



A REVIEW ON SECURED IMAGE SHARING AND PRIVACY PRESERVING IN SOCIAL NETWORK

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Abstract—

Today we live in a world where everything is connected to the Internet and the social networks play an important role in our lives. The security and privacy of users is an essential factor of users in the social network. Multitudes of pictures are uploaded daily to social networks and, with them, parts of our private life are disclosed. With the development of social media technologies, sharing photos in online social networks has now become a popular way for users to maintain social connections with others. However, the rich information contained in a photo makes it easier for a malicious viewer to infer sensitive information about those who appear in the photo. How to deal with the privacy Disclosure problem incurred by photo sharing has attracted much attention in recent years. When sharing a photo that involves multiple users, the publisher of the photo should take into all related users' privacy into account. In this work, we propose a practical solution for secure photo sharing on social network with independence of its architecture which can be either centralized or distributed. This solution solves the inconsistencies that appear in distributed social network as a consequence of treating photos and access policies separately. Specifically, we solve this open problem by attaching an access policy to the images and thus, each time a photo is re-shared, the access policy will travel together with the image. In this paper, we explore and propose the design of a privacy-preserving photo sharing architecture, which ensures users privacy and at the same time preserves the usability and convenience of online photo sharing activity.

Keywords— Privacy, Social networks, cryptography, image sharing

Introduction

Online social networks (OSNs) have gained a lot of popularity on the Internet and become a hot research topic attracting many professionals from diverse areas. Since the advent of OSN sites like Facebook, Twitter, and LinkedIn, Instagram, OSNs continue to influence and change every aspect of our lives. A recent study shows that Facebook [17] has at least 1.71 billion active users per month. Moreover, according to that study, it is estimated that more than 300 million photos per day are being uploaded. Most OSN users have the tendency to share photos. There are several works that are focused on the reason for sharing personal information such as photos on SNS from a sociological perspective [7, 10, 11, 12]. These studies found out that most users share photos on OSNs to seek affection. Nevertheless, users are aware of the risks of their actions which might reveal personal aspects of their lives. Due to this, users usually weigh the risks of disclosing private information against benefits of not doing it.

Both security and privacy issues have been pointed out in several papers as unsolved and challenging problems [9]. Specifically, in the privacy domain, some authors have addressed photo sharing as an open problem in SN [15, 9]. This problem arises when users take photos they have access to and increase the audience of the photo by re-sharing it. For instance, imagine that Alice shares a photo with her friends, and later, Bob—who is a friend with Alice—re-shares it with his own friends, thus increasing the audience to his own friends as well. Essentially, this circumstance is given because the privacy policies that Alice has previously defined are applied only to her public domain and are not attached to the objects she shares out.

OSNs can be classified into centralized and distributed social networks. In centralized SNs there is only one instance which has a global view of the state of the system and where all information is handled. On the other hand, in Distributed Online Social Networks (DOSNs), there are different servers where each one of them has its own instance of the SN and has the ability of sharing and exchanging information between them. Facebook, Twitter or Instagram are some examples of centralized SNs. However, under the hood, the store infrastructure of

these SNs is geographically distributed. For instance, Facebook developers have deployed a distributed data store for the resources of the SN[2,14]. This storage system is based on a master/slave architecture which replicates the information geographically so that it is accessed efficiently. In the context of photo sharing, it might originate problems while updating the audience of a photo. Imagine that Alice initially shares a photo with her friends, but after a while she decides to restrict the audience to her family and rewrites the access control policy of the photo. Before this policy is replicated in the whole system-a few milliseconds according to [2]-there will be slaves which would show Alice's photo to the incorrect audience.

PROPOSED WORK

Diaspora [6] is the most popular example of DOSNs with more than 0.6 million users. Moreover, in Diaspora, each server is called a pod and has its own database. Thus, this architecture prevents a single party to have all the users' personal information. In a DOSN when users from different nodes of the system share information, it is replicated on each node. This highly distributed architecture makes very hard to keep consistency between pods and it directly affects the photo sharing problem we are tackling here. Furthermore, in Diaspora after a user has shared a photo, it is not possible to update its access control policies because once the photo is replicated, an access control policy is sent to specify the audience of the photo in that pod. Due to this unpleasant restriction, it originates some inconsistencies if the user updates the relations with users from different pods. For instance, imagine that Alice shares a photo with her friends. Bob, who signed up in a different pod, gets access to the photo, given that it was replicated to his pod and the access control policy allows him to see it. A few days afterwards, Alice decides to end her friendship with Bob. One would expect Bob to not be able to see the photo that was shared with Alice's friends. However, the unfriend event is not replicated to all pods where the photo was sent, and therefore Bob continues having access to the photo.

Note that in both architectures the problem arises from having two separate entities, i.e., the photo and its access control policy, and inconsistencies while updating the access control policy of a photo. Here we propose a solution where access control policies are "stuck" to the photo. Therefore when a photo is replicated in different nodes, its access policy travels together with it.

In this work, we focus on how to share private images on DOSN in a secure way. To do so, we propose a solution where the access policy is attached to the image by using Attribute Based Encryption (ABE), instead of defining a common access control policy in the generic privacy settings, e.g., "only family" or "colleagues and friends"[3]. Moreover, we have tested our proposal on Diaspora to demonstrate its viability on both modes centralized and decentralised. As far as we know, this is the first solution which allows different images formats such as PNG, JPEG or TIFF. Finally, by using the centralized mode of Diaspora, we will show how this could be easily deployed into real applications such as Facebook, Instagram. Or any other SN.

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PRELIMINARIES

For completeness and readability, this section provides a brief overview of the cryptographic primitives and security assumptions used throughout the paper.

Access Structure

Let U be the attribute universe and A a non-empty collection of attributes $\{Att_1, Att_2, \dots, Att_n\}$, with $Att_i \in \{0,1\}$. A is an access structure over U where the sets specified by A are called the authorized sets. Notice that each time that new users join the network, a set of attributes is assigned to them. Moreover, an access structure A is monotone if $\forall B, C \in A$, with $B \in A$ and $B \subseteq C$ then $C \in A$

Multi-Authority Attributes

Due to our solution uses the Multi Authority-Attribute Based Encryption (MA-ABE) scheme proposed in [16], we do assume that there is a computable function T which links each attribute u to a unique authority ϕ of the set of authorities' u_ϕ i.e. $T: u \rightarrow u_\phi$. Moreover, this function creates a second labeling of rows in the policy (A, ρ) , which maps rows to attributes by $T(\rho(x))$. We additionally follow the same notation introduced by the original authors where the attributes are defined according to the next pattern: [attribute-id] @ [authority-id].

MA-ABE Algorithms

MA-ABE scheme is mainly based on four different algorithms: *GlobalSetup*, *AuthSetup*,

KeyGen, Encrypt and Decrypt. In the following we summarize the five algorithms

(For a more detailed description check [19]):

GlobalSetup (1^λ) \rightarrow GP. This method requires a security parameter λ . It outputs the global parameters GP = $\{\rho, G, g, H, \mathcal{F}, \mathcal{U}, \mathcal{U}_\phi\}$.

AuthSetup; (GP, ϕ) \rightarrow $\{PK_\phi, SK_\phi\}$. this algorithm generates both a public and a private key for each one of the authorities.

KeyGen ($GID, \phi, Att, SK_\phi, GP$) $\rightarrow SK_{GID, Att}$. This method takes as input the user's GID, the authority ϕ , the attribute A_{tt} , the secret key of the authority SK_ϕ . And the general parameters GP and it outputs the user's secret key for a given attribute A_{tt}

—controlled for the authority ϕ —

Encrypt ($M, \mathcal{T}, \{PK_\phi\}, GP$) $\rightarrow CT$. This algorithm is run by the users and it receives as input the message to be encrypted M , the access policy $\mathcal{T} = (A, \rho)$, the public keys of the authorities $\{PK_\phi\}$, and the general parameters GP. It outputs

the cipher text CT (ciphered under the access policy \mathcal{T}) together with \mathcal{T} .

Decrypt ($CT, \{SK_{GID, Att}\}, GP$) $\rightarrow M$. When a user wants to decrypt a cipher text, she runs this algorithm. The GP, the cipher text CT and all the secret keys of that user $SK_{GID, Att}$ (to recover the shares of the access matrix) should be provided to get the plaintext.

System design

In this section we explain in detail our proposed solution for re-sharing photos in DOSNs. Concretely, we describe the design we implemented in Diaspora.

Diaspora's architecture and Assumptions

As mentioned in the introduction, Diaspora is very popular DOSNs. The source of its popularity lies on a distributed architecture which prevents a single party to control users' data. Moreover, Diaspora can work as a centralized social network if there is only one pod in the system. The distributed architecture of Diaspora consists of pods. A pod is a server which runs an instance of Diaspora's source code. In order for users to join Diaspora they can either join an existing pod or create their own. Every pod has its own database, therefore users join a pod, and their information is not available to everyone. Moreover, only the owner of the pod has direct access to the information of the database.

Users can connect with other users from the pod they joined as well as users who signed up in other pods. As usual in SNs, they can define connection relations to classify their contacts such as friends, acquaintances, family and so on. Using these relations, users can define the audience of their information, i.e., posts, photos, polls, etc. When information is shared with users from different pods it needs to be replicated. For example, when a set of photos are accessed in different pods then they are replicated in the databases of each one of the involved pods. After the photo is replicated, the access control policies (of the target pod) are updated to determine which users in the pod can access it. If the owner of the pod were to update the photo audience, the access control policies should be updated in all the pods where the photo was distributed to.

Note that this approach requires distributing the photo and (separately) the access control policy. In this way, consistency errors can easily appear, e.g., if the photo is successfully distributed but there is an error while distributing the access control policy. An additional problem is updating the policies of a photo. If a user decides to update the audience of a photo from her friends to nobody, this policy must be transmitted to all the pods where the photo has been replicated. As before, it can originate inconsistencies, for instance, when a pod with a replica of the photo loses connectivity. Currently in Diaspora it is not possible to update the access control policies of a photo after sharing it. This is, probably, because of the difficulties to enforce consistency in such a distributed environment. The previous example can be seen in Figure 1. Finally, in our proposal assume the following: i) the KeyGen algorithm is only run by the pods of Diaspora and thus they are trustworthy; ii) photos can be stored either in the pods or in public repositories so it is not mandatory to be secure; and iii) there is a function named *getAtt* that given a user, it returns the set of a attributes of the user to all the pods in the network.

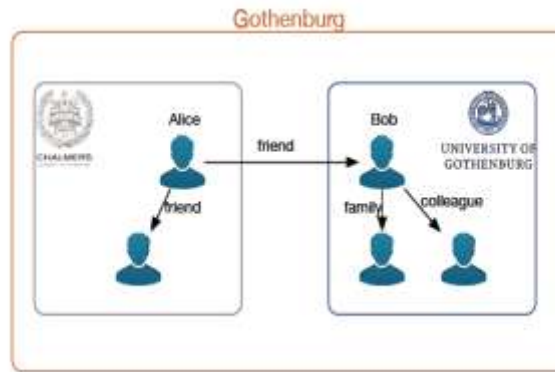


Fig. 1: DOSN example

MA-ABE Algorithms

In our solution we propose to attach the “access control policies” to the photo by using a decentralized version of ABE. Classical ABE approaches are based on a centralized assumption where a Trusted Party (TP) is in charge of distributing the keys of the scheme and sets up the system. However this is infeasible because of two main problems: 1) the authority has the power to decrypt everything in the system and 2) there is no practical solution if there are n -different authorities running the same cryptographic schema and users from different authorities want to share information with them.

Our approach consists in encrypting (parts of) the photo with a policy which specifies the attributes that other users must possess in order to see the encrypted parts. In what follows we provide a detailed description of our design of photo sharing in Diaspora based on MA-ABE.

Attributes in Diaspora: We define the attribute universe \mathcal{U} to be the set of all possible connections between users. For instance, in a pod with only two users, Alice and Bob, and the *friend* relation, the universe of attributes is $\mathcal{U} = \{friend(Alice), friend(Bob)\}$. the attribute *friend(Alice)* will be granted to users that Alice marked as friends. In

General, given a set of users \mathcal{US} and a set of connections C , the shape of \mathcal{U} is as follows: $\mathcal{U} = \{c(u) | \forall u \in \mathcal{US}, \forall c \in C\}$.

The universe of attributes in the system is not centralized. Due to Diaspora’s distributed architecture, the universe of attributes is composed by the attributes in each pod. Let $\mathcal{U}_{Chalmers}$ and \mathcal{U}_{GU} be the universe of attributes of the Diaspora pods of Chalmers university and Goteborg’s University (GU), respectively. Hence, we say that the universe of attributes in Gothenburg is $\mathcal{U}_{Gbg} = \mathcal{U}_{Chalmers} \cup \mathcal{U}_{GU}$. We use the same notation to denote the set of users $\mathcal{US}_{Gbg} = \mathcal{US}_{Chalmers} \cup \mathcal{US}_{GU}$ and the set of connections in Gothenburg pods $C_{Gbg} = C_{Chalmers} \cup C_{GU}$.

In this way, diaspora pods act as authorities which grant attributes to users. Determining whether a user has an attribute can be easily checked by querying the database of the pod. Note that users might have attributes which belong to different pods, e.g., Alice (from the Chalmers pod) can mark Bob (from the GU pod) as friend. Therefore, Bob will have attributes that come, not only from the GU pod, but also from the Chalmers pod. We use the same notation as in the original definition of MA-ABE in [19] to specify the provenance of an attribute, e.g., *friend(Alice)@Chalmers*. This example can be

Seen in Figure 1

Key Generation

Initially, when users join Diaspora, they have no connections to other users. Thus, they possess no attributes. As they interact with the system they start to create new connections, and consequently, grant (and being granted with) new attributes. As we mentioned in the preliminaries section, there exists a *KeyGen* algorithm which given the attributes Att_1, \dots, Att_n of a user, her *GID* and some additional parameters it produces

the corresponding secret keys, $SK_{GID,Att1} \dots SK_{GID,AttN}$ for $n \in N$. Nevertheless, note that the set of attributes that a user has is dynamic, i.e., it will change as users interact with each other. Therefore, a very important question to answer is: When should the key generation step be carried out?

We chose to perform the key generation algorithm only when the set of attributes of a user changes. Checking a change in the set of attributes of a user requires performing a broadcast call to all pods in the network. We use a function $getAtt:US \rightarrow \mathcal{U}$ which given a user, it requests the set of a attributes of the user to all the pods in the network and returns the union of all the resulting sets. Afterwards, we execute *KeyGen* for the new attributes of the user—in the corresponding pod—and remove the keys from attributes that might have been revoked³. Though executing *getAtt* is not computationally expensive, it requires communication between pods and might introduce delays; therefore it is important to minimize its use. Having an updated set of attributes is only necessary when decrypting photos since the set of attributes that a user has determines which parts of the photo that are visible. Therefore, in order to reduce the overhead of this operation to the minimum, we only execute *getAtt*—and the corresponding calls to *KeyGen*—after receiving a set of photos to show. This occurs, for instance, every time users access their stream of posts, or whenever they access a particular photo. Encrypting a photo does not require these secrets key. It only requires having access to the plain attributes the user will use for the policy. As mentioned earlier, this attributes are easily accessible by querying the database.

Attaching policies to photos. In the same way that users can now choose the audience of a photo, in our proposal users choose the attributes that other users must have in order to access a photo. Moreover, we let users to grab the area of the photo that they want to protect and the actions that can be performed with the photo e.g., re-share, like, comment, etc. This information constitutes the access policy, \mathcal{T} . The photo to protect together with \mathcal{T} —and, as before, some additional parameters, are the input parameters of the encrypt algorithm, which returns a cipher text CT. This cipher text is distributed in the system and it contains both the picture and the access policy. Example 1. Imagine that the department of vehicle's design from Chalmers decides to use Diaspora to share the photo shown in Figure 2a. However, this photo contains some parts that are still pending of the patent's decision and the researchers only want their colleagues to see the final design. In our system, researchers can select the part of the photo—where some compromised design appears—and encrypt it with the attribute colleague ($Department_{design}$)@Chalmers. Later users with the attribute colleague ($Department_{design}$)@Chalmers will be able to decrypt the photo and see Figure 2a and the remaining users will see Figure 2b.



Fig. 2: Sample photo with and without encrypted area

Several access policies can be attached to a photo. The only restriction we impose is that encrypted areas cannot be re-encrypted. For instance, let Alice be an engineer working at the Swedish vehicle manufacturer *Volvo*, and also collaborating with the department of vehicle's design at Chalmers. She decides that there are some parts of the images that the researchers at Chalmers shared (Figure 2b) that are still visible but should only be accessible by *Volvo* employees. In other words, some areas of Figure 2b that were not encrypted by Chalmers researchers. Therefore, she decides encrypt some of those parts and share the photo again. The resulting cipher text will allow users with the attribute colleague ($Department_{design}$)@Chalmers to only see some parts of the photo, users with the attribute employee (*Volvo*)@*Volvo* to see others parts of the image, and users with both attributes to see the complete photo.

Related Work

Despite the fact that there are several works that try to guarantee both security and privacy on photos, we only have found a few proposals that are specifically focused on DOSNs [1, 3, 4, 13, 16, 18, 19] and only a subset where ABE is used [1, 13, 18]. Authors in [13] proposed a DOSN called Cachet. The main characteristic of this schema is that both ABE and a symmetric encryption are used together. Basically, the secret key is encrypted using ABE and only those users that satisfy the policy will get the secret key and decrypt the content. This architecture is similar to the one proposed by Baden et al. some years before in [1].

Recently, a work published by Yuan et al. in [18] proposed to encrypt an image under an access policy by using an ABE scheme. Moreover, this proposal uses three different encryption schemes: symmetric encryption, RSA and Cipher text Policy-Attribute Based Encryption (CP-ABE). Symmetric encryption, in particular AES, is used to encrypt the areas of the image. The RSA algorithm is used to encrypt a secret key for a given user. Finally, CP-ABE is used to check who can access to a given secret key in order to decrypt a given photo. ABE it is commonly used as an encryption scheme to share the secret key of a symmetric encryption such as Advanced Encryption Standard (AES). This is especially useful because symmetric encryption performance is significantly lower than any other public encryption schema. Additionally, by using this technique the size of the cipher text produced by the ABE remains always constant.

However, using symmetric encryption to hide some area of the picture and ABE for encrypting that secret key, has one problem when it is applied to a SN: once a user has access to decrypt that piece of information, she might share the secret key and thus no more security will be provided.

Our proposal, in comparison to [18], contemplates both DOSNs and SNs. We do not need to include two more parties in the architecture such as a key server and a Certified Authority (CA). We do not need to create a dedicated application on the client's side to view the encrypted photo. We support both, JPEG files and PNG. Additionally, we have tested our proposed solution based on different attributes on both, the universe \mathcal{U} and in the access policy \mathcal{T} .

Furthermore, it is worth mentioning that classical ABE approaches are based on a centralized assumption where a TP is in charge of distributing the keys of the schema and sets up the system. However this is infeasible in DOSNs because there were no practical solution if there are n -different authorities running the same cryptographic scheme and users from different authorities want to share out private information. Nonetheless, Rouselakis et al. proposed a decentralized and MA-ABE where different authorities spread all over the world can share information in a secure way by using an ABE scheme. Regarding attribute revocation, our approach is based on running the *KeyGen* algorithm each time a photo is requested by a user. However this is still an open issue. In the literature there are some other approaches such as using an expiration time in the access policy \mathcal{T} or using specific cryptographic primitives [16].

Conclusions

In this paper we have proposed a solution for re-sharing photos securely on distributed social networks. We have used ABE to encrypt and decrypt the content of the picture that belongs to that person and thus, users can define different access control according to some policies previously defined over the same image. Moreover, as far as we know, this is the first solution that can be deployed into both decentralized and centralized social networks and we also allow different photograph's formats such as PNG, JPEG or TIFF. Finally, we have tested our solution on the distributed social network Diaspora, with one pod (centralized mode) and more than three pods (decentralized mode), a hundred of attributes each and the evaluations show that our solution can encrypt/decrypt images in less than 2 seconds.

Future work

Currently there are no well-defined rules about who can encrypt which parts of a photo. We only impose the simple rule that the encrypted area of a photo cannot be re-encrypted by anybody. This simple rule might not be enough from the point of view of usability. It might still lead to undesirable behaviors. For instance, imagine that Alice uploads a photo of herself without encryption. Later Bob—who has access to the photo—decides to encrypt some part of it so that only he can see the photo. In other words, now Alice cannot see parts of the photo that she uploaded. This authorization problem goes beyond the scope of this paper and requires a detail analysis of the interactions that can be performed in the social network together with the encryption algorithms. There

are formal techniques to attack this problem, in particular, there exist formal language to encode privacy settings of social networks and formally reason about them [7, 15, 16]. We plan to formalize our solution in order to precisely define which actions are allowed and prove that no undesirable behaviors can occur.

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