EDU-DRM: A Digital Rights Management (DRM) System for K-12 Education

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Abstract

The technological achievements in digital publishing have made paperless education possible even in K-12 education. Aside from high bandwidth distribution infrastructure, main problems of digital publishing are preserving personal information and protecting the rights of copyrighted contents. Although, specially designed digital rights management (DRM) systems can be used to control distribution and usage of private and/or copyrighted contents in K-12 education, dealing with large number of bursty concurrent access requests and changing the access rights of large amount of students from one content class to another at the end of each education period makes the problem different from existing ones. This paper introduces a new DRM system, called EDU-DRM, which includes a novel bit based authorization approach that reduces the processing time for authorization requests and automatize the access right adjustments with predefined rules for K-12 education. During the study, an experimental framework is designed using Apache Bench to analyze the proposed approach and its evaluation. The system is compared with XML based authorization approach and the results are presented in the paper.

\textit{Keywords:} Digital Rights Management (DRM), intellectual property, K-12 education, digital publishing, secure content distribution.

1. Introduction

Computer and communication technologies have changed dramatically in the last two decades. The form, functionality and connectivity of the computer systems have evolved, and new products have taken place in the market such as smart-phones, wearable computers etc. These new computer
technologies have changed our view to information by means of creation, access, storage and usage of
digital data. Now, any kind of teaching material such as books, pictures, videos or animations can be
stored in digital format. Distribution of the digital content have been changed, and it is called digital
publishing.

While achievements in the technology eases sharing digital data, it creates some new problems
such as preserving the privacy and protecting the copyright. Especially book authors, music and film
producers are suffering from illegal replications of their works. Last decade many systems have been
developed to overcome these problems, and they are named Digital Rights Management (DRM)
systems. Main aims of a DRM system are to store private or copyrighted material securely, and control
the distribution or usage. In this manner, a DRM system can be used to manage any kind of valuable
digital content starting from static data such as medical records up to dynamic stream data like digital
TV/Video broadcast.

In addition to above examples, privacy and copyright rules are also important for digital
materials used in education. Nowadays, the systems that protect the intellectual property of educational
publishers are becoming quite valuable since technological advances force publishers to convert the
way of publishing to digital. As an example, a project called Movement of Enhancing Opportunities
and Improving Technology, known as FATIH, has been started for K-12 education in Turkey by the
government at the end of 2011. One of the most important components of this project is a DRM system
to provide and manage digital educational materials to the end-users without violating the intellectual
property of providers. Developing such a DRM system which protects digital rights of the contents
becomes a challenging problem because the number of end-users is about almost 18 million students in
Turkey.

In this study, we have developed a new DRM system that includes new approaches in
authorization module and client application. The new system is called EDU-DRM, developed for K-12
education, and it is planned to serve millions of students and teachers. In education, the characteristics
of requests differ from existing DRM systems. Bursty and concurrent requests create performance
bottleneck for such systems that causes long delays [1]. The new approach changed the way of
accessing the contents by implementing a logic based access control instead of REL. For example, once
a request to a content arrived, EDU-DRM scans user profiles and automatically resolves access rights
through to authorization process. EDU-DRM encrypts the content in the first step during the upload
time, and preserve the encrypted form in the system throughout the life cycle, till it is consumed by a specifically developed plug in reader for web browsers.

2. Related work

2.1 Existing DRM systems

In literature, there are some commercial and academic DRM systems, some of which are in use and the others have developed just as research projects. One of the academic studies is “Open and Secure DRM” (OpenSDRM) project. In this project SSL/TLS connection is preferred to provide secure transmission among DRM components [2, 3]. OpenSDRM is known by its open source structure and interoperability, and the contents are encrypted with MPEG-4 standards [4]. Multimedia Information Protection and Management Systems (MIPAMS) is another important work which has been developed by Distributed Multimedia Applications Group (DMAG) as a European funded research project [5]. In this system, the contents are encrypted with MPEG-21 standard, and the system is implemented with web services in a modular fashion [6]. AXMEDIS, a European research project is a Java based DRM system which was developed for a variety of end-user devices [7]. It was not developed as open source but has a lot of open specifications that provides libraries to create independent usage scenarios. Coral is an integrator framework for DRM systems which mainly focuses on interoperability [8]. This is an important work for unifying different DRM systems, and has been developed by a consortium.

The commercial DRM systems usually hide internal details due to security reasons. One of the commercial DRM examples is Open Mobile Alliance DRM (OMA-DRM) which mainly focuses on standardization process of DRM systems on cellular phones [9]. OMA-DRM uses a specially designed Rights Expression Language (REL) where it differs from OpenSDRM and MIPAMS which use MPEG-21 based REL. In Microsoft's Windows Media Rights Manager (WMRM) system, audio and video contents are transferred in compressed format [10, 11]. However WMRM works only on Microsoft based operating systems. It has specially designed Audio Stream Format (ASF), Windows Media Audio (WMA) and Windows Media Video (WMV) formats. Adobe PDF Merchant is a specifically designed DRM system for Portable Document Format (PDF) documents [12]. It reaches to contents by means of a plug-in at Acrobat Reader. Since it is not supported by some operating systems such as Unix and some security concerns, Adobe replaced this system with Adobe Digital Experience Protection.
Technology in 2012. A personal mobile DRM system has been developed by Siddharth et. al. for Motorola smart phones [13].

Besides these DRM systems, there are also studies on security schemes of DRM systems in literature. For example, Das et. al. [14], Chang et. al. [15], Chen [16], and Chang et. al. [17] presented secure Enterprise Digital Rights Management (E-DRM) schemes. At some other studies security issues are studied for peer-to-peer music distribution and on mobile DRM devices [18, 19]. In this study, a fingerprint for every user is produced using by the RSA algorithm, and then it is embedded within the music file in a protected form to identify any unauthorized distribution.

2.2. DRM system architecture

The general architecture of DRM systems are client-server model due to demand distribution is homogeneous and the payload size of the contents are not very large. Once the number of end-user count or the content size increases or content type becomes time critical then performance bottleneck problem may occur in the client-server architecture. As this study is about to protect the copyrighted educational materials such as books, the DRM systems are examined from the point of bulk volume contents and user interaction platform.

There are many uses of DRM systems from protecting privacy of people to protecting copyrighted materials. However, every DRM system has specifically designed software modules such as authentication, authorization, license module etc. (see Figure 1). These modules are serving the user of the DRM system. Three main user group of a DRM system is producer, reader and publisher. A producer is the owner of a content, and is responsible for creating and uploading. From the view of a producer, a DRM system must provide authentication, authorization and the uploading functionalities. A reader, on the other hand, is a person who consumes (views, downloads, prints etc.) the contents. Sometimes a reader can be a guest who can only access the free materials as well as previews meta-data information of copyrighted materials. On the contrary, a normal reader is an authorized user who has some kind of authorizations on the copyrighted materials; like viewing, downloading, and printing etc. A producer is authorized to set/edit the rights (license rules) of uploaded contents and users, so needs management functionalities.

On the software side, there are three main building blocks of a DRM system: Content Server, License Server and Client Application. The illustration of a basic DRM system which includes these modules is shown in Figure 1.
The **client application** can be a web browser, a media player, an image viewer or any other application developed for specific needs. For example, a client application of a publisher is responsible for managing whole users of the system. The client application of the producer is responsible for the upload operation of the content and its meta-data to the content server. Then, the producer sets up the required rights about the uploaded content. General responsibilities of the reader client application are authenticating the reader, browsing the content meta-data, downloading the content in a secure way when needed and rendering the content.

In general, the **content server** is responsible for managing the content. Content management includes a wide range of operations from uploading and downloading the content and its meta-data to encrypting it and checking the rights of the content by the help of the license server.

The **license server** is responsible for managing and storing the rights of the content and the licenses purchased by users. In conjunction with the content server, the license server helps to store the rights on the content for each user of the system. It also checks the rights on the content for a particular user whenever the user requests that content. The license server fulfills the management of rights by using special languages called Rights Expression Language (REL). REL provides a flexible and interoperable mean for accessing digital contents. One of the well-known REL is Open Digital Rights Language (ODRL) [20]. It is XML based, and has been developed by W3C ODRL Community Group. The other well-known REL is MPEG-21 which has been developed by Moving Picture Experts Group (MPEG) [21].

Although these are the main building blocks of any DRM system, the implementation of any real-life DRM system generally requires the splitting of these blocks to smaller modules to enable the creation of a more modular, flexible and manageable structure. Creating a modular system also enables the easy integration of the standards such as MPEG-21, therefore making it more interoperable. For this purpose many DRM systems developed so far includes more components such as authentication and authorization. These blocks are responsible for authenticating the users and authorizing them to use the permitted services and contents of the system.

For instance, while a producer is authorized to upload contents to the system, a reader can only be authorized to download specific contents from the system. Besides this, the publisher can also authorize a user to manage a content (read, print etc.) depending on the authority of the user on the particular content which is stored by the license server. On some systems (e.g. MIPAMS [5]) authentication and authorization services can be divided into two components.
3. EDU-DRM: A DRM System for K-12 Education

Technological advances in digital publishing and front-end devices affect education materials and methods in K-12 education. In near future, today's paper materials in K-12 education are going to diminish gradually, and equivalent digital materials will replace them, and privacy and copyright rules become the most important issues for these materials. Some countries start taking initial steps for this era. For example, a project called Movement of Enhancing Opportunities and Improving Technology, known as FATIH, has been started by the government at the end of 2011, is among the most significant educational investments of Turkey. FATIH Project proposes that “Smart Class” project is put into practice in all schools around Turkey. With this project, thousands of schools and classes will be equipped with the latest information technologies and will be transformed into computerized classes (Smart Classes) [22]. In this scope, it is planned to distribute tablet PCs to all primary and secondary education (K-12) students besides interactive smart boards in classrooms.

In terms of FATIH project, digital copies of educational materials such as books and periodicals are distributed to authorized users like students and teachers for free of charge in Turkey. The digital contents are prepared by many authors for all grades and copyright costs are payed by the government (Ministry of National Education). FATIH project requires a specific DRM system to distribute the digital contents. Turkish government have made several project calls to overcome the problem. A novel DRM system that achieves the task must meet the following properties:

1. **Users:** Students, teachers, producers, guests and administrators are defined as user groups of the system. The student group is the most populated user group, and expected to be more than 18 million pupil. The teachers are forming the second largest group. Guests are a dynamic group and its population may vary but expected to be smaller than the size of teachers group. A group of officers are assigned as administrators who are responsible for editing meta-data of contents and users. Authentication information of the users are provided by Ministry of National Education.

2. **Contents:** Contents are split into 12 different classes based on K-12 curricula and a pool for newly uploaded but not approved documents. Producers must also enter necessary meta-data for their newly uploaded contents. A new content is first uploaded to the pool, and after
approval, it is moved to the respective grade class. Unapproved contents cannot be reached by the students and the teachers.

3. **Rule based authorization:** Since almost all students' status change annually, a rule based authorization must be implemented in the DRM system to adapt the access rights respectively.

4. **Users and contents relation:** Students and teachers must be allowed to reach only their own grade contents. Students grade records and their allowed target contents must change automatically every year. However, the system must easily allow a teacher to access the contents that reside different grades.

Based on above specifications, a new DRM system is designed. All possible “access rights” are determined and put into a table (see Table 1). Then, different roles are defined for the users of the system, shown in Table 2. A bit wise logic based encoding approach is used to implement REL for such complex, flexible management system with consuming minimum database disk space.

### 3.1 EDU-DRM Access Types

Table 1 shows seven different access types in the system. These access types are assigned to the roles given in Table 2. Some example content records stored in license table are shown with their respective access vectors in Table 3. EDU-DRM access types are explained in detail as follows:

**Edit records:** This access type permits only the admins to modify the profile data in the system. Further access limits are imposed at business logic of the system. For example a user with the user admin role is not allowed to modify the content profile data, likewise a user with the content admin role cannot modify the user data. The roles with this access type are expected to fix exceptions caused by generalization of rule based access distribution.

**Monitor:** This access type is specifically designed to generate different reports from the log tables of the system. These log tables are filled by the activities such as editing meta-data or content browsing. For example, a teacher with this access type can create a report that shows “how many times each student in a class accessed to a specific content?”

**Download:** This access type allows downloading an encrypted content into a device. The downloaded content is stored into disk in encrypted format. This feature is not utilized in this version of EDU-DRM, planned for future use.
**Upload:** Uploading is designed for loading the contents from remote sites to the system. Usually producers are granted for uploading.

**View:** The access type “view” is created for buffered viewing of a content data without saving it into the disk. For example a web browser gets the content data as a stream in this type, decrypt it in the buffer and displays. Once viewing action ends, no digital data from the content remains in the client machine. A special code has developed for server side to block client side caching.

**Erase:** This access type is provided for deleting contents from the server disk.

**Print:** This access type enables/disables printing hard copy of viewed contents.

### 3.2 Roles

Users of the system are divided into groups to treat them differently when they interact with the system. Eight distinct roles are created in the system level to simplify management of assigning the access rights to the user groups (Table 2). These roles are not the same as database level roles provided by any database system such as Oracle. Assigning an access type to a role is accomplished by using bit oriented vector. The following list explains the roles and their default access rights.

**Super admin:** This role is assigned to a group of people with very few members. These users have full access to anything (contents and tables etc.) in the system.

**User admin:** This group can edit only standard user profiles. Every region in the country may have one or more user admin, and they change a user profile when necessary.

**Grade admin:** This group can edit only user grade cells in the profile tables. User admin and grade admin roles are expected to resolve exceptions which may occur beginning of a semester. Both of these roles, for example, can be assigned to officers at schools to fix such problems caused by generalization of the rule based management. Figure 2 shows a user record structure designed for EDU-DRM.

**License admin:** License admin is a role that can be assigned to a group of users formed by experts. They have the power to accept or decline draft contents in the pool. Accepted contents are published by moving them to respective grade class by resetting the pool bit in the record (see Figure 3).

**Teacher:** A teacher may access multiple grade contents, can create a report from log data. For example, a teacher can create various reports that show access frequency of the students to a specific content for a period of time.
Student: Different from teachers, students can access contents only for viewing, and they only can reach their grade contents: downloading is not allowed.

Producer: A user can be a producer by role bit R7 in the user profile record (see Figure 2). Producers can upload draft contents to the pool only. The encryption keys are created at the beginning of an uploading process; then, the content is immediately encrypted and stored to the system disk. A producer can also view and print own documents uploaded to the system.

Guest: Guest users do not have passwords. If a user wants to login as “guest”, he/she must enter “guest” as user id. The system immediately let that user login to the system without asking a valid password. Then, the system automatically creates a user record for that user with empty profile data except R8 bit is set. A guest user can reach only public documents in the system. Public documents are marked by setting public bit (see PB in Figure 3).

3.3. Licensing

Licenses are usually distributed dynamically in general DRM systems, whereas in EDU-DRM licensing process is a static task. Assigning a student user to a class authorizes him to access a sub class of contents. At another point, assigning a content to a grade makes it available to respective classes. Student users' authorization does not change throughout the academic year, so they can reach to their contents. Next year, students' grades automatically change and their authorized sub classes also change. Similarly, a license of a content is set after evaluation process ends and the content is accepted. The content's grade does never change.

For example, this is totally different form iTunes by Apple. A user has to pay for licensing a movie in iTunes. Limited number of different devices registered to that account are authorized to download as many times the content as the user wishes. In another way a user can rent a movie, then in this case the license ends after a period of time. That means the authorization ends to access that content.

In EDU-DRM, licensing is managed by the license admins. A license admin should be an expert in the area because he evaluates the internals of a content just uploaded by a producer. Hence, a license admin can reject a content if the content is not suitable. If the content is appropriate, then licensing of a content is quite easy and accomplished by resetting just respective pool bit (PL) of the content profile data. After giving license to a content; then, that content becomes available to all authorized users.
The system automatically creates log data for all of these activities and the logs can be traced by the super admin. The system provides software tools to examine log data and create various reports about content and user activities.

3.4. Modules of the EDU-DRM System

The EDU-DRM has been developed in modular fashion. The system consists of several servers that their responsibilities are defined clearly at the beginning. These servers are authentication server, license server, content server and monitoring server which are implemented as separate objects in the system.

**Authentication server:** This server does login control if a user wants to retrieve a content in the list. A profile data must be created for a user to pass this step. All user profile data are stored at another site in the government. If a user does not pass the authentication he/she can log in to the system as a guest and can retrieve only public contents.

**License server (authorization server):** An authenticated user must also pass the license server to see if the user is authorized for the requested action. The requests coming from authorized users are fulfilled right away, otherwise a negative answer is turned back. Figure 4 depicts the activities coordinated by the license server.

**Content server:** The content server is responsible for the followings:

1. creates a new record with a unique id for newly uploaded content based on MPEG-21 digital item declaration (DID) standard [23].
2. responsible for encrypting and decrypting a content whenever requested.
3. managing and storing encryption keys for the contents and supply them when needed.

**Monitoring server:** A monitoring server generates different kinds of reports and logs of the system like authentication information, user activities, content information etc. It also creates an activity list about users on specific grade contents. For example, a teacher can create a report that shows how many times each student accessed some specific contents.

**Encryption:** The EDU-DRM system creates a pair of 4096 bit public/private keys with RSA algorithm at the initial setup phase. The private key is stored in the disk where only the root can access it. Then, a 256 bit symmetric key is generated by random number generator to encrypt a new content. The symmetric key is encrypted using asymmetric keys for security and stored into the database table.
Before encryption, a 160 bit summary information is taken by “SHA1” algorithm from the original content to prove originality and integrity. This 160 bit characteristic data is also stored into the database.

**Upload:** After passing authentication and authorization steps, a producer selects upload option from default menu configured for this group of users. The producer must enter definitive data for the new content and then press the upload button from the user interface shown in Figure 5. The meta-data is formed in MPEG-21 DID standard, and saved into the database [23]. There is no constraint on file format for upload, however currently the viewer (web browser) supports only PDF files. A content is encrypted on-the-fly during upload, and the encrypted form of the content is saved into the disk.

**View:** After passing authentication and authorization steps, a root process in the server fetches the encrypted key from the database. The symmetric key is resolved and sent along with the content and some Java-Script control script to the client side. Sending the content and the key to the client is accomplished by HTTPS protocol. The Java-Script disables some control buttons on client browser while decrypts the content. Copying and printing the content at the client side is prevented by this way. Resolved content key is never stored into the disk at client side, and once the session ends the key is deleted.

4. Experimental

A fully functional prototype EDU-DRM system has been implemented in Sakarya University and installed to the test servers for performance analysis. An alternative XML based authorization module was also implemented for EDU-DRM as a web service in the local domain. The XML file format is taken form the study by Polo at al. [24]. The size of the XML file used in the tests was approximately 1 KB which is usually much larger than this depending on interoperability conditions. Apache Benchmark is used to create bursty requests and timing of the events during the experiments [25].

Figure 6 shows the test bed used in the performance comparison studies. The web server, the license server and the database servers are created from a physical blade server system using a VMware, vSphere v6.0 virtualization software. The blades inside the chassis contain the following blade boards: Blade 1: 6 Intel Xeon E5-2630 CPU v4 2.20 GHz. 10 cores, Blade 2: 2 Intel Xeon E5-2640 CPU v4 2.40 GHz. 10 cores, Blade 3: 2 Intel Xeon E5-2650 CPU v4 2.40 GHz. 10 cores, Blade 4:
1 Intel Xeon X5650 CPU v4 2.66 GHz. 6 cores. The chassis contains 2.47 TB global memory of RAM shared by all blades. The computer is attached to a storage system (Hitachi HUS130 Storage) with a total of 100.78 TB disk space obtained from SSD, SAS, NL-SAS and SATA technologies. The chassis has 10 Gbps bandwidth in its backbone, and the local network infrastructure from servers to main switches is made of fiber optical cables with 40 Gbps bandwidth.

Figure 7 shows the events between the timestamps that happen during both type of authorization. As it can be seen from the figure, XML based authorization includes more events to satisfy interoperability.

Graphs in Figure 8 show performance results of various tests conducted with 100, 1000, 5000 and 10000 concurrent requests. The request tests are continued till the 10000 request reached, and the response time of each request is measured in milliseconds.

5. Results and Discussions

In the first part of the experiments, bundles of 100 concurrent requests are sent to the web server, and the response times are measured (see Figure 8(a)). Even though 100 concurrent request is far less than from the expected load, bit-based approach makes better than XML based approach. As it can be seen from the figure, the delay difference is about 10 ms and it steadily increases up to 9000 requests. It becomes exponential for both approach at the end of the experiment with a delay difference of 50 ms.

In the second part of the experiments, bundles of 1000 concurrent requests are sent to the system. As it can be seen in Figure 8(b), after 9700 requests, the delay time dramatically increases for XML based approach. When 10000 requests are reached, the delay difference between the two methods is about 15 seconds. After this point, each individual authorization request waits for about 26 seconds in the XML-based approach, while in the bit-based approach it is about 11 seconds.

In the third part of the experiments, bundles of 5000 concurrent requests are sent to the web server (see Figure 8(c)). This time the difference has started from 5000 requests and increased steadily till the end of the experiment. The final delay difference is about 35 seconds, which means every individual request that arrive after this point will wait at least 35 seconds for authorization process.

At the last part of the experiment, 10000 requests are sent concurrently all at once and the processing delays are observed (see Figure 8(d)). The XML based authorization causes significant
delays after 7000 requests have been reached, and a similar pattern repeats for bit-based approach after 8500 requests have been processed. Interestingly, the delay stays horizontal for some time and then a sudden increase occurs when physical limits such as network bandwidth or data retrieval bandwidth in the database server are saturated.

As a result, bit-based authorization approach makes EDU-DRM system more robust against bursty demands. Since XML-based approaches take interoperability more seriously, the time taken to process the detailed XML description files causes more delays in response to sudden requests. The client number is very large (18 million students), and the access pattern is quite bursty for DRM system in K-12 education, hence reducing the license processing time becomes more critical than interoperability of the system.

The system also has a rule based authorization adjustment module that automatically assigns the new licenses to the students at the end of each educational season. This approach significantly reduces the workload of license distribution that must be done at the end of each year. There is no license selling mechanism in the system as in classical DRMs.

The main disadvantage of bit-based role definition is that the encoded roles reduces interoperability with other DRM systems. However, smaller message size and shorter processing time significantly reduces the traffic in the network and possibility of a contention in the central server. Since EDU-DRM is developed for education only, interoperability has not been considered in the architecture.

6. Conclusions

The main problems of educational DRM systems are the delays that incurs in response to bursty requests coming from the students and to create/manage license conditions for millions of end-users every year. Hence, the licensing module of the educational DRM systems must be different. In this study, a DRM system architecture, called EDU-DRM, has been developed specifically for K-12 schools to manage proprietary digital material at educational institutions from primary schools up to colleges. In the system, a novel bit-based role and access right definition schemes have been developed instead of a Right Expression Language (REL) to process the requests within the least amount of time. A rule based authorization adjustment module has also been developed in the system that automatically assigns the new licenses to the students at the end of each educational season. EDU-DRM has been
developed as platform independent, neither an operating system nor a specific client application is required. Only a web browser is sufficient to retrieve the private contents. Since all the interfaces are developed using web based techniques, the system can easily be managed independently from any location. Many comparative experiments have been conducted to test the system authorization module performance for bursty requests, and promising results have been obtained.

As a future work, we are planning to distribute the central content server dynamically to locations closer to the end-users based on the request frequency. It is expected that this enhancement will improve the system response time further by hiding network latencies.

References


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**Figure 1.** Basic components of a DRM system.

**Figure 2.** A user profile record structure created in EDU-DRM system for a student user in grade K-1.

**Figure 3.** Content record structure in the system. (a) A draft K-11 content in the pool. (b) The content is reviewed and licensed by an authorized user simply resetting the pool bit (PL) in the record. It is now accessible by grade K-11 classes.

**Figure 4.** Flow diagram shows a content request by a user.

**Figure 5.** A screen shot for content uploading process. The producer must select a proper grade for the content before uploading.

**Figure 6.** The test bed block diagram used for bit based and XML based authorization comparative studies.

**Figure 7.** Authentication and authorization events: (a) XML-based, (b) bit-based licensing.

**Figure 8.** Comparative performance results are shown in milliseconds between EDU-DRM and XML based authorization for total of 10000 requests which are sent in concurrent bundles. (a) 100 concurrent requests in a bundle, (b) 1000 concurrent requests in a bundle, (c) 5000 concurrent requests in a bundle, (d) 10000 concurrent requests in a bundle.

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**Table 1.** Table depicts specified access types for EDU-DRM. They cover all kind of requests which may come from standard users or administrators of the system.

**Table 2.** Table shows the roles and respective authorization codes defined in the system. The authorization codes are encoded using binary logic for the access types given in Table 1.

**Table 3.** Table shows some example content records where a special access vector is assigned to each. The access vectors are created using the roles in the system, and they are kept in the license table in the server.
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(a)

<table>
<thead>
<tr>
<th>K1</th>
<th>K2</th>
<th>K3</th>
<th>K4</th>
<th>K5</th>
<th>K6</th>
<th>K7</th>
<th>K8</th>
<th>K9</th>
<th>K10</th>
<th>K11</th>
<th>K12</th>
<th>PL</th>
<th>PB</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard content profile data</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(b)
Figure 4

start

Browser (client)

User selects a content from the list
content_id

User enters user_id and password

user_id, password, content_id

Authentication server

Authenticated?

N

Licence server

Authorized?

N

Content server

Provide encrypted content to the user

Y

stop
Figure 5
Figure 6
Figure 7.a, 7.b
Figure 8.a, 8.b, 8.c, 8.d
## List of Tables

Table 1

<table>
<thead>
<tr>
<th>Access ID</th>
<th>Access Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Edit records</td>
</tr>
<tr>
<td>2</td>
<td>Monitor</td>
</tr>
<tr>
<td>3</td>
<td>Download</td>
</tr>
<tr>
<td>4</td>
<td>Upload</td>
</tr>
<tr>
<td>5</td>
<td>View</td>
</tr>
<tr>
<td>6</td>
<td>Erase</td>
</tr>
<tr>
<td>7</td>
<td>Print</td>
</tr>
<tr>
<td>Role ID</td>
<td>Role name</td>
</tr>
<tr>
<td>---------</td>
<td>---------------</td>
</tr>
<tr>
<td>1</td>
<td>Super admin</td>
</tr>
<tr>
<td>2</td>
<td>User admin</td>
</tr>
<tr>
<td>3</td>
<td>Grade admin</td>
</tr>
<tr>
<td>4</td>
<td>License admin</td>
</tr>
<tr>
<td>5</td>
<td>Teacher</td>
</tr>
<tr>
<td>6</td>
<td>Student</td>
</tr>
<tr>
<td>7</td>
<td>Producer</td>
</tr>
<tr>
<td>8</td>
<td>Guest</td>
</tr>
</tbody>
</table>
Table 3

<table>
<thead>
<tr>
<th>Content ID</th>
<th>Access Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>234</td>
<td>1 0 0 0 1 1 0 0</td>
</tr>
<tr>
<td>34</td>
<td>1 1 0 0 1 1 0 0</td>
</tr>
<tr>
<td>245</td>
<td>1 0 0 0 0 0 1</td>
</tr>
<tr>
<td>171</td>
<td>1 0 0 1 0 0 1 0</td>
</tr>
</tbody>
</table>