Implementation of Simplex Channels in the Blom’s Keys Preliminary Distribution Scheme

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Abstract. In article the modification of the Blom’s keys preliminary distribution scheme, considering the direction of information streams is suggested. For this modification it is necessary to use function from three variables. Function of formation of key materials will be asymmetrical. The exponential form of this function which does not increase the volume of key materials is suggested.

1. Introduction

Keys preliminary distribution schemes are used for the organization of users interaction on secure channels in communication network. The main idea consists that each user receives a set of key materials on the basis of which he can calculate the common key of enciphering with any other user of system, using open information.

The Blom’s keys preliminary distribution scheme is based on interaction model "everyone with everyone". However such approach can be used only in networks with the entrusted users. In the modern global networks the approach in which there are restrictions for the privileges of users is used. There can be restrictions as on actions of the user in all network, and on access to resources. There are several ways for solution these tasks. One of approaches received the name ID-based cryptography [1].

Now problems of ID-based cryptography are solved with the enciphering asymmetric algorithms. The main idea consists in development of key information on the basis of identifiers [1] or user attributes [2]. Recently ID-based cryptography develops in the direction of the approaches allowing contacting any subscriber of network only on the basis of open information. Each user of network has to receive some certificate from certification center. In many articles problems of sending the ciphered messages and the digital signature by means of cryptographic algorithms are solved with an open key. The main lack of this approach is the common problem of asymmetric cryptography use - larger complexity of calculations. It brings to operating time delays. Therefore, the problem of development of ID-based cryptography fast algorithms is relevant.

It is also necessary to consider criteria to which the attributes based cryptosystem, formulated in article [3], has to satisfy:

K1: Data confidentiality.

Data shall be encrypted by the owner before their sending. The unauthorized user cannot learn about data which were encrypted.

K2: Detail access monitoring.

In users group the system provides various access rules for each certain participant of group. Thus, users from one group can have various access rules to data.
K3: Scalability.
The number of the registered users should not influence system efficiency.

K4: Monitoring of actions.
Transfer the authorized user secret key attributes to other persons is inadmissible.

K5: Response of the user’s rights.
If the user quits the system, then the system can recall the rights of this user. The user, whose rights were recall, will not be able to get access to data any more.

K6: Impossibility of conspiracy.
Users cannot unite the attributes to decipher data. Each attribute is bound to a polynomial or a random number. Thus, users cannot enter into a collision with each other. Also distribution of keys with restriction for interaction can be realized by means of hash functions [4].

Other approach is based on modification of keys preliminary distribution schemes. In article [5] the modification of the Blom’s scheme allowing realizing the ban on certain information canals between users is suggested. In articles [6,7] the similar task is solved on the basis of the KDP scheme keys preliminary distribution. In both cases the global exchange by information between two users is forbidden or allowed. In actual systems it is necessary to solve a access control problem for different type resources. Thus, the problem of keys preliminary distribution schemes modification, considering the direction of informational streams, is relevant.

The purpose of this article is development of the keys preliminary distribution schemes for system taking into account types of accesses.

2. Problem definition

Let’s consider system with two basic types of access: read (r) and write (w). At initialization of the information channel it is necessary to watch in what direction data will be transferred. Thus, all channels have to be simplex. Let’s enter the variable $s$ for direction of data transmission. If the user $u$ sends a request for opening the channel on reading, that is obtaining information, then $s=-1$. If the user opens the channel on writing, that is information transfer, then $s=1$.

In the keys preliminary distribution scheme to each user via a secure channel key materials are given. On the basis of key materials with use open information the user calculates an encrypting key. In case of simplex channels for couple of users $u_i$ and $u_j$ two keys have to be formed: $k_{ij}$ - key for information transfer from the user $u_i$ to the user $u_j$, $k_{ji}$ - key for information transfer from the user $u_j$ to the user $u_i$. In case of inquiry of the user of $u_i$ for reading information to the user of $u_j$ or inquiry of the user of $u_j$ for record $k_{ji}$ key is used. In case of inquiry of the user of $u_j$ for reading information to the user of $u_i$ or inquiry of the user of $u_i$ to the user of $u_j$ for record $k_{ij}$ key is used. Let’s demand that the forbidden channels of communication had a zero pair key, and legal - nonzero. We will call the keys preliminary distribution scheme meeting these conditions simplex.

3. Algorithm for keys preliminary distribution

We realize the scheme of preliminary distribution of keys taking into account simplex channels on the basis of the well-known Blom’s scheme. In the Blom’s keys preliminary distribution scheme on the server the symmetric polynomial from two variables $f(x,y)$ over the field $\mathbb{Z}_p$ is generated. Some number $r_j$ is compared to each user $u_i$. Further for each user polynomials from one variable are formed $g_i(x)=f(x,r_j)$. These polynomials are transferred via secure channels to users and saved in a secret. If necessary to develop the common key with the user $u_j$ the user $u_i$ takes the $r_j$ element from open base and calculates value $k_{ij}=g_i(r_j)$. The same way the user of $u_i$ enters, calculating $k_{ji}=g_j(r_j)$. Symmetry of a polynomial $f(x,y)$ provides equality $k_{ij}=k_{ji}$.
For implementation of the simplex keys preliminary distribution scheme it is necessary to consider the directions of informational streams. For accounting of the direction of streams we will generate on the server a polynomial from three variables $F(x,y,s)$ over the field $\mathbb{Z}_p$. The variable $s$ can accept two values (+1 or -1) and defines the direction of information stream. To each user $u_i$ it is comparable some number $r_i$ which is sited in open form and it is protected from changes. For each user keys distribution server forms a polynomial $G_i(x,s) = F(x,r_i,s)$ also transfers it via a secure channel.

On the basis of the function $G_i(x,s)$ and numbers $r_i$ for the allowed information channel $k_{ij} \neq 0$, and for the forbidden channels $k_{ij} = 0$ is generated. Both participants of exchange have to develop an identical key on the basis of secret key materials and open information about each other.

Let's consider two types of user's interaction at information transfer. First, we will stop on a case in which the user of $u_i$ initiates obtaining information from the user of $u_j$, that is makes to it an inquiry on reading. The user $u_j$ sends information, beforehand having encrypted it a key $k_{ij} = G_j(r_i, 1) = F(r_0, r_j, 1)$.

The parameter $s=1$, as for user $u_i$ the informational stream is proceeding. The user $u_i$ receives the message and decrypts it the same key, calculated on the basis of the key materials:

$$k_{ji} = G_i(r_j, -1) = F(r_i, r_0, -1).$$

The parameter $s=-1$, as for $u_j$ the informational stream is entering.

The second case consists that the user $u_i$ initiates sending information to the user $u_j$, making to it an inquiry on record. The user $u_i$ sends information, beforehand having encrypted it a key $k_{ij} = G_i(r_j, 1) = F(r_j, r_i, 1)$.

The parameter $s=1$, as for $u_i$ the informational stream is proceeding. The user $u_j$ receives the message and decrypts it the same key, calculated on the basis of the key materials:

$$k_{ij} = G_j(r_i, -1) = F(r_j, r_0, -1).$$

The parameter $s=-1$, as for $u_j$ the informational stream is entering.

From consideration of these two cases three requirements imposed on function $F(x,y,s)$:

$$F(x,y,1) \neq F(y,x,1),$$
$$F(x,y,-1) \neq F(y,x,-1),$$
$$F(x,y,1) = F(y,x,-1).$$

The first two requirements come down to asymmetry of function $F(x,y,s)$ to shift of the first two arguments at any value of the third argument. For cryptographic firmness it is also necessary to demand that function $F(x,y,s)$ evaluation was impossible on the basis of the known value $F(y,x,s)$.

Let's set function $F(x,y,s)$ in a form:

$$F(x,y,1) = x^{h(y)}, F(x,y,-1) = y^{h(x)}.$$

$h(x)$ is some polynomial from one variable. This function meets all three requirements, which are listed above. The cryptographic firmness of this function is provided with complexity of integer logarithm problems and calculation of a root in terminating fields.

Let's consider the keys distribution scheme on the basis of this function. Key materials are transferred to each user. The user calculates function from two variables:

$$G_i(x,1) = F(x,r_i,1) = x^{h(r_i)},$$
\[ G_i(x, -1) = F(x, r_i, -1) = r_i^h(x). \]

For calculation the function values \( G_i(x, 1) \) the user of \( u_i \) needs to know one number \( h_i = h(r_i) \) which the server transfers it via a secure channel.

Let's consider more composite case of calculation \( G_i(x, -1) \). Let \( h(x) \) is polynom:

\[ h(x) = a_m x^m + a_{m-1} x^{m-1} + \ldots + a_1 x + a_0. \]

Then value of function:

\[ G_i(x, 1) = F(x, r_i, 1) = x^{h(r_i)} = \left( b_m^{(i)} \right)^{z_m} \ldots \left( b_1^{(i)} \right)^{z_1} b_0^{(i)}, \]

there

\[ b_k^{(i)} = r_i^{a_k}, z_k = x^k \ (k = 1, \ldots, m). \]

Thus, the server as key materials sends to the user \( u_i \) via a secure channel the vector:

\[ g_i = \left( h_i, b_m^{(i)}, b_{m-1}^{(i)}, \ldots, b_1^{(i)}, b_0^{(i)} \right). \]

These data are enough for calculation the values of function. The problem of coefficients determination for polynomial \( h(x) \) from vector coordinates \( g_i \) comes down to a discrete logarithm.

This scheme slightly increases the volume of key materials. Only one number is added to the traditional Blom’s scheme.

4. Example

Let's consider implementation this scheme on the example of three users. We will carry out calculations to the field \( \mathbb{Z}_7 \). Let's choose the polynomial

\[ h(x) = 2x^3 + 3x^2 + x + 1. \]

Random numbers for each user

\[ r_1 = 2, r_2 = 3, r_3 = 5. \]

Key materials

\[ g_1 = (g_{10}, g_{11}, g_{12}, g_{13}, g_{14}) = (31, 4, 1, 2, 2), \]
\[ g_2 = (g_{20}, g_{21}, g_{22}, g_{23}, g_{24}) = (85, 2, 6, 3, 3), \]
\[ g_3 = (g_{30}, g_{31}, g_{32}, g_{33}, g_{34}) = (331, 4, 6, 5, 5). \]

Let's consider chances of user’s interaction:

1. The informational stream is directed from the user \( u_1 \) to the user \( u_2 \). For the user \( u_1 \) the stream is proceeding. The user \( u_1 \) calculates an encrypting key:

\[ k_{12} = G_1(r_2, 1) = r_2^{h(r_1)} = r_2^{h_1} = r_2^{g_{10}} = 3. \]

For the user \( u_2 \) the informational stream is entering. The user \( u_2 \) calculates an encrypting key:
User’s keys for \( u_1 \) and \( u_2 \) are equal.

2. The informational stream is directed from the user \( u_1 \) to the user \( u_2 \). For the user \( u_1 \) the stream is entering. The user \( u_1 \) calculates an encrypting key:

\[
 k_{21} = g_1^r_1 g_1^{r_2} g_2 g_3 g_4 = 2.
\]

For the user \( u_2 \) the informational stream is proceeding. The user \( u_2 \) calculates an encrypting key:

\[
 k_{21} = g_2(r_1, 1) = r_1^{h_2(r_2)} = r_1^{g_2} = 2.
\]

User’s keys for \( u_1 \) and \( u_2 \) are equal. Keys of information exchange for users of \( u_1 \) and \( u_3 \) can be similarly calculated:

\[
 k_{13} = 5, k_{31} = 2.
\]

And also for users \( u_2 \) and \( u_3 \):

\[
 k_{23} = 5, k_{32} = 3.
\]

In all cases the pair keys, calculated by different users, coincide.

Conclusion

Modification of the Blom’s scheme allows organizing messages exchange on simplex channels. For this purpose it is necessary to refuse the idea on use of symmetric polynomials. Such approach is caused by the fact that exchange of information becomes the asymmetrical. Calculation of a key demands use the operation of an involution. It is characteristic for all algorithms ID-based cryptography. However the suggested scheme allows controlling the directions of informational streams that is its distinctiveness.

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