission Revocations	120	300
Unauthorized Access	3 incidents	0 incidents

A healthcare provider experienced significant improvements in security, with no unauthorized access incidents reported after implementing DUPL**.**

Case Study 3: Educational Platform

Metric	Static RBAC	DUPL
Role Change Time	**10 minutes**	**1 minute**
User Complaints	**15**	**3**

An educational platform that implemented DUPL reported a drastic reduction in the time required to update roles during exam seasons. Professors and administrators expressed satisfaction with the system's responsiveness and transparency.

Performance Metrics

Metric	Static RBAC	DUPL
Average Latency	**2 seconds**	**1 second**
System Overhead	**High**	**Low**
Scalability	**Limited**	**High**
Compliance Rate	**70%**	**95%**

User Feedback

- **Financial Sector Users:** Reported improved trust in security systems**.**
- **Healthcare Administrators:** Praised the real-time adjustments to roles.

DISCUSSION

The results demonstrate that dynamic permission locking provides a significant advantage over static systems, particularly in environments with frequent role changes. By automating permission adjustments, organizations can:

1. Reduce administrative workload.
2. Enhance data security.
3. Improve system scalability.

Challenges and Limitations

1. **Role-Complexity Management:** Managing complex role hierarchies can be challenging.
2. **Resource Overhead:** Initial implementation may require significant resources.
3. **Dependency on Accurate Mapping:** Errors in role-permission mappings can lead to security lapses.
4. **Blockchain Costs**: Integrating blockchain can increase system costs.

Future Directions

1. **Machine Learning Integration:** Predictive analytics can further enhance dynamic locking mechanisms.
2. **Blockchain for Audit Trails:** Immutable audit logs can improve transparency and security.
3. **Cross-Platform Compatibility:** Expanding support to non-relational databases.

4. **Enhanced User Interfaces**: Simplifying management interfaces for non-technical users.

CONCLUSION

Dynamic User Permission Locking is a transformative approach to database security, addressing the limitations of static RBAC systems. By leveraging real-time monitoring and automation, organizations can ensure optimal security while minimizing administrative overhead. This approach is particularly beneficial for dynamic environments such as healthcare, finance, and e-commerce, where roles and permissions frequently change. The integration of machine learning and blockchain technology in the future can further enhance the adaptability and transparency of these systems. By addressing implementation challenges and refining user interfaces, DUPL can become a universal standard for secure and adaptive access control. This research lays a robust foundation for the continued evolution of access control mechanisms, ensuring organizations are equipped to handle modern security challenges effectively.

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