Centralized group key management scheme for secure multicast communication without re-keying

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Abstract—In the secure group communication, data is transmitted in such a way that only the group members are able to receive the messages. The main problem in the solution using symmetric key is heavy re-keying cost. To reduce re-keying cost tree based architecture is used. But it requires extra overhead to balance the key-tree in order to achieve logarithmic re-keying cost. The main challenging issue in dynamic and secure multimedia multicast communication is to design a centralized group key management scheme with minimal computational, communicational and storages complexities without breaching security issues. Several authors have proposed different centralized group key management schemes, wherein one of them proposes reducing computational complexity but increases computational and storage costs however another proposes decreasing the computational and storage costs which eventually breaches forward and backward secrecy. In this paper we propose a comparatively more efficient centralized group key management scheme that not only minimize the computational, communicational and storages complexities but also maintaining the security at the optimal level. The message encryptions and decryptions costs are also minimized. Further, we also provide an extended multicast scheme, in which the several requests towards leaving or joining the group can be done by large number of members simultaneously. In order to obtain better performance of multicast encryption, the symmetric-key and asymmetric-key cryptosystems may be combined.

Keywords: - Group key management, Re-keying, Secure multicast communication

1. Introduction

In secure group communication, key management plays an important role. In the internet scenario, for sending and exchanging private messages among group members, the group formation and group communication are very common[1]. Multimedia services like video conferences, pay-per-view, audio and video broadcasting where multimedia data are sent to a group of members are based on multicast communication [1].

In Group communication the groups may be static and dynamic. For secure communication, a common key is required for individual member in the group. In the static groups, the membership of the group does not change during the communication, therefore an unchanged group key is distributes to the group members [1]. In order to achieve the forward and backward secrecy in the dynamic Group, the group key needs to be updated frequently whenever member leave and join the group. This process is known as group re-keying. The Backward secrecy ensures that a joining member cannot gather information about past communication and the Forward secrecy ensures that an expelled member cannot gather information about future communication.

In this paper, we propose a scheme that preserves the forward and backward secrecy in group communication. In addition, proposed scheme does not need to maintain the key tree balancing and eliminates the re-keying process whenever member joins/leaves the group. We also provide a multicast scheme which support joining and leaving operation simultaneously for bulk number of members. For better performance of multicast encryption we combine symmetric and asymmetric-key cryptosystems.

The remainder of this paper is organized as follows. Some existing multicast key management schemes are illustrated in section 2. The comparative analysis of proposed scheme with exiting key management schemes is given in section 3. The results of proposed scheme are presented in section 4. The comparative analysis of proposed scheme with exiting key management schemes is given in section 5. At last the conclusion is given in section 6.

2. Brief review of Existing multicast key management schemes

For centralized group communication, the author’s Pandi Vijayakumar, Sudan Bose, Arputharaj Kannan [1] proposed a key management scheme based on Chinese remainder theorem that reduces computation complexity of the key server up to O(1) and the computation complexity of group member is also minimized. The author’s H. Wang and B. Qin [2] proposed a novel authentication scheme for access control in pay-TV systems that has shorter transmission message and can be applied in the environment which has limited bandwidth.

L. Pang, H. Li,Q. Pei [4] proposed a new MSK distribution protocol that is more efficient than the original one in WAPI and can be used to substitute the original protocol in WAPI. Wen Tao Zhu [5], proposed two new variations of LKH. One is based on hash functions while other is for generating new keys based on existing ones. The authors also address minimizing the computational overhead of the key server. Deuk-Whee Kwak, SeungJoo Lee, JongWon Kim,and Eunjin Jung[6] Proposed an efficient LKH key tree balancing algorithm for a highly dynamic and large secure group.

Mingyan Li, R. Poovendran, and C. Berenstein [7], describe how the number of keys to be stored by the group controller can be minimize. The author’s Wong et al. and Waller et al. [21] proposed a scheme ‘logical key hierarchy (LKH) tree approach’ which provides an efficient and secure mechanism to maintain the keys. The communication and computation cost increases logarithmically with the group size for a join or leave request. The Communication cost in LKH reduces from O (n) to O (logn) for the re-keying.

One-way function (OFT) scheme was proposed by Sherman and McGrew [3] to reduce the communication cost from 2log2N−1 to log2N. To overcome the above problem, Lin et al. [9] proposed the SBMK scheme using the star based architecture, in which there is no need for re-keying when a member joins/leaves the group. In
Extended group key management scheme is given in figure 1.0. The star-based architecture of proposed centralized group key management scheme is in figure 1.0. The proposed scheme is divided into three phases, the Brief description of three phases are given as:

3.1 Centralized group key management scheme

The star-based architecture of proposed centralized group key management scheme is given in figure 1.0. The proposed scheme is divided into three phases, the Brief description of three phases are given as:

3.1.1 Key assignment phase

The steps for key assignment phase are as follows:

1. The server authenticates the member who wants to join the group.
2. After authentication the individual member $U_i$ chooses two prime number $p_i$ and $q_i$ randomly and compute $X_i$ as

$$X_i = p_i \times q_i$$

3. The authenticated members send their $X_i$ value to the key server.
4. The key server computes the product of each $X_i$ value of authenticated members and stores the product value in $Z$.
5. The server registers the members if and only if $gcd(Z, X_i) = 1$.
6. The key server chooses a large prime number $p$ and declares as a public key for server as well as members.
7. The key server computes the product of each $X_i$ value of authenticated members and stores the product value in $Z$.
8. The authenticated members send their $X_i$ value to the key server.
9. The server registers the members if and only if $gcd(Z, X_i) = 1$.
10. The key server chooses a large prime number $p$ and declares as a public key for server as well as members.

3.1.2 Message encryption phase

The steps for message encryption phase are as follows:

1. After determining the set of members who wants to join the group, the server uses $e$ and $X_i$ value of each member in the group to encrypt message $M$ as:

$$M_{pi} \equiv M^{d_{pi}} \mod X_i$$

2. Convert $e$ exponent into binary sequence which can be represented as

$$e = \sum_{k=0}^{r-1} e_k 2^k$$

3. Take the binary sequence of $e$ as:

$$e = (e_{r-0}e_{r-2}e_{r-3} \ldots \ldots \ldots e_2e_1e_0)_{2}$$

4. Set the initial value of cipher text $C = 1$

5. Repeat steps in eqn. (5) from $i = k - 1$ downto 0

$$C = (C \times M) \mod \prod_{i=1}^{r} X_i$$

if $e_i = 1$

$$C = (C \times C) \mod \prod_{i=1}^{r} X_i$$

otherwise

6. The key server broadcast the message cipher text $C$ to the members in the group.

3.1.3 Message decryption phase

After receiving the cipher text $C$, the individual member $U_i$ of the group can decrypt $C$ using its own private key $d_{pi}$ and the value of $X_i$. The steps for message decryption phase are as follows:

1. The group members can compute the following modular components:

$$d_{pi} \equiv d_i \mod (p_i - 1)$$

$$d_{qi} \equiv d_i \mod (q_i - 1)$$

$$C_{pi} \equiv C \mod (p_i)$$

$$C_{qi} \equiv C \mod (q_i)$$

$$M_{pi} \equiv (C_{pi})^{d_{pi}} \mod (p_i)$$

$$M_{qi} \equiv (C_{qi})^{d_{qi}} \mod (q_i)$$

2. The members can use Chinese Remainder theorem, to solve the congruence’s for message $M$ as:

$$M = \left[ M_{pi}q_{i}^{-1} \mod p_i + M_{qi}p_{i}^{-1} \mod q_i \right] \mod X_i$$

Now using Fermat’s little theorem

$$M = \left[ M_{pi}q_{i}^{p_{i}-2} \mod p_i + M_{qi}p_{i}^{q_{i}-2} \mod q_i \right] \mod X_i$$

The members can also use the following equation to decrypt the message

$$M = M_{pi} + [(M_{qi} - M_{pi} + q_i).A] \mod q_i$$

Where $A$ is a constant integer such that $A.p_i \equiv 1 \mod q_i$, i.e $A$ is known as multiplicative inverse of $q_i$ and can be determined by using the Extended Euclid’s Algorithm.
The proposed scheme ensures that only the members whose $X_i$ values are used to encrypt the message are able to decrypt the message.

3.1.4 Member joining the group

Whenever a new member ‘$U_{n+1}$’ is authorized to join the group, the server repeats the same procedure as that of key assignment. The re-keying for existing members is not required because their $X_i$ values and private key $d_i$ are not affected.

3.1.5 Member leaving the group

Whenever a member $U_i$ wants to leave the group, the key server deletes their $X_i$ value from the active list. The remaining members do not need to modify the secret information $X_i$ and private key $d_i$.

3.2 Group key management scheme for bulk number of members

We proposed a new concept for group key management that is designed with the focus upon the bulk members. The pool of members is divided into several small groups called the subgroup (SG). These subgroups together represent the whole group of members. Each subgroup has its own subgroup controller (SGC) responsible for the respective subgroup. These subgroup controllers form a group known as all-controller-group (ACG). There is a group controller (GC) who is responsible for the ACG.

![Figure1: Proposed Architecture for GKM for Bulk number of members](image)

The group public key is generated by the GC and is propagated to all the members through the SGCs. All members of the group (including GC and SGCs) use the same group public key. In this approach, the GC does not need to manage all the members of the group; GC only has to manage the SGCs. The members of the each subgroup send their respective factors to the SGC. The SGC verifies the factors of the members and manages the joining/leaving of members in the respective subgroup. The SGCs compute their factors, independently of their respective subgroup members, and send these factors to the GC. The GC verifies these factors of SGCs and maintains the uniqueness of the SGCs’ parameters.

In communication, the message is encrypted by the group controller GC using the group public key and AGC parameters. This encrypted message is then sent to the subgroup controllers SGCs. The SGCs decrypt the message using their respective secrets and again encrypt the message using the public key and the respective SGC parameters. Now this cipher text is received by the group members who decrypt the message using their respective secrets. The response time for members’ joining (in bulk) is reduced as the members are divided into the subgroup. Also the subgroups are independent of each other, so the users are provided with a large pool of prime numbers to select the parameters. Therefore, the chances of rejections of parameters are less in proposed approach that resulting into lesser computation cost. The detail description of scheme is given below:

3.2.1 Key Assignment phase

The key assignment phase is divided into two parts: key assignment in ACG and key assignment in subgroups.

(i) Key assignment in ACG

The steps for key assignment in ACG are as follows:

1. The individual subgroup controller $SGC_i$ chooses two prime numbers $P_i$ and $Q_i$ randomly and also compute the product $X_i$ and $\Phi(X_i)$, where, $X_i = P_i \times Q_i$ and $\Phi(X_i) = (P_i - 1) \times (Q_i - 1)$ and deliver the value of $X_i$ to the key server.

2. The GC computes the product of $X_i$ value of each $SGC_i$ and stores their product value in $Z$.

3. The GC registers the $SGC_i$ if and only if $gcd(Z, X_i) = 1$

4. The GC declares the large prime $E$ as a public key to the $SGC_i$s.

5. The $SGC_i$s calculates the private key $D_i$ by applying the extended Euclidean algorithm such that $e \times D_i \equiv 1 \mod(\Phi(X_i))$

(ii) Key assignment in SG

The similar procedure is used for key assignment in SG where the individual members in the subgroup chooses two prime numbers $P_i$ and $Q_i$ randomly and compute $x_i = p_i \times q_i$ and $\Phi(x_i) = (p_i - 1) \times (q_i - 1)$ and deliver the $x_i$ values to the subgroup controller $SGC_i$. The $SGC_i$s computes the product of each $x_i$ value of every member and store the product value in $Z$. The $SGC_i$s registers the member if and only if $gcd(Z, x_i) = 1$. The $SGC_i$s sends the group public parameter $e$ to all the members. The $SGC_i$s calculates the private key $d_i$ by applying the extended Euclidean algorithm such that $e \times d_i \equiv 1 \mod(\Phi(x_i))$

3.2.2 Message Broadcast

Message broadcasting comprises of three steps namely, message encryption by the group controller, message propagation by the subgroup controller and message decryption by the members.

(i) Message Encryption by the Group Controller

To encrypt message $M$, the group controller uses $E$ as well as the secret value $X_i$ of each $SGC_i$ and follow the same procedure as described in section 3.1.2. After computing the cipher text $C$, the GC sends a broadcast message to the registered subgroup controllers.

(ii) Message Propagation by the Subgroup Controllers

After receiving the cipher text $C$, the individual $SGC_i$s decrypt $C$, using his private key $D_i$, secret information $X_i$, and the same procedure described in section 3.1.3 to obtain the confidential message $M$. After that the $SGC_i$s uses $e$ as well as secret value $x_i$ to again encrypt message $M$ by using the same procedure as described in section 3.1.2. After computing the cipher text $c$, the SGC broadcasts message to the registered members in the subgroup.
(iii) Message Decryption by the Members

After receiving the cipher text $c$, the individual member obtain the confidential message $M$, using his private key $d$, as well as secret information $x_i$ and follows the same procedure as described in section 3.1.3.

3.3 The Improved Centralized group key management scheme

In this section, we propose an improved centralized group key management scheme to enhance the performance by combining the asymmetric-key and symmetric-key cryptosystem. We use the key management scheme described in section 3.1 to encrypt the secret key $K$, and then use symmetric-key cryptosystem with the secret-key $K$ to encrypt the transmitted message. Thus the broadcast size and computational cost is reduced.

3.3.1 Key distribution

In the proposed scheme, the public-key assignment and the joining & leaving process of members is same as described in section 3.1

3.3.2 Message encryption and decryption

If server wants to sends a confidential message $M$ to all the members in the group. Before sending the confidential message, the server randomly chooses a symmetric key $k$ (the symmetric key $k$ change dynamically with different group members) and encrypts the symmetric key $k$ using the public key $e_0$. Therefore the server can use the symmetric-key cryptosystem with symmetric key $k$ to broadcast the encrypted message to the members of the group. The server can use the same symmetric key $k$ to encrypt the transmitted message until the group member’s change. However, the non-group members cannot use its private key $d_i$ to decrypt the encrypted symmetric key $k$, therefore they cannot obtain symmetric key to decrypt encrypted confidential message.

4 Results

In this section, we illustrate our proposed scheme with suitable examples and results obtained for secure multicast communication. Suppose that there are five members $U_1$, $U_2$, $U_3$, $U_4$ and $U_5$ who want to join the group.

4.1 Key assignment

The following steps are performed for key assignment:-

1. The server authenticates the members $U_1$, $U_2$, $U_3$, $U_4$ and $U_5$ to join the group.

2. The individual member $U_i$ chooses two prime number $p_i$ and $q_i$ randomly and also compute the product $X_i = p_i 	imes q_i$ and $\Phi(X_i) = (p_i-1) 	imes (q_i-1)$

   $U_i$ chooses $p_i = 281$ and $q_i = 373$ computes $X_i = 104813$ and $\Phi(X_i) = 104160$

3. $U_2$ chooses $p_2 = 179$ and $q_2 = 211$ computes $X_2 = 37769$ and $\Phi(X_2) = 37380$

4. $U_3$ chooses $p_3 = 157$ and $q_3 = 107$ computes $X_3 = 16799$ and $\Phi(X_3) = 16536$

5. $U_4$ chooses $p_4 = 163$ and $q_4 = 109$ computes $X_4 = 17767$ and $\Phi(X_4) = 17496$

6. $U_5$ chooses $p_5 = 157$ and $q_5 = 211$ computes $X_5 = 33127$ and $\Phi(X_5) = 32760$

3. The Individual members send their $X_i$, $X_2$, $X_3$, $X_4$, $X_5$ values to the server.

4. The Server initialize the value of $Z=1$ and checks that the values of $p$ and $q$ should be unique for all members using GCD function as $GCD (Z, X_i) = GCD (1, 104813) = 1$, the member $U_i$ is registered in the group.

   And new $Z = Z \times X_i = 1 \times 104813 = 104813$

   Now GCD $(Z, X_i) = GCD (104813, 37769) = 1$, the member $U_i$ is registered in the group.

   And new $Z = Z \times X_i = 104813 \times 37679$

   $= 3958682197$

   Now GCD $(Z, X_i) = GCD (3958682197, 16799) = 1$, the member $U_i$ is registered in the group.

   And new $Z = Z \times X_i = 3958682197 \times 16799$

   $= 66501902227403$

   Now GCD $(Z, X_i) = GCD (66501902227403, 17767) = 1$, the member $U_i$ is registered in the group.

   And new $Z = Z \times X_i = 66501902227403 \times 17767$

   $= 1181539296874269101$

   Now GCD $(Z, X_i) = GCD (1181539296874269101, 33127) \neq 1$, the member $U_i$ is not registered in the group.

5. The server declares the parameter $e = 103$ as a public key to the members.

6. The private key $d_i$ is calculated by members using extended Euclid’s algorithm

   $103 \times d_i = 1 \mod 104160$

   $d_i = 61687$ and $103 \times d_2 = 1 \mod 37380$

   $d_2 = 8347$ and $103 \times d_3 = 1 \mod 16536$

   $d_3 = 9151$ and $103 \times d_4 = 1 \mod 17496$

   $d_4 = 13759$

4.2 Message encryption

When the server wants to send a secret message $M = 17$ to selected group members $U_1$, $U_2$, $U_4$, among a group of five members ($U_1$, $U_2$, $U_3$, $U_4$) then the key server uses public key $e = 103$ as well as the values $X_1$, $X_2$, $X_4$ to encrypt the message. The cipher text is generated by the key server as follows

First Convert public key $e = 103$ into binary number

$S_0, e = 103 = (011010111)_2$

$= (e_7 = 0, e_6 = 1, e_5 = 1, e_4 = 0, e_3 = 0, e_2 = 1, e_1 = 1, e_0 = 1)$

$C = 1$

$e_7 = 0 \rightarrow C = C \times C \mod (X_1 \times X_2 \times X_4)$

$= 1 \times 1 \mod (104813 \times 37769 \times 17767)$

$= 1$

$e_6 = 1 \rightarrow C = C^2 \times M \mod (X_1 \times X_2 \times X_4)$

$= 1^2 \times 17 \mod (104813 \times 37769 \times 17767)$

$= 17 \mod (70333906594099)$

$= 17$

$e_5 = 1 \rightarrow C = C^2 \times M \mod (X_1 \times X_2 \times X_4)$
\[ C = 17^2 \times 17 \mod (7033906594099) = 4913 \]
\[ e_4 = 0 \rightarrow C = C^2 \mod (X_1 \times X_2 \times X_4) = 4913^2 \mod (7033906594099) = 24137569 \]
\[ e_3 = 0 \rightarrow C = C^2 \mod (X_1 \times X_2 \times X_3) = 24137569^2 \mod (7033906594099) = 19950984476969 \]
\[ e_2 = 1 \rightarrow C = C^2 \times M \mod (X_1 \times X_2 \times X_4) = 19950984476969^2 \times 17 \mod (7033906594099) = 3761940221430 \]
\[ e_1 = 1 \rightarrow C = C^2 \times M \mod (X_1 \times X_2 \times X_3) = 3761940221430^2 \times 17 \mod (7033906594099) = 1219820530109 \]
\[ e_0 = 1 \rightarrow C = C^2 \times M \mod (X_1 \times X_2 \times X_4) = 1219820530109^2 \times 17 \mod (7033906594099) = 24986809583876 \]

The key server then broadcast cipher text C to all the members of the group.

### 4.3 Message decryption

After receiving the cipher text C, the members U_1, U_2, U_3 in the group can decrypt the encrypted message using their respective private keys d_1, d_2, d_3 and secret information X_1, X_2, X_3. The message M is decrypted by the members as follows:

For member U_1:
\[ d_{p_1} = d_1 \mod (p_1 - 1) = 61687 \mod 280 = 87 \]
\[ d_{q_1} = d_1 \mod (q_1 - 1) = 61687 \mod 372 = 307 \]
\[ C_{p_1} = C \mod (p_1) = 24986809583876 \mod 281 = 169 \]
\[ C_{q_1} = C \mod (q_1) = 24986809583876 \mod 373 = 156 \]
\[ M_{p_1} = (C_{p_1})^{d_{p_1}} \mod (p_1) = 169^{87} \mod 281 = 17 \]
\[ M_{q_1} = (C_{q_1})^{d_{q_1}} \mod (q_1) = 156^{307} \mod 281 = 17 \]

Now, \[ M = M_{p_1} + [(M_{q_1} - M_{p_1} + q_1) \cdot A] \mod q_1 \]
And \[ A \cdot p_1 \equiv 1 \mod q_1 \]
\[ A \cdot 281 \equiv 1 \mod 373 \rightarrow A = 150 \]
\[ M = 17 + [(17 - 17 + 109) \times 107 \mod 109] \times 163 
= 17 + [(11663 \mod 109] \times 163 
= 17 \]

For member U_2:
\[ d_{p_2} = d_2 \mod (p_2 - 1) = 8347 \mod 178 = 159 \]
\[ d_{q_2} = d_2 \mod (q_2 - 1) = 8347 \mod 210 = 157 \]
\[ C_{p_2} = C \mod (p_2) = 24986809583876 \mod 179 = 129 \]
\[ C_{q_2} = C \mod (q_2) = 24986809583876 \mod 211 = 165 \]
\[ M_{p_2} = (C_{p_2})^{d_{p_2}} \mod (p_2) = 129^{159} \mod 179 = 17 \]
\[ M_{q_2} = (C_{q_2})^{d_{q_2}} \mod (q_2) = 165^{157} \mod 211 = 17 \]

Now, \[ M = M_{p_2} + [(M_{q_2} - M_{p_2} + q_2) \cdot A] \mod q_2 \]
And \[ A \cdot p_2 \equiv 1 \mod q_2 \]
\[ A \cdot 163 \equiv 1 \mod 211 \rightarrow A = 178 \]
\[ M = 17 + [(17 - 17 + 211) \times 178] \mod 211 
= 17 + [(3798 \mod 281 \times 281 \times 179 
= 17 \]

For member U_3:
\[ d_{p_3} = d_4 \mod (p_4 - 1) = 13759 \mod 162 = 151 \]
\[ d_{q_4} = d_4 \mod (q_4 - 1) = 13759 \mod 108 = 43 \]
\[ C_{p_4} = C \mod (p_4) = 24986809583876 \mod 163 = 86 \]
\[ C_{q_4} = C \mod (q_4) = 24986809583876 \mod 109 = 19 \]
\[ M_{p_4} = (C_{p_4})^{d_{p_4}} \mod (p_4) = 86^{151} \mod 163 = 17 \]
\[ M_{q_4} = (C_{q_4})^{d_{q_4}} \mod (q_4) = 19^{43} \mod 109 = 17 \]

Now, \[ M = M_{p_4} + [(M_{q_4} - M_{p_4} + q_4) \cdot A] \mod q_4 \]
And \[ A \cdot p_4 \equiv 1 \mod q_4 \]
\[ A \cdot 163 \equiv 1 \mod 109 \rightarrow A = 107 \]
\[ M = 17 + [(117 - 17 + 109) \times 107] \mod 109 \times 163 
= 17 + [(11663 \mod 109] \times 163 
= 17 \]

As shown, only members U_1, U_2, U_3 can obtain the original message.

### 4.4 Member joining

When a new member U_5 wants to join the group, the server performs the following steps:
1. The server authenticates the member U_5.
2. The Member U_5 chooses two prime number p_5=149 and q_5=113 randomly and also compute the product X_5 and \( \Phi(X_5) \) where, \( X_5 = p_5 \times q_5 \) and \( \Phi(X_5) = (p_5-1) \times (q_5-1) \)
   \( X_5 = 16837 \) and \( \Phi(X_5) = 16576 \)
3. The Member U_5 sends his X_5 value to the server
4. Server registers the member if gcd (Z, X_5) = 1.
   Now \( \text{gcd} (4196857772502064457107, 16837) = 1 \) U_5 is registered in the group.
5. The Server informs his public key e = 103 to the member U_5.
6. Private key is calculated by member U_5 using the extended Euclidean algorithm
   \( 103 \cdot d_5 = 1 \mod (\Phi(X_5)) = 1 \mod 16576 \) and \( d_5 = 9495 \)

When the key server wants to send a new confidential message M to all the members in the group, the server will compute cipher text and broadcast cipher text C to all the members of the group. After receiving the cipher text C, all the pre-existing members U_1, U_2, U_3, U_4 and the new member U_5 in the group can decrypt the encrypted message using their private keys d_i and his/her secret information X_i.

### 4.5 Member leaving

Suppose the member U_1, U_4 and U_5 want to leave the group, the remaining members U_2, U_3 do not need to change their private keys d_2, d_3 and secret information X_2, X_3. The key server deletes the secret values X_1, X_4, X_5 corresponding to U_1, U_4, U_5, from the active list. Thus, the key server does not include X_1, X_4, X_5 in the cipher text computation.
5. Comparative Analysis

In this section, we compare the security parameters, computation cost, communication complexity and storage complexity of proposed scheme with various existing centralized group key management schemes. Table 1 provides comparisons of security parameters of proposed scheme with CRGK, FCRGK [10], KTCRT [11] which are based on CRT, SBMK [9] and efficient SBMK [8]. As compare to the Efficient SBMK scheme [8], our scheme is more secure as it preserves the forward and backward secrecy in multicast group key management.

Table 1 A comparison of security parameters

| Schemes   | Group secrecy | Forward secrecy | Backward Secrecy |
|-----------|---------------|-----------------|------------------|
| CRGK      | Yes           | Yes             | Yes              |
| FCRGK     | Yes           | Yes             | Yes              |
| KTCRT     | Yes           | Yes             | Yes              |
| SBMK      | Yes           | Yes             | Yes              |
| CRTGKM    | Yes           | Yes             | Yes              |
| Efficient SBMK | Yes     | No              | No               |
| Proposed scheme | Yes      | Yes             | Yes              |

Table 2 illustrates the comparison of communication complexity and computation cost of our proposed scheme with CRGK, FCRGK [10], key tree CRT (KTCRT) [11], CRTGKM [1] which are based on CRT, SBMK [9] and efficient SBMK [8] which are based on RSA public key cryptosystem. The various notations used for comparisons are as follows: n represents the number of users, t is the degree of the tree, EEA represents the time taken to find modular multiplicative, M represents multiplication operation, A and S represent addition and subtraction operation.

Table 2 A comparison of communication and computation cost

| Schemes   | Communication Complexity | Computation Cost |
|-----------|--------------------------|------------------|
| CRGK      | 1 broadcast, 0 unicast   | O(n)(xor+A+m+EEA) 1 mod + 1 xor   |
| FCRGK     | 1 broadcast, 0 unicast   | O(t)(xor+A+m+EEA) 1 mod + 1 xor   |
| KTCRT     | 1 broadcast, 0 unicast   | O(log(n)(xor+A+m+EEA)) 1 mod + 1 xor   |
| CRTGKM    | 1 broadcast, 0 unicast   | O(t)(A or S) 1 mod   |
| SBMK      | 0 broadcast, 1 unicast   | O(1) 1 EEA         |
| Efficient SBMK | 0 broadcast, 0 unicast | O(1) 1 EEA         |
| Proposed scheme | 0 broadcast, 1 unicast | O(1) 1 EEA         |

According to our scheme, when new members join the group, server computation cost is O (1) and the user performs 1 modular multiplicative inverse to obtain the key and is NIL whenever a member leaves the group. Therefore, the cost is less compared to CRGK, FCRGK [10], KTCRT [11] and CRTGKM [1].

The comparison of storage cost with the related schemes is shown in Table 3. The storage cost of our proposed scheme at the server side is much less than the Chinese remainder theorem based schemes CRGK, FCRGK [10], KTCRT [11], CRTGKM [1], and RSA cryptosystem based scheme SBMK [9].

Table 3 A comparison of storage Complexity

| Schemes   | Storage Complexity |
|-----------|-------------------|
| CRGK      | Server: 2n+1, User: 2 |
| FCRGK     | Server: 2n+1, User: 2 |
| KTCRT     | Server: 2n-1, User: (log(n)) |
| CRTGKM    | Server: 4n+3, User: 2 |
| SBMK      | Server: 2n+2, User: 3 |
| Efficient SBMK | Server: n+2, User: 3 |
| Proposed scheme | Server: n+1, User: 3 |

6. Conclusion

This paper proposes a centralized group key management scheme which provides efficient results than the various existing centralized key management schemes in terms of less computation cost, communication and storage complexities. In the proposed scheme the communicational cost is reduced by eliminating the re-keying processes and avoiding the tree balancing. To reduce the server computational cost the member’s private key is computed by individual members at their own site. The proposed scheme maintains the uniqueness of the prime factors contributing to the secret value X that helps in maintaining the forward and backward secrecy. The storage overhead is distributed among the members and the server to reduce the storage complexity. The message encryptions are performed by using the Square and multiply method to reduce the encryption cost. The decryption operation is based on the Chinese Remainder Theorem that speeds up the message decryption process. We also provide an extended multicast scheme in which the bulk number of members can leave or join the group simultaneously. In order to get better performance of multicast encryption, symmetric-key and asymmetric-key cryptosystems may be combined.

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