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Encrypted Columns Users Guide

Adaptive Server® Enterprise

15.7

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CHAPTER 1

Overview of Encryption

This guide describes the Adaptive Server® Enterprise encrypted columns feature, encryption of external passwords and the SQL text of stored procedures, views, and triggers.

Adaptive Server authentication and access control mechanisms ensure that only properly identified and authorized users can access data. Data encryption further protects sensitive data against theft and security breaches.

The Adaptive Server encrypted columns feature enables you to encrypt column-level data that is at rest, without changing your applications. This native support provides the following capabilities:

- Column-level granularity
- Use of a symmetric, National Institute of Standards and Techology (NIST)-approved algorithm: Advanced Encryption Standard (AES)
- Performance optimization
- Enforced separation of duties
- Fully integrated and automatic key management
- Application transparency: no application changes are needed
- Data privacy protection from the power of the system administrator

Data encryption and decryption is automatic and transparent. If you have insert or update permission on a table, any data you insert or modify is automatically encrypted prior to storage. Daily tasks are not interrupted.

Selecting decrypted data from an encrypted column requires decrypt permission in addition to select permission. Decrypt permission can be granted to specific database users, groups, or roles. Sybase® gives you more control by providing you with granular access capability to sensitive data. Sybase also automatically decrypts selected data for users with decrypt permission.

Encrypting columns in Adaptive Server is more straightforward than using encryption in the middle tier, or in the client application. You use SQL statements to create encryption keys and to specify columns for encryption, and existing applications continue to run without change.

Column encryption keys are stored in the database in encrypted form. You can encrypt a column encryption key using a key encryption key (KEK) derived from a

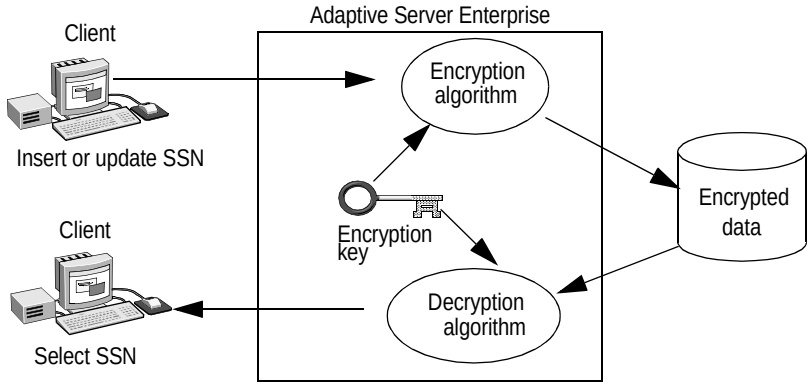
- System-level user-supplied password
- KEK derived from a user-supplied password (which can be the user's login password)
- Separately created database-level KEK (master key or dual master key)

The password you select reflects your ability to preserve data privacy, even from system administrators. You may choose to protect your column encryption key using dual-control mode to increase the security. See Chapter 2, "Creating and Managing Column Encryption Keys."

When data is encrypted, it is stored in an encoded form called "cipher text." Cipher text increases the length of the encrypted column from a few bytes to 32 extra bytes. See "Length of encrypted columns" on page 54. Unencrypted data is stored as plain text.

Figure 1-1 describes encryption and decryption processing in Adaptive Server. In this example, a client is updating and encrypting a Social Security Number (SSN).

Figure 1-1: Encryption and decryption in Adaptive Server



Column encryption uses a symmetric encryption algorithm, which means that the same key is used for encryption and decryption. Adaptive Server tracks the key that encrypts a given column.

When you insert or update data in an encrypted column, Adaptive Server transparently encrypts the data immediately before writing the row. When you select from an encrypted column, Adaptive Server decrypts the data after reading it from the row. Integer and floating point data are encrypted in the following form for all platforms:

- Most significant bit format for integer data
- Institute of Electrical and Electronics Engineers (IEEE) floating point standard with MSB format for floating point data

You can encrypt data on one platform and decrypt it on a different platform, provided that both platforms use the same character set.

Generally, using encrypted columns requires these steps:

1 Install the license option ASE_ENCRYPTION. See the *Adaptive Server Enterprise Installation Guide*.

2 The system security officer (SSO) enables encryption in Adaptive Server:

```
sp_configure 'enable encrypted columns', 1
```

3 Depending on the method you chose to protect column encryption keys, create a database-level master key or set the system encryption password. See “Creating the master and dual master keys” on page 19 for information about creating a master key.

"Protecting column encryption keys with the system-encryption password" on page 15 describes how to set the system encryption password.

4 Create one or more named encryption keys. See Chapter 2, "Creating and Managing Column Encryption Keys." Consider using passwords to protect data even from the database administrator. See Chapter 7, "Protecting Data Privacy from the Administrator.".

5 Specify the columns for encryption. See "Specifying encryption on new tables" on page 40 and "Encrypting data in existing tables" on page 42.

6 Grant decrypt permission to users who must see the data. You may choose to specify a default plain text value known as a "decrypt default." The Adaptive Server returns this default, instead of the protected data, to users who do not have decrypt permission. See "Permissions for decryption" on page 60.

Once you perform these steps, you can run your existing applications against your existing tables and columns, but now the data in your database is securely protected against theft and misuse. Adaptive Server utilities and other Sybase products can process data in encrypted form, protecting your data throughout the enterprise. For example, you can:

- Use Sybase Control Center or Sybase Central Adaptive Server Plug-in to manage encrypted columns using a graphical interface. See the online help.
- Use the bulk copy utility (bcp) to securely copy encrypted data in and out of the server. See the *Utility Guide*.
- Use the Adaptive Server migration tool sybmigrate to securely migrate data from one server to another. See the *Adaptive Server Enterprise System Administration Guide*.
- Use Sybase Replication Server to securely distribute encryption keys and data across servers and platforms. See the *Replication Server Administration Guide* for information on encryption when replicating.

See Chapter 4, "Securing External Passwords and Hidden Text," for information about strong encryption of external passwords and hidden SQL text.

CHAPTER 2

Creating and Managing Column Encryption Keys

Adaptive Server includes commands for creating column encryption keys, altering the properties of column encryption keys, and dropping unused column encryption keys. Key owners must grant permission to table owners to use a specific key or keys to configure encryption at the column level.

Protecting Data with Column Encryption Keys

Adaptive Server keeps keys encrypted when they are not in use. Users must have access to the column encryption key (CEK) before they can access encrypted data, but the CEK must be encrypted before you store it on disk or in memory. Adaptive Server encrypts the CEK using a key encryption key (KEK) and stores it in encrypted form in sysencryptkeys. The KEK is also used to decrypt the CEK, allowing you to access decrypted data. See “Key encryption” on page 13.

CEK management includes creating, dropping, and modifying column encryption keys, distributing passwords, creating key copies, and providing for key recovery in the event of a lost password.

Creating column encryption keys

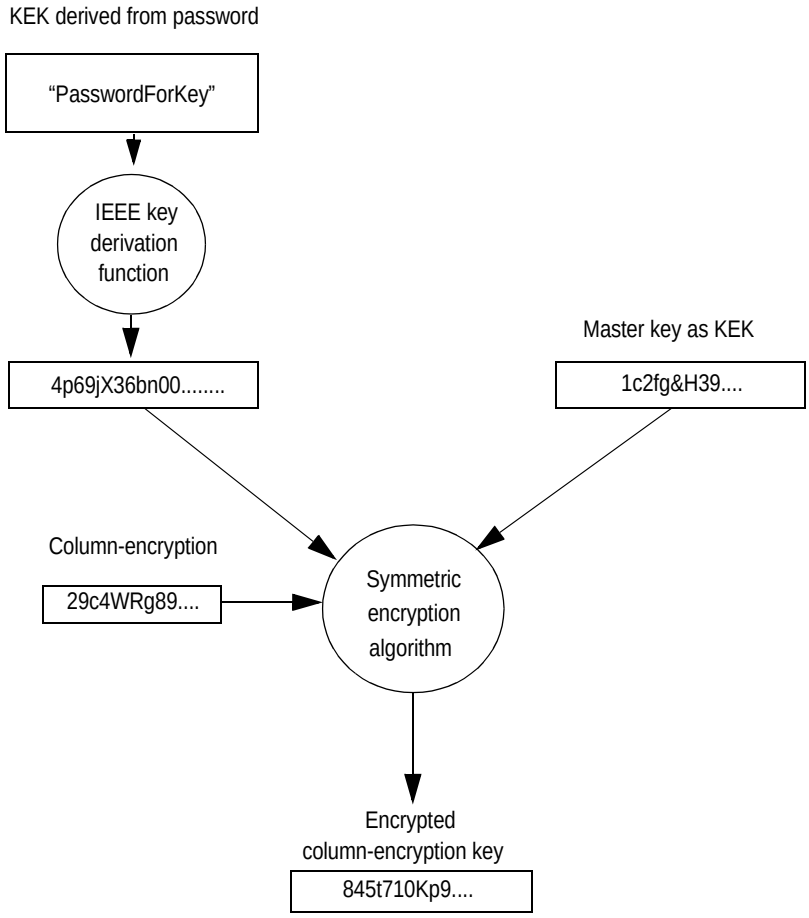
A column encryption key must exist before a table owner can mark a column for encryption on a new or existing table. When you set up keys for the first time, consider:

- Key owner or custodian assignment – the system security officer (SSO) must grant create encryption key permission to create keys. By default, the sso_role and the keycustodian_role have create encryption key permission. See “Role of the key custodian” on page 63.
- Whether keys should be created in a separate key database – Sybase recommends that you use a separate database for keys, especially if keys are encrypted by the system encryption password.
- The number of keys needed – you can create a separate key for each encrypted column, or you can use the same key to encrypt columns across multiple tables. From a performance standpoint, encrypted columns that join with equivalent columns in other tables should share the same key. For security purposes, unrelated columns should use different keys.

Column encryption in Adaptive Server uses the Advanced Encryption Standard (AES) symmetric key encryption algorithm, with available key sizes of 128, 192, and 256 bits. Random-key generation and cryptographic functionality is provided by the FIPS 140-2 compliant modules.

To securely protect key values, Adaptive Server uses a 256-bit key-encrypting key (KEK), which may be a master key, or an internal key derived from either the system encryption password or a user-specified password. See Chapter 3, “Using Database-Level Master and Dual Master Keys.” Adaptive Server encrypts the new key (the column encryption key) and stores the result in sysencryptkeys.

Figure 2-1: Encrypting column encryption keys using KEK



By default, Adaptive Server creates 256-bit key-encryption keys. For compatibility with versions earlier than 15.7, it uses a 128-bit key if the KEK is derived from the system encryption password.

Syntax for create column encryption key

The syntax for create column encryption key is:

```
create encryption key [[database.][owner].]keyname
    [as default] [for algorithm]
    [with
        {[key_length num_bits]
        [{passwd 'passwd_phrase' | passwd system_encr_passwd |
            master key}]
        [init_vector {null | random}]
        [pad {null | random}]
```

```
        [[no] dual_control]
    }]
```

where:

- *keyname* – must be unique in the user's table, view, and procedure name space in the current database. Specify the database name if the key is in another database, and specify the owner's name if more than one key of that name exists in the database. The default value for owner is the current user, and the default value for database is the current database. Only the system security officer can create keys for other users.

  Note You cannot create temporary key names that start with "#".

- as default – allows the system security officer or key custodian to create a database default key for encryption. This enables the table creator to specify encryption without using a keyname on create table, alter table, and select into. Adaptive Server uses the default key from the same database. The default key may be changed.
- *for algorithm* – Advanced Encryption Standard (AES) is the only algorithm supported. AES supports key sizes of 128, 192, and 256 bits, and a block size of 16 bytes. The block size is the number of bytes in an encryption unit. Large data is subdivided for encryption.
- keylength *num_bits* – the size, in bits, of the key to be created. For AES, valid key lengths are 128, 192, and 256 bits. The default keylength is 128 bits.
- passwd *password_phrase* – indicates to ASE to protect the CEK using the user password *password_phrase*, which can be a quoted alphanumeric string up to 255 bytes in length.
- passwd *system_encr_passwd* – indicates to ASE to protect the CEK using the system encryption password.
- master key – indicates to ASE to protect the CEK using the master key. By default, Adaptive Server uses the master key (if it exists) to protect column encryption keys. See "Key protection" on page 11.
- init_vector
  - random – specifies use of an initialization vector during encryption. When an initialization vector is used by the encryption algorithm, the cipher text of two identical pieces of plain text are different, which prevents detection of data patterns. Using an initialization vector can add to the security of your data.

Use of an initialization vector implies using a cipher-block chaining (CBC) mode of encryption, where each block of data is combined with the previous block before encryption, with the first block being combined with the initialization vector.

However, initialization vectors have some performance implications. You can create indexes and optimize joins and searches only on columns where the encryption key does not specify an initialization vector. See Chapter 10, “Performance Considerations.”

- null – omits the use of an initialization vector when encrypting. This makes the column suitable for supporting an index.

  The default is to use an initialization vector, that is, init_vector random.

  Setting init_vector null implies the electronic codebook (ECB) mode, where each block of data is encrypted independently.

  To encrypt one column using an initialization vector and another column without using an initialization vector, create two separate keys—one that specifies use of an initialization vector and another that specifies no initialization vector.

- pad
  - null – the default, omits random padding of data.

    You cannot use padding if the column must support an index.

  - random – data is automatically padded with random bytes before encryption. You can use padding instead of an initialization vector to randomize the cipher text. Padding is suitable only for columns whose plain text length is less than half the block length. For the AES algorithm the block length is 16 bytes.

- dual control – indicates whether the new key must be encrypted using dual control. By default, dual control is not configured. See Chapter 3, “Using Database-Level Master and Dual Master Keys.”

create encryption key examples

These examples use various encryption attributes when creating a column encryption key, and many assume you have already created the master key or set the system encryption password (see “Key protection” on page 11).

- Example 1 – specifies a 256-bit key called “safe_key” as the database default key. Because the key does not specify a password, Adaptive Server uses the database-level master key as the KEK for safe_key. If there is no master key, Adaptive Server uses the system encryption password:

```
create encryption key safe_key as default for AES
```

```
        with keylength 256
```

Only the system security officer or a user with the keycustodian_role can create a default key.

- Example 2 – creates a 128-bit key called “salary_key” for encrypting columns using random padding:

```
create encryption key salary_key for AES with
     init_vector null pad random
```

- Example 3 – creates a 192-bit key named “mykey” for encrypting columns using an initialization vector:

```
create encryption key mykey for AES
     with keylength 192 init_vector random
```

- Example 4 – creates a key protected by a user-specified password:

```
create encryption key key1
     with passwd 'Worlds1Biggest6Secret'
```

If a key is protected by a user-specified password, that password must be entered a column encrypted by the key can be accessed. See Chapter 7, “Protecting Data Privacy from the Administrator,” for information about using keys with explicit passwords.

- Example 5 – creates a key protected by dual-control:

```
create encryption key dualprotectedkey
with passwd "Pass4Tomorrow"
dual_control
```

Key “dualprotectedkey” is protected by the master key and a user password (in dual control). To access the key, you must enter both the user password for the key and the password for the master key.

create encryption key permissions

The sso_role and keycustodian_role implicitly have permission to create encryption keys. The system security officer or the key custodian uses this syntax to grant create encryption key permissions to others:

grant create encryption key
    to *user_name* | *role_name* | *group_name*

For example:

```
grant create encryption key to key_admin_role
```

To revoke key creation permission, use:

```
revoke create encryption key
    {to | from} user_name | role_name | group_name
```

Note grant all does not grant create encryption key permission to the user. It must be explicitly granted by the system security officer.

Key protection

The key administrator must decide where keys are stored, when they should be renewed, and which table owners can use a given key to encrypt columns in their tables.

Granting access to keys

The key owner or a user with the sso_role must grant select permission on a key before another user can specify the key in the create table, alter table, and select into statements. The key owner can be the system security officer, the key custodian or, for non-default keys, any user with create encryption key permission. Key owners should grant select permission on keys as needed.

The following example allows users with db_admin_role to use the encryption key named "safe_key" when specifying encryption on create table, alter table, and select into statements:

```
grant select on safe_key to db_admin_role
```

Note Users who process encrypted columns through insert, update, delete, and select do not need select permission on the encryption key.

Changing the key

Periodically change the keys used to encrypt columns. Create a new key using create encryption key, then use alter table...modify to encrypt the column with the new key

In the following example, assume that the "creditcard" column is already encrypted. The alter table command decrypts and reencrypts the credit card value for every row of customer using cc_key_new.

```
create encryption key cc_key_new for AES
```

```
alter table customer modify creditcard encrypt with
      cc_key_new
```

Separating keys from data

When you specify a column for encryption, you can use a named key from the same database or from a different database. If you do not specify a named key, the column is automatically encrypted with the default key from the same database.

Encrypting with a key from a different database provides a security advantage because, in the event of the theft of a database dump, it protects against access to both keys and encrypted data. Administrators can also protect each database dump with a different password, making unauthorized access even more difficult.

Encrypting with a key from a different database needs special care to avoid data and key integrity problems in distributed systems. Carefully coordinate database dumps and loads. If you use a named key from a different database, Sybase recommends that, when you dump a database that contains:

- Encrypted columns, you also dump the database where the key was created. You must do this if new keys have been added since the last dump.
- An encryption key, dump all databases containing columns encrypted with that key. This keeps encrypted data in sync with the available keys.

The system security officer or the key custodian can use sp_encryption to identify the columns encrypted with a given key.

Dropping encryption keys

To drop an encryption key, use:

drop encryption key [[*database*.][*owner*.]*keyname*

For example, this drops an encryption key named cc_key:

```
drop encryption key cust.dbo.cc_key
```

Key owners can drop their own keys. The system security officer can drop any key. A key can be dropped only if there are no encrypted columns in any database that use the key.

When executing drop encryption key, Adaptive Server does not check for encrypted columns in databases that are suspect, archived, offline, not recovered, or currently being loaded. In any of these cases, the command issues a warning message that names the unavailable database, but does not fail. When the database is brought online, any tables with columns that were encrypted with the dropped key are unusable. To restore the key, the system administrator must load a dump of the dropped key's database that precedes when the key was dropped.

The system security officer can use sp_encryption to identify all the columns encrypted with a given key.

Key encryption

There are actually two keys between the user and the data: the column-encryption key (CEK) and the key-encryption key (KEK). The CEK encrypts data and users must have access to it before they can access encrypted data. It cannot be stored on disk in an unencrypted form. Instead, Adaptive Server uses a KEK, or 2 KEKs iin dual-control, to encrypt the CEK when you create or alter an encryption key. The KEK also decrypts the CEK before you can access decrypted data. CEKs are stored in encrypted form in sysencryptkeys.

The KEK is a master key, created separately by the system security officer or key custodian, is an internally derived key from the system encryption password, a user-specified password, or a login password, depending on how you specify the key's encryption with the create and alter encryption key statements. Both the system encryption password and the master key are stored in encrypted form.

Figure 2-2 on page 14 describes creating and storing a column encryption key for a create encryption key statement. The KEK is derived from a password and the KEK and the raw CEK are fed into the encryption function to produce an encrypted CEK.

Figure 2-2: Steps to create an encryption key

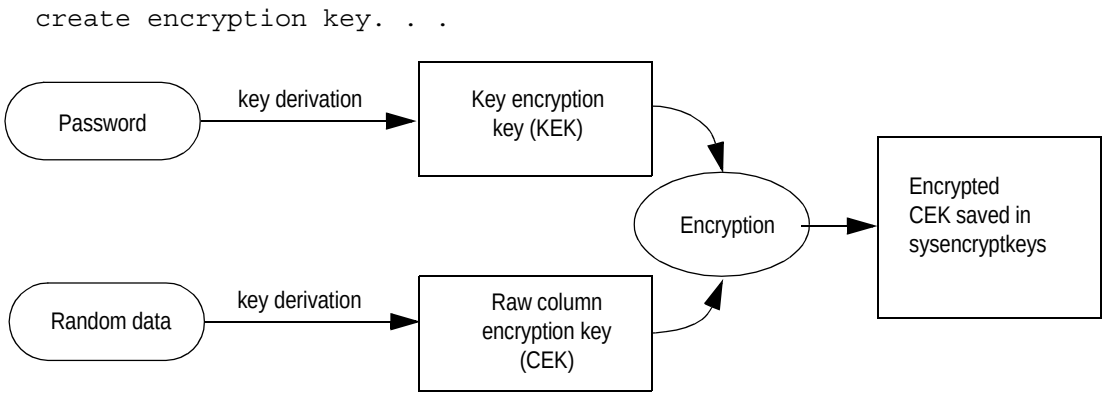
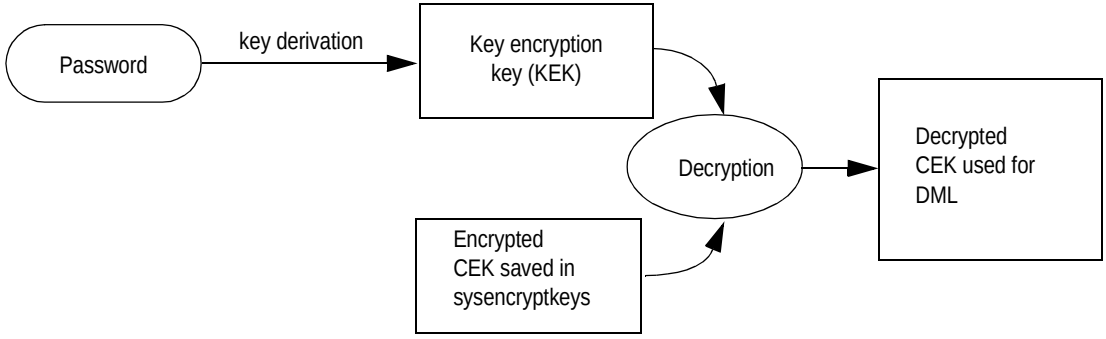


Figure 2-3 describes how the KEK is used during a DML operation to decrypt the CEK. The raw CEK is then used to encrypt or decrypt data.

Figure 2-3: Accessing a CEK to encrypt or decrypt on DML statement



Protecting column encryption keys with the master key

The master key is a database-level key created by a user with the sso_role or keycustodian_role, and is used as a KEK for user-created encryption keys. Once created, the master key replaces the system encryption password as the default KEK for user-created keys. Although Adaptive Server supports the system encryption password for compatibility with versions earier than 15.7, Sybase recommends that you use the master key.

You can use the master key with the dual master key to create a composite key that provides dual control and split knowledge for all user-created keys. You can also create a composite key by using the master key with a CEK's explicit password.

Using a master key simplifies the administration of encrypted data because:

- Managing passwords for keys is restricted to setting the password for the master key.
- You need not specify passwords on create and alter encryption key statements.
- Allows for password distribution and recovery from lost column encryption key passwords.
- Access control over encrypted data is enforced through decrypt permission on the column. See "Restricting decrypt permission" on page 46.
- You need not make any changes to the application.

The syntax for creating a master key is:

```
create encryption key master
    [for AES] with passwd char_literal
```

See the *Reference Manual: Commands*.

Protecting column encryption keys with the system-encryption password

The system encryption password is a database-specific password, and is the secondary default encryption method for the CEK. That is, you need not create a master key for the database. Adaptive Server uses the system encryption password to encrypt keys created in a specified database without an explicit password clause. Once the system security officer or key custodian has set a system encryption password, you need not specify this password to process encrypted columns. Adaptive Server internally accesses the system encryption password when it needs to encrypt or decrypt column encryption keys.

The system security officer or key custodian usse sp_encryption to set the system encryption password. The system password is specific to the database using sp_encryption, and its encrypted value is stored in the sysattributes system table in that database.

```
sp_encryption system_encr_passwd, password
```

password can be as many as 255 bytes in length.

Set a system encryption password only in the database where encryption keys are created.

The system encryption password protects your encryption keys. Choose long and complex system encryption passwords. Longer passwords are harder to guess or crack by brute force. Include uppercase and lowercase letters, numbers, and special characters in the system encryption password. Sybase recommends that the system encryption password be at least 16 bytes in length.

Adaptive Server enforces compliance of the system encryption password with the minimum password length and check password for digit configuration parameters.

Change the system password by using sp_encryption and supplying the old password:

```
sp_encryption system_encr_passwd, password [ , old_password]
```

Periodically change the system encryption password, especially when an administrator who knows the system encryption password leaves the company. When the system password is changed, Adaptive Server automatically reencrypts all keys in the database with the new password. Encrypted data is unaffected when the system password is changed, in other words, it is not decrypted and reencrypted.

You can u-set the system encryption password by supplying “null” as the argument for *password* and supplying the value for *old_password*. Unset the system password only if you have dropped all the encryption keys in that database that were encrypted by the system encryption password.

Protecting column encryption key with user-specified password

You can limit the power of the system administrator or database owner to access private data when you specify passwords on keys using create encryption key or alter encryption key. If keys have explicit passwords, users must have, before they can decrypt data:

- decrypt permission on the column
- The encryption key’s password

Users must also know the password to run DML commands that encrypt data.

See “Key protection using user-specified passwords” on page 66.

Protecting column encryption keys with dual control

You can secure column encryption keys with dual control using the create encryption key command.

If you specify create encryption key with dual_control, but do not specify a user password, the column encryption key is protected by the master key and the dual master key.

If you specify with dual_control and include a user-specific password, the column encryption key is protected by the master key and the user password.

- Example 1 – protects CEK “Reallysecret” with both the master and dual master keys and fails, unless both keys exist in the database:

```
create encryption key Reallysecret
     with init_vector random dual_control
```

- Example 2 – encrypts CEK “k3” with both the master key and user password “Whybother”:

```
create encryption key k3
     with passwd 'Whybother'
     dual_control
```

See “Changing a key’s protection method” on page 67 to alter existing keys to use dual control.

CHAPTER 3

Using Database-Level Master and Dual Master Keys

Adaptive Server allows users to create database-level encryption keys called the master key and the dual master key. These keys both act as key encryption keys, and are used to protect other keys, such as column encryption keys and service keys. Once created, master keys become the default protection method for column encryption keys. The dual master key is required only for dual control of column encryption keys.

Only users with sso_role or keycustodian_role can create the master key and dual master key. There can only be one master and one dual master key for a database.

The master key and the dual master key must have different owners. You can provide passwords for the master keys using either isql, or through a server-private file that is accessible only by the Adaptive Server. The passwords to these keys are not stored in the database.

Creating the master and dual master keys

To create the master and dual master keys use:

```
create encryption key [dual] master
    [for AES] with passwd char_literal
```

where:

- master and dual master refer to database-level keys used to encrypt other keys within the database in which they are defined. These keys are not used to encrypt data. The master key is named internally as sybencrmasterkey in sysobjects, and the dual master key is named internally as sybencrdualmasterkey in sysobjects.
- with passwd must be followed by a character string password that adheres to sp_passwordpolicy.

See the *Reference Manual: Commands*.

- Example 1 – creates master key in database tdb1:

```
use database tdb1
create encryption key master with passwd
'unforgetablethatswhatyouare'
```

- Example 2 – creates a dual master key in database tdb1:

```
use database tb1
create encryption key dual master with passwd
'dualunforgettable'
```

- Example 3 – generates an error because you cannot use a master key as a column encryption key:

```
create table t2 (c1 int encrypt with master)
```

To change the password of a master key or dual master key, use:

```
alter encryption key [dual] master
    with passwd <char_literal>
    modify encryption
    with passwd <char_literal>
```

Creating master key copies

Users or master key owners with sso_role or keycustodian_role can create copies for master keys, which you may need to:

- Provide access to the master key or dual master key for unattended start-up of the Adaptive Server. Such a key copy is referred to as the automatic_startup copy.
- Support recovery of the master keys should their passwords be lost. Such a key copy is referred to as the recovery copy. See Chapter 8, “Recovering Keys from Lost Passwords.”

- Allow a user other than the base key owner to set up encryption passwords for the master or dual master key. This key copy is referred to as a regular copy.

To add master key copies in a database, use:

```
alter encryption key [dual] master
    with passwd char_string
    add encryption
    {with passwd char_string
    for user user_name
    [ for recovery ] | [ for automatic_startup ] }
```

where:

- *char_string* – (first reference) specifies the password that currently encrypts the base copy of the master or dual master key.
- *char_string* – (second reference) specifies the password for the regular or recovery copy. It must not be used for automatic_startup copies.
- for user – indicates the user to whom the regular or recovery copy must be assigned. Do not use this parameter to enter a password for automatic_startup copies.
- for recovery – indicates that the key copy is to be used to recover the master key in case the password is lost.
- for automatic_startup – indicates that the key copy is to be used to access the master or dual master key after the server is restarted with automatic master key access enabled.
- Example 1 – master key owner creates a key copy for Mary:

```
alter encryption key master
     with passwd 'unforgettablethatswhatur'
     add encryption
     with passwd 'just4now'
     for user mary
```

- Example 2 – dual master key owner Smith creates a key copy for automatic_startup with:

```
alter encryption key dual master
     with passwd 'Never4Getable'
     add encryption
     for automatic_startup
```

Setting passwords for the master and dual master keys

The base key owner, or a user who owns a regular key copy, can set the password for the master and dual master keys. Passwords must be set before master keys can be used. To set passwords for master keys, you can either use the:

- set encryption passwd command
- Use the unattended start-up feature
- (Master key only) the dataserver command

The set encryption command is:

```
set encryption passwd char_literal
    for key [dual] master
```

where:

- *char_literal* – if the user is the key owner, this is the password that currently encrypts the base copy of the master or dual master key. If the user is not the key owner, this is the password that currently encrypts the user's copy of the key.

Example – sets the password "MasterSecret" for the master key in database tdb1:

```
use tdb1
set encryption passwd 'MasterSecret' for key master
```

Adaptive Server sets the password in the server memory for the database in which the master or dual master key is defined, and also records the identity of the user setting the password. Once set, the password is available for all access to the master key in the database.

Altering passwords and key encryption keys for master key copies

Users who own master key copies can change the passwords for their key copies using:

```
alter encryption key [dual] master
    with passwd char_string
```

```
modify encryption
{with passwd char_string [for recovery]
     | for automatic_startup}
```

where:

- *char_string* – (first instance) If the user is the key owner, this is the password that currently encrypts the base copy of the master or dual master key. If the user is not the key owner, this is the password that currently encrypts the user's copy of the key.
- *char_string* – (second reference) specifies the new password for the regular or recovery copy. Do not use this parameter to enter a password for automatic_startup copies.
- for automatic_startup – generate a new KEK and use it to create a new automatic_startup key copy.

If neither for recovery nor for automatic startup is specified, and the command is issued by the key owner, Adaptive Server alters the password of the base key copy. If the command is not issued by the key owner, Adaptive Server alters the password of the base key copy only if the current user has sso_role or keycustodian_role.

- Example 1 – master key owner "Jones" creates a key copy for "Mary" using:

```
alter encryption key master
     with passwd 'unforgettablethatswhatyouare'
     add encryption
     with passwd 'just4now'
     for user Mary
```

- Example 2 – "Mary" changes the password for her copy using:

```
alter encryption key master
     with passwd 'just4now'
     modify encryption
     with passwd 'maryspasswd'
```

- Example 3 – master key owner "John" changes the password for the base key using:

```
alter encryption key master
     with passwd 'unforgettablethatswhatyouare'
     modify encryption
     with passwd 'notunforgettable'
```

Users with sso_role or keycustodian_role can modify the automatic_startup key copies to change their key encryption keys. For example, such a user with knowledge of the master key password, can change the key encryption key of the automatic_startup key copy using:

```
alter encryption key master
     with passwd 'unforgettablethatswhatyouare'
     modify encryption for automatic_startup
```

The Adaptive Server:

- Decrypts the base master key with a key encryption key derived from the password.
- Creates a new master key encryption key and replaces the old key in the master key start-up file with this new key.
- Creates a new automatic_startup key copy by encrypting the master key using the new master key encryption key, and replacing the old automatic_startup key copy in sysencryptkeys with this new copy.

Regenerating master keys

Periodically change the master and dual master keys. However, each time you change the master and dual master keys, you must also reencrypt all column encryption keys using the new master and dual master keys. To automate this process, Adaptive Server uses the regenerate key option which replaces the master or dual master key values with the new values, and reencrypts all the column encryption keys that are currently encrypted by the master or dual master keys being regenerated:

alter encryption key [dual] master
    with passwd *char_string*
    regenerate key
    [with passwd *char_string*]

When regenerate key command is executed, Adaptive Server:

- Validates that the supplied password decrypts the base master or dual master key.
- Creates a new master or dual master key.

- Decrypts all column encryption keys that are encrypted either solely or partially by the master or dual master key. Adaptive Server reencrypts them using the new master or dual master key.
- Replaces the base master or dual master key with the new key encrypted by the second password. If the second password is not supplied, Adaptive Server uses the currently configured password to encrypt the new key.
- Drops the regular key copies. The master key owner must re-create regular key copies for designated users using alter encryption key.
- Drops the key recovery copy. The master key owner must add a new recovery key copy using alter encryption key, and inform the recovery key owners of the new password.
- Replaces the automatic_startup copy with a new key copy created by encrypting the new master key with a new randomly generated master key encryption key. Adaptive Server writes the new master key encryption key into the master key start-up file.

Dropping master keys and key copies

A user with sso_role or keycustodian_role can drop a master or dual master key provided that there are no other column encryption keys that are currently encrypted using that master or dual master key. Use:

```
drop encryption key [dual] master
```

When a master or dual master key is dropped, Adaptive Server:

- Drops the master or dual master key, and its key copies. All regular key copies, the automatic_startup key copy, and recovery key copies are deleted from the database.
- Deletes the master key encryption keys from the master keystart-upfile, if an automatic_startup key coply exists.

To delete only the regular key copy, use:

```
alter encryption key [dual] master
    drop encryption for user username
```

To delete only the recovery key copy, use:

```
alter encryption key [dual] master
    drop encryption for recovery
```

To delete only the automatic_startup key copy, use:

```
alter encryption key [dual] master
    drop encryption for automatic_startup
```

Recovering the master key and dual master key

A user with sso_role or keycustodian_role can recover the master or dual master key using:

```
alter encryption key [dual] master
    with passwd char_string
    recover encryption
    with passwd char_string
```

where the first reference to passwd is the password to the recovery key copy and the second reference to passwd is the new password for the base key.

Starting Adaptive Server in unattended start-up mode

Use unattended start-up mode to allow access to the master keys when the password holders unavailable.

Generally, using unattended start-up mode requires that you:

1 Enable the automatic master key access configuration parameter.

2 (Optional) set the master key startup file path and name. Otherwise, Adaptive Server uses the default file path and name.

3 Add automatic_startup copies for the master keys or dual master keys for databases for which you intend to have unattended start-up.

Configuring the unattended start-up mode

Users with sso_role can configure Adaptive Server to use unattended start-up mode by setting:

```
sp_configure 'automatic master key access', 1
```

In this mode, Adaptive Server accesses master keys, even if their passwords are not present in server memory, by reading and decrypting the master key encryption keys from the master key start-up file. To use unattended start-up mode, you must also create automatic_startup key copies for the master key and dual master key in the database.

Master key start-up file

When you enable automatic master key access, Adaptive Server reads in the key encryption keys from the master key start-up file, if it exists. If it does not exist, Adaptive Server creates a master key start-up file, but does not write the key encryption key values to the file until automatic_startup key copies either of the master or dual master keys are created.

When you disable automatic master key access, Adaptive Server drops the key encryption keys for master and dual master keys from the server memory. Adaptive Server does not erase the key encryption key values from the master key start-up file.

Creating the master key start-up file

A user with the sso_role can specify the master key start-up file path and name using:

```
sp_encryption mkey_startup_file
        [, {new_path | default_location | null}]
        [, {sync_with_mem | sync_with_qrm}]
```

where:

- *new_path* – specifies the location and name of the master key start-up file. new_path is not supported in standalone Adaptive Server Cluster Edition installations.
- default location – sets the master key start-up file to the default path and name: *$SYBASE_ASE/security/ase_encrcols_mk_<servername>.dat*. default location is not supported in standalone Adaptive Server Cluster Edition installations.
- null – displays the current master key start-up file path and name.
- sync_with_mem – writes the master key encryption keys existing in server memory to the master key start-up file, if configuration option automatic master key access is enabled. sync_with_mem is not supported in standalone Adaptive Server Cluster Edition installations.

- sync_with_qrm – (Available only with standalone Cluster Edition installations) updates the key copy in the local master key start-up file with the copy on the quorum device.

How Adaptive Server uses the master key start-up file

Adaptive Server reads the master and dual master key encryption keys from the master key start-up file into the server memory, if:

- The server is started with automatic master key access enabled, or
- automatic master key access is enabled while the server is running.

If:

- An automatic_startup key copy of the master or dual master key is created, Adaptive Server writes the master or dual master key encryption keys to the file.
- The key encryption key of the automatic_startup key copy of the master or dual master key is altered, Adaptive Server writes the new master or dual master key encryption keys to the file.
- An automatic_startup key copy is dropped, Adaptive Server deletes the corresponding record in the file.
- A database is dropped, Adaptive Server deletes all records belonging to the dropped database.
- A master or dual master key is dropped, Adaptive Server deletes the corresponding record.
- A new master key start-up file is specified using sp_encryption mkey_startup_file, Adaptive Server synchronizes the server memory with the contents of the new file.

Once a master key encryption key is in memory, the master key can be accessed through the automatic_startup copy even if the master key password is not set.

CHAPTER 4

Securing External Passwords and Hidden Text

Adaptive Server provides strong encryption for external login passwords and hidden text, using the AES-256 symmetric encryption algorithm. You may choose strong encryption for external passwords to:

- Replication Agents – replicated databases.
- CIS – remote descriptors and logins.
- Job Scheduler – Job Scheduler Agent.
- RTMS – real time messaging.
- Secure Sockets Layer (SSL) and Lightweight Directory Access Protocol (LDAP) – SSL and LDAP access accounts. Passwords are administered using stored procedures sp_ldapadmin and sp_ssladmin can be secured.

Objects that have SQL text stored in syscomments, such as stored procedures, user-defined functions and computed columns can be optionally encrypted with strong encryption using sp_hidetext.

Note Encrypting external passwords and hidden text requires the ASE_ENCRYPTION license.

Service keys

Service keys are 256-bit, persistent encryption keys that are used to strongly encrypt external login passwords and hidden text, and are stored in sysencryptkeys.

Encrypt service keys using either:

- A static key – is the default key encryption key for service keys, and can be used if no master key has been created in the current database. With this method, Adaptive Server can use service keys after an unattended startup.
- The master key – provides stronger protection than a static key. Adaptive Server requires the password to decrypt the database-specific master key.

The database objects that describe these service keys include:

- syb_extpasswdkey – identifies service key for encryption of external login passwords in sysattributes. Only one syb_extpasswdkey exists for any database. When the syb_extpasswdkey is changed, all data encrypted using the key is reencrypted using the new key.

  Although external login passwords are generally stored in the master database, RepAgent stores this information in replicate databases.
- syb_syscommkey_dddddd – identifies service key for encryption of hidden text in syscomments, where "dddddd" is a global identifier generated by Adaptive Server to uniquely identify the key. The global identifier is included with the name to distinguish names when there are many syb_syscommkey keys associated with the same object. The global identifier distinguishes the key, on both the local database and in the replicate database.

  Strong encryption of hidden text requires a service key in each database where sp_hidetext is executed to hide SQL text. When a new service key is created, any existing service key in the database persists until explicitly dropped, and any hidden text is not reencrypted until you reissue sp_hidetext.

Note The system encryption password does not encrypt service keys.

Creating service keys

A user with sso_role or keycustodian_role can create a service key using:

```
create encryption key [syb_extpasswdkey | syb_syscommkey]
    [ with { static key | master key }]
```

By default, the static key encrypts the keys. To use the master key, use the with master key parameter.

The user who creates the service key becomes the owner of the key.

When a syb_extpasswdkey is created, all external passwords in sysattributes are reencrypted with the new key using strong encryption.

When a syb_syscommkey is created, any subsequent execution of sp_hidetext uses the new key with strong encryption. sp_hidetext must be executed on an existing database object for the object to be encrypted with the new key. Because reencrypting hidden text may involve very large amounts of data, database administrators should defer executing sp_hidetext to times when there is low system demand.

To create service keys:

- An ASE_ENCRYPTION license is required.
- The enable encrypted columns configuration parameter must be set.
- The user creating the service key must have sso_role or keycustodian_role.
- The master key must be created before the service key, if you are protecting service keys with the master key.

Note You cannot use dual control with service keys.

Dropping service keys

drop encryption key ensures that there are no remaining references to the encryption key, and then deletes it. You cannot drop a nonexistent syb_extpasswdkey or syb_syscommkey_dddddd. To ensure that you delete all hidden text keys, use sp_encryption to identify all existing keys.

Note If your ASE_ENCRYPTION license has expired, encrypted data is no longer available, and you cannot execute the drop encryption key command. Contact Sybase Technical Support to obtain a temporary license.

A user with sso_role or keycustodian_role can delete an unused service key for external logins using:

```
drop encryption key syb_extpasswdkey
    with password encryption downgrade
```

When with password encryption downgrade is specified, Adaptive Server resets external login passwords with the algorithm used in versions earlier then 15.7. The Replication Agent password, and the CIS and RTMS external login passwords are reset to an invalid value. The administrator must manually reenter the passwords, after the key is dropped, to resume usage of the corresponding services.

A user with sso_role or keycustodian_role can delete an unused service key for hidden text by using:

- This command to indicate you are dropping a single key:

  ```
  drop encryption key syb_syscommkey_dddddd
  ```

  Adaptive Server checks if there are any references to the specified key _dddddd, and drops the key if no references are found.

  Because syb_syscommkey_dddddd indicates a single key, you cannot specify syb_syscommkey_dddddd with the with text encryption downgrade parameter.

- This command to indicate you are dropping multiple keys:

  ```
  drop encryption key syb_syscommkey with text encryption
  downgrade
  ```

  - If you specify with text encryption downgrade, you cannot specify a single service key with syb_syscommkey_dddddd, only with syb_syscommkey.
  - Without the “dddddd” suffix for the syb_syscommkey, Adaptive Server reencrypts all the hidden text in syscomments with the algorithm used in versions earlier than 15.7, and drops all syb_syscommkey_dddddd keys

Modifying service keys

You can regenerate syb_extpasswdkey or change its protection encryption from master key to static key, or vice versa. You cannot regenerate syb_syscommkey.

Changing the *syb_extpasswdkey*

Change the syb_extpasswdkey using:

```
alter encryption key syb_extpasswdkey
    [ with { static key | master key} ]
        { regenerate key [ with { static key | master key } ]
        | modify encryption [ with { static key | master key } ] }
```

where:

- The first instance of with {static key | master key} is optional and represents how the syb_extpasswdkey is currently encrypted.
- The second instance of with {static key | master key} allows the administrator to change the encryption on the regenerated key from static to dynamic, or vice versa. If you omit this parameter, the regenerated key remains encrypted as it was before issuing this command.
- The third instance of with {static key | master key} changes the protection on the existing key to use the static key or the master key as specified. If you omit this parameter, by default, the static key is used.

Regenerating syb_extpasswdkey is a single transaction that:

1 Creates a new service key for the external login passwords.

2 Reencrypts the passwords in sysattributes using the new key.

3 Drops the old key.

For example:

- Create a service key for external login passwords and encrypt all external login passwords with the service key protected by the static key:

```
create encryption key syb_extpasswdkey
```

- Regenerate the service key for external login passwords, leaving the new service key protected by the static key and reencrypting all external passwords encrypted by the old service key:

```
alter encryption key syb_extpasswdkey
       regenerate key
```

- Change the protection of the service key to be encrypted by the master key. The service key does not change, and external login passwords are not reencrypted:

```
alter encryption key syb_extpasswdkey
```

```
modify encryption with master key
```

Note Before issuing this command, ensure that the master key password has already been entered by the master key owner.

Changing the *syb_syscommkey*

To change the syb_syscommkey, create a new key and use sp_hidetext to reencrypt with the new key.

For example:

- Example 1 – Create a new hidden text encryption key and encrypt all SQL text objects in the syscomments table with the newly created key:

  ```
  create encryption key syb_syscommkey
  go
  sp_hidetext
  go
  ```

  Note When a new syb_syscommkey is created, it becomes the default key used by sp_hidetext in that database.

- Example 2 – Create a new hidden text encryption key, encrypt the text of a specific stored procedure in syscomments with the newly created key, and protect the key with the master key:

  ```
  create encryption key syb_syscommkey
         with master_key
  go
  sp_hidetext sp_mysproc
  go
  ```

  In this example, all other hidden text rows in syscomments remain encrypted with the previous encryption key.

Using service keys with external passwords

Service keys decrypt the private-key password for network listeners using SSL. The private key password initializes the SSL certificate.

SSL passwords

If the service keys are encrypted by the master key and the master key is unavailable:

- When only SSL listeners are specified in the interfaces file, no user can log in to enter the master key or dual master key password. The Adaptive Server shuts down because it cannot start any listeners.
- When both SSL and non-SSL listeners are specified in the interfaces file, the non-SSL listener can accept login requests. The SSL listeners are blocked until the master key password is entered manually by an authorized user after connecting to the Adaptive Server on a non-SSL listener port using:

  ```
  use master
  go
  set encryption passwd password for key master
  go
  ```

  When the master key password is correctly entered, Adaptive Server wakes the SSL listener processes and they begin to accept incoming login requests.

LDAP passwords

Service keys are needed to decrypt the password for LDAP administration accounts when Adaptive Server authenticates users during the LDAP user authentication process. Until authentication is complete, users cannot log in using LDAP. An authorized user that can authenticate locally using Adaptive Server authentication can manually enter the master key password using:

```
use master
go
set encryption passwd password for key master
go
```

See the chapter on external authentication in the *Security Administration Guide* for details on configuring LDAP user authentication.

Replication Agent passwords

Service keys decrypt passwords that initiate connections by Replication Agents on user databases. Agents that are configured to start automatically are blocked until an authorized user enters the master key password manually, if the service key is encrypted by a master key.

If a service key is in a user database that is replicated, the service key is also available on the replicate database because the sysencryptkeys table that stores the encryption keys is also replicated. The master key is also stored in the sysencryptkeys table that is replicated, and also available on the replicate database. Because they are encrypted, service keys remain protected during the replication process.

After the Adaptive Server has been started, an authorized user can connect and set the master key password for each database using:

```
use mydb
go
set encryption passwd password for key master
go
```

A Replication Agent that is waiting for the master key password can be identified by the status value “passwd sleep”:

```
sp_who
go

fid spid status loginame origname hostname blk_spid
dbname tempdbname cmd block_xloid
--- ---- ----------- ------ -------- -------- ------
------ ---------- --------- -----------
0   38  passwd sleep NULL   NULL      NULL     0
tdb4   tempdb     REP AGENT  0
```

Using service keys with hidden text during upgrade

During an upgrade to version 15.7, procedural objects are recompiled from source. Connected users are restricted in what they can do until the master key password is entered for databases where strong encryption of hidden text is enabled, and service key is protected by master key. An authorized user must set the master key password on such databases using:

```
use mydb
go
set encryption passwd password for key master
go
```

Considerations for service keys encrypted with the master key

If your service keys are encrypted with the master key, the master key's password must be entered into Adaptive Server, either automatically or manually, depending on how you specify the master key.

If you do not use automatic master key access, you typically enter the master key's password with set encryption passwd. However, if a service key is required to decrypt the private key password for network listeners during startup, you can supply the master key at the command line, or through a command line prompt.

Use the dataserver . . . -- master_key_password parameter to prompt for a master key password during Adaptive Server startup. The user issuing the --master_key_passwd parameter must know the master key password for the master database and have physical access to the console and keyboard to enter the password.

If you do not include a password, -- master_key_password prompts for password at the command line. For example:

```
dataserver --master_key_passwd  -dd_master  -eerrorlog

master_key_passwd:_
```

The password characters do not appear, and the password is not validated until later in the Adaptive Server start-up sequence.

If you include the password with the --master_key_passwd parameter:

```
dataserver --master_key_passwd=mysecret  -dd_master  -eerrorlog
```

The password, `mysecret`, is blanked out in memory after it is read and used. However, the clear password is visible until the memory is blanked out.

If you enter the incorrect password, attempts to use service keys fail, and Adaptive Server services that require the service keys remain unavailable. After the server has started, an authorized user can connect and set the master key password in the master database with:

```
use master
go
set encryption passwd password for key master
go
```

If you have configured only SSL listeners and you enter the wrong password, Adaptive Server shuts down because it cannot start any listeners.

Sybase recommends that you do not use passwords at the command line because the passwords are visible:

- In memory that can be seen with the UNIX ps command,
- In memory, on an unattended terminal screen, or on disk in command history buffers and files
- On the screen

Sybase encourages customer sites to prompt for passwords to avoid these vulnerabilities when using attended startup.

CHAPTER 5

Encrypting Data

You can encrypt these datatypes:

- int, smallint, tinyint
- unsigned int, unsigned smallint, unsigned tinyint
- bigint, unsigned bigint
- decimal and numeric
- float4 and float8
- money, smallmoney
- date, time, smalldatetime, datetime
- char and varchar
- unichar, univarchar
- binary and varbinary
- bit

Specifying encryption on new tables

To encrypt columns in a new table, use the encrypt column qualifier on the create table statement.

The following partial syntax for create table includes only clauses that are specific to encryption. See the *Reference Manual: Commands*.

```
create table table_name
(column_name
. . .

[constraint_specification]
[encrypt [with [database.[owner].]keyname]]
[, next_column_specification . . .]
)
```

keyname – identifies a key created using create encryption key. The creator of the table must have select permission on *keyname*. If *keyname* is not supplied, Adaptive Server looks for a default key created using the as default clause on the create encryption key.

Note You cannot encrypt a computed column, and an encrypted column cannot appear in an expression that defines a computed column. You cannot specify an encrypted column in the *partition_clause* of a table.

The following example creates two keys: a database default key, and another key (cc_key) which you must name in the create table command. Both keys use default values for length and an initialization vector. The ssn column in the employee table is encrypted using the default key, and the creditcard column in the customer table is encrypted with cc_key:

```
create encryption key new_key as default for AES
create encryption key cc_key

create table employee_table (ssn char(15) encrypt,
   ename char(50), ...))

create table customer (creditcard char(20)
   encrypt with cc_key, cc_name char(50), ...)
```

This example creates key k1, which uses nondefault values for the initialization vector and random pad. The employee esalary column is padded with random data before encryption:

```
create encryption key k1 init_vector null pad random
create table employee (eid int, esalary money encrypt with k1, ...)
```

Specifying encryption on *select into*

By default, select into creates a target table without encryption even if the source table has one or more encrypted columns. To encrypt any column in the target table, you must qualify the target column with the encrypt clause, as shown:

```
select [all|distinct] column_list
    into table_name
    [(colname encrypt [with [[database.][owner].]keyname]
            [, colname encrypt
            [with[[database.][owner].]keyname]])]
        from table_name | view_name
```

You can encrypt a specific column in the target table even if the data was not encrypted in the source table. If the column in the source table is encrypted with the same key specified for the target column, Adaptive Server optimizes processing by bypassing the decryption step on the source table and the encryption step on the target table.

The rules for specifying encryption on a target table are the same as those for encryption specified on create table in regard to:

- Allowable datatypes on the columns to be encrypted
- The use of the database default key when the *keyname* is omitted
- The requirement for select permission on the key used to encrypt the target columns.

The following example selects the encrypted column creditcard from the daily_xacts table and stores it in encrypted form in the #bigspenders temporary table:

```
select creditcard, custid, sum(amount) into
     #bigspenders
     (creditcard encrypt with cust.dbo.new_cc_key)
     from daily_xacts group by creditcard
     having sum(amount) > $5000
```

Note select into requires column-level permissions, including decrypt, on the source table.

Encrypting data in existing tables

To encrypt columns in existing tables, use the modify column option on the alter table statement with the encrypt clause:

alter table *table_name* modify *column_name*
[encrypt [with [[*database*.][*owner*.]*keyname*]]

where *keyname* identifies a key created using create encryption key. The creator of the table must have select permission on *keyname*. If *keyname* is not supplied, Adaptive Server looks for a default key created using the as default clause on the create encryption key.

See the *Reference Manual: Commands*.

There are restrictions on modifying encrypted columns:

- You cannot modify a column for encryption or decryption on which you have created a trigger. You must:
  a Drop the trigger.
  b Encrypt or decrypt the column.
  c Re-create the trigger.
- You cannot change an existing encrypted column, modify a column for encryption or decryption on a table, or modify the type of an encrypted column if that column is a key in a clustered or placement index. You must:
  a Drop the index.
  b Alter the table/modify the type of column.
  c Re-create the index.

You can alter the encryption property on a column at the same time you alter other attributes. You can also add an encrypted column using alter table.

For example:

```
alter table customer modify custid null encrypt with cc_key
alter table customer add address varchar(50) encrypt with cc_key
```

Creating indexes and constraints on encrypted columns

You can create an index on an encrypted column if the encryption key has been specified without any initialization vector or random padding. An error occurs if you execute create index on an encrypted column that has an initialization vector or random padding. Indexes on encrypted columns are generally useful for equality and nonequality matches. However, indexes are not useful for matching case-insensitive data, or for range searches of any data.

Note You cannot use an encrypted column in an expression for a functional index.

In the following example, cc_key specifies encryption without using an initialization vector or padding. This allows an index to be built on any column encrypted with cc_key:

```
create encryption key cc_key
    with init_vector null

create table customer(custid int,
    creditcard varchar(16) encrypt with cc_key)

create index cust_idx on customer(creditcard)
```

You can encrypt a column that is declared as a primary or unique key.

You can define referential integrity constraints on encrypted columns when:

- Both referencing and referenced columns are encrypted with the same key.
- The key used to encrypt the columns specifies init_vector null and pad random has not been specified.

Referential integrity checks are efficient because they are performed on cipher text values.

In this example, ssn_key encrypts the ssn column in both the primary and foreign tables:

```
create encryption key ssn_key for AES
    with init_vector null
create table user_info (ssn char(9) primary key encrypt
    with ssn_key, uname char(50), uaddr char(100))
create table tax_detail (ssn char(9) references user_info encrypt
    with ssn_key, return_info text)
```

Creating domain and access rules on encrypted columns

You can create domain rules, check constraints, or access rules on encrypted columns. However, decrypt permission is required on the encrypted column when the encrypted column is used in target list, where clause, and so on. This example creates the rule_creditcard rule on the creditcard column, which has a domain rule defined:

```
create encryption key cc_key
    with init_vector null

create table customer(custid int,
        creditcard varchar(16) encrypt with cc_key)

create rule rule_creditcard
as @value like '%[0-9]'
sp_bindrule rule_creditcard, creditcard
```

bcp in -C bypasses the domain rule or check constraint for encrypted columns because Adaptive Server uses fast bcp with bcp in -C. bcp out -C generates error number 2929 if an access rule exists on the encrypted column. Adaptive Server bypasses the rule or constraint for insert and update statements when you replicate encrypted columns with domain rules or check constraints. Adaptive Server also generates error number 2929 when you replicate encrypted columns with access rules for update, delete, or select statements.

Decrypt permission

Users must have decrypt permission to select plain text data from an encrypted column, or to search or join on an encrypted column.

The table owner or a user with the sso_role uses grant decrypt to grant explicit permission to decrypt one or more columns in a table to other users, groups, and roles. Decrypt permission may be implicitly granted when a procedure or view owner grants:

- exec permission on a stored procedure or user-defined function that selects from an encrypted column where the owner of the procedure or function also owns the table containing the encrypted column

- decrypt permission on a view column that selects from an encrypted column where the owner of the view also owns the table

In both cases, decrypt permission need not be granted on the encrypted column in the base table.

The syntax is:

grant decrypt on [*owner*.] *table*
[(*column*[{,*column*}])]
to *user*| *group* | *role*
[with grant option]

Granting decrypt permission at the table or view level grants decrypt permission on all encrypted columns in the table.

To grant decrypt permission on all encrypted columns in the customer table, enter:

```
grant decrypt on customer to accounts_role
```

The following example shows the implicit decrypt permission of user2 on the ssn column of the base table "employee". user1 sets up the employee table and the employee_view as follows:

```
create table employee (ssn varchar(12)encrypt,
    dept_id int, start_date date, salary money)

create view emp_salary as select
    ssn, salary from employee

grant select, decrypt on emp_salary to user2
```

user2 has access to decrypted Social Security Numbers when selecting from the emp_salary view:

```
select * from emp_salary
```

Note grant all on a table or view does not grant decrypt permission. Decrypt permission must be granted separately.

Configure Adaptive Server for restricted decrypt permission to restrict users from implicit decrypt permission. See "Restricting decrypt permission" on page 46.

Users with only select permission on an encrypted column can still process encrypted columns as cipher text through the bulk copy command. Additionally, if an encrypted column specifies a decrypt default value, the column can be named in a select target list or in a where clause by users who do not have permission to decrypt data. See “Returning default values instead of decrypted data” on page 47.

Revoking decryption permission

You can revoke a user’s decryption permission using:

revoke decrypt on [*owner*.] *table*[(*column*[{,*column*}])] from *user* | *group* | *role*

For example:

```
revoke decrypt on customer from public
```

Restricting decrypt permission

Adaptive Server protects data privacy from the powers of the administrator even if you use the master key or system encryption password for key protection. If you prefer to avoid password management and use the master key or the system encryption password to protect encryption keys, you can restrict access to private data from the database owner by setting the restricted decrypt permission configuration parameter. System security officers (SSOs) can use this parameter to control which users have decrypt permission. Once restricted decrypt permission is enabled, the SSO is the only user who receives implicit decrypt permission and who has implicit privilege to grant that permission to others. The SSO determines which users receive decrypt permission, or delegates this job to another user by granting decrypt permission with the with grant option. Table owners do not automatically have decrypt permission on their tables.

Users with execute permission on stored procedures or user-defined functions do not have implicit permission to decrypt data selected by the procedure or function. Users with decrypt permission on a view column do not have implicit permission to decrypt data selected by the view.

Note Users with aliases continue to inherit all decrypt permissions of the user to whom they are aliased. set proxy/set user statements continue to allow the administrator or database owner the decrypt permissions of the user whose identity is assumed by this command.

Assigning privileges for restricted decrypt permissions

If you are using restricted decrypt permission, you can assign the privileges for creating the task's schema and managing keys as follows:

- System security officer – configures restricted decrypt permission, creates encryption keys, grants select permission on keys to the database owner, and grants decrypt permission to the end user.
- Database owner – creates the schema and loads data.

Returning default values instead of decrypted data

This section describes how to use decrypt defaults with encrypted columns. When users who are not permitted to see confidential data run queries against encrypted columns, they see the decrypt defaults instead of the decrypted data. Decrypt defaults allow legacy applications and reports to run without error, even for users not permitted to see confidential data.

Defining a decrypt default

The decrypt_default parameter for create table and alter table allows an encrypted column to return a user-defined value when a user without decrypt permission attempts to select information from the encrypted column, avoiding error message 10330:

```
Decrypt permission denied on object <table_name>,
```

```
database <database name>, owner <owner name>
```

Using decrypt defaults on encrypted columns allows existing reports to run to completion without error, and allows users to continue seeing the information that is not encrypted. For example, if the customer table contains the encrypted column creditcard, you can design the table schema so that:

```
select * from customer
```

Returns the value "`***************`" instead of returning the credit card data to users who lack decrypt permission.

Adding and removing a decrypt default

Specify a decrypt default on a new column with create table. The partial syntax for create table is:

create table *table_name* (*column_name datatype*
[[encrypt [with *keyname*]] [decrypt_default *value*]], ...)

- decrypt_default – specifies that this column returns a default value on a select statement for users who do not have decrypt permissions.
- *value* – is the value Adaptive Server returns on select statements instead of the decrypted value. A constant-valued expression cannot reference a database column but it can include a user-defined function which itself references tables and columns. The value can be NULL on nullable columns only, and the value must be convertible into the column's datatype.

For example, the ssnum column for table t2 returns "`?????????`" when a user without decrypt permissions selects it:

```
create table t2 (ssnum char(11)
     encrypt decrypt_default '???????????', ...)
```

To add encryption and a decrypt default value to an existing column not previously encrypted, use:

alter table *table_name* modify *column_name* [type]
[[encrypt [with *keyname*]] [decrypt_default *value*]], …

This example modifies the emp table to encrypt the ssn column and specifies decrypt default:

```
alter table emp modify ssn encrypt
     with key1 decrypt_default '000-00-0000'
```

To add a decrypt default to an existing encrypted column or change the decrypt default value on a column that already has a decrypt default, use:

alter table *table_name* replace *column_name* decrypt_default *value*

Tthis example adds a decrypt default to the salary column, which is already encrypted:

```
alter table employee replace salary
     decrypt_default $0.00
```

This example replaces the previous decrypt_default value with a new value and uses a user-defined funcion (UDF) to generate the default value:

```
alter table employee replace salary
     decrypt_default dbo.mask_salary()
```

To remove a decrypt default from an encrypted column without removing the encryption property, use:

alter table *table_name* replace *column_name* drop decrypt_default

This example removes the decrypt default for salary without removing the encryption property:

```
alter table employee replace salary
     drop decrypt_default
```

Permissions and decrypt default

You must grant decrypt permission on encrypted columns before users or roles can select or search on encrypted data in those columns. If an encrypted column has a decrypt default attribute, users without decrypt permission can run queries that select or search on these columns, but the plain text data is not displayed and is not used for searching.

In this example, the owner of table emp allows users with the hr_role to view emp.ssn. Because the ssn column has a decrypt default, users who have only select permission on emp and who do not have the hr_role see the *decrypt_default* value only and not the actual decrypted data.

```
create table emp (name char(50), ssn (char(11) encrypt
     decrypt_default '000-00-000', ...)
grant select permission on table emp to public
grant decrypt on emp(ssn) to hr_role
```

If you have the hr_role and select from this table, you see the values for ssn:

```
select name, ssn from emp
name                           ssn
-----------------------------  ------------
Joe Cool                       123-45-6789
Tinna Salt                     321-54-9879
```

If you do not have the hr_role and select from the table, you see the decrypt default:

```
select name, ssn from emp
name                              ssn
------------------------------  -----------
Joe Cool                        000-00-0000
Tinna Salt                      000-00-0000
```

order by clauses have no effect on the result set if you do not have the hr_role for this table.

Columns with decrypt default values

There are no restrictions on how you use columns with the decrypt default attribute in a query. You can use them in a target list expression, where clause, order by, group by, or subquery. Although expressions on the decrypt default constant value may not have a practical use, placing a decrypt default on a column does not impose any syntactic restrictions on use of the column in a Transact-SQL™ statement.

This example uses a select statement on a column with a decrypt default value in the target list:

```
create table emp_benefits (col1 name char(30),
     salary float encrypt decrypt_default -99.99)

select salary/12 as monthly_salary from emp_benefits
     where name = 'Bill Smith'
```

When you perform the select statement against this table, but do not have decrypt permission, you see:

```
monthly_salary
---------------------
8.332500
```

When Adaptive Server returns a column's decrypt default value on a select into command, this decrypt default value is inserted into the target table. However, the target column does not inherit the decrypt default property. You must use alter table to specify a decrypt default on the target table.

Decrypt default columns and query qualifications

If you use a column with the decrypt default property in a where clause, the qualification evaluates to false if you do not have decrypt permission. These examples use the emp table described above. Only users with the hr_role have decrypt permission on ssn.

1 If you have the hr_role and issue the following query, Adaptive Server returns one row.

```
select name from emp where ssn = '123-456-7890'

name
------------------------------
Joe Cool
```

2 If you do not have the hr_role, Adaptive Server returns no rows:

```
select name from emp where ssn = '123-456-7890'

name
------------------------------
(0 rows affected)
```

3 If you have the hr_role and include an or statement on a nonencrypted column, Adaptive Server returns the appropriate rows:

```
select name from emp where ssn = '123-456-7890' or
name like 'Tinna%'

name
------------------------------
Joe Cool
Tinna Salt
```

4 If you do not have the hr_role and issue the same command, Adaptive Server returns only one row:

```
select name from emp where ssn = '123-456-7890' or
name like 'Tinna%'

name
------------------------------
Tinna Salt
```

In this case, the qualification against the encrypted column with the decrypt default property evaluates to false, but the qualification against the nonencrypted column succeeds.

If you do not have decrypt permission on an encrypted column, and you issue a group by statement on this column with a decrypt default, Adaptive Server groups by the decrypt default constant value.

decrypt default and implicit grants

If you do not have explicit or implicit permission on a table, Adaptive Server returns the decrypt default value.

In this example (using the emp table described above), the database owner creates the p_emp procedure which selects from the emp table that he or she owns:

```
create procedure p_emp as
     select name, ssn from emp
grant exec on p_emp to corp_role
```

Because you have the corp_role, you have implicit select and decrypt permission on emp

```
exec p_emp
```

```
name                           ssn
-----------------------------  ------------
Tinna Salt                     123-45-6789
Joe Cool                       321-54-9879
```

If the emp table and p_emp stored procedure have been created by different users, you must have select permission on emp to avoid permissions errors. If you have select permission but not decrypt permission, Adaptive Server returns the decrypt default value of emp.ssn.

In this next example, "joe," who does not own the database, creates the v_emp view, which selects from the emp table. Any permissions granted on the view are not implicitly applied to the base table.

```
create view v_emp as
     select name, ssn from emp
grant select on v_emp to emp_role
grant select on emp to emp_role
grant decrypt on v_emp to emp_role
```

Although you have the emp_role, when you issue:

```
select * from joe.v_emp
```

Adaptive Server returns the following because decrypt permission on dbo.emp.ssn has not been granted to the emp_role, and there is no implicit grant to emp_role on dbo.emp.ssn:

```
name                        ssn
--------------------------  ---------------
Tinna Salt                  000-00-0000
Joe Cool                    000-00-0000
```

decrypt default and *insert*, *update*, and *delete* statements

The decrypt default parameter does not affect target lists of insert and update statements.

If you use a column with a decrypt default value in the where clause of an update or delete statement, Adaptive Server may not update or delete any rows. For example, when using the emp table and permissions from the previous examples, if you do not have the hr_role and issue the following query, Adaptive Server does not delete the user's name:

```
delete emp where ssn = '123-45-6789'
(0 rows affected)
```

Decrypt default attributes may indirectly affect inserting and updating data if an application, particularly one with a graphical user interface (GUI) process:

1 Selects data

2 Allow a user to update any of the data.

3 Applies the changed row back to the same or a different table

If the user does not have decrypt permission on the encrypted columns, the application retrieves the decrypt default value and may automatically write the the unchanged decrypt default value back to the table. To avoid overwriting valid data with decrypt default values, use a check constraint to prevent these values from being automatically applied. For example:

```
create table customer (name char(30)),
cc_num int check (cc_num != -1)
encrypt decrypt_default -1
```

If the user does not have decrypt permission on cc_num and selects data from the customer table, this data appears:

```
name                               cc_num
---------------------              ------------
```

```
Paul Jones                          -1
Mick Watts                          -1
```

However, if the user changes a name and updates the database, and the application attempts to update all fields from the values displayed, the default value for cc_num causes Adaptive Server to issue error 548:

```
"Check constraint violation occurred, dbname =
<dbname>, table name = <table_name>, constraint name =
<internal_constraint _name>"
```

Setting a check constraint protects the integrity of the data. For a better solution, you can filter these updates when you write the application's logic.

Removing decrypt defaults

You can remove the decrypt default using any of these commands:

- drop table
- alter table .. modify .. drop col
- alter table .. modify .. decrypt
- alter table .. replace .. drop decrypt_default

For example, to remove the decrypt default attribute from the ssn column, enter:

```
alter table emp replace ssn drop decrypt_default
```

If you do not have the hr_role and select from the emp table after the table owner removed the decrypt default, Adaptive Server returns error message 10330.

Length of encrypted columns

During create table, alter table, and select into operations, Adaptive Server calculates the maximum internal length of the encrypted column. To make decisions on schema arrangements and page sizes, the database owner must know the maximum length of the encrypted columns.

AES is a block-cipher algorithm. The length of encrypted data for block-cipher algorithms is a multiple of the block size of the encryption algorithm. For AES, the block size is 128 bits, or 16 bytes. Therefore, encrypted columns occupy a minimum of 16 bytes with additional space for:

- The initialization vector. If used, the initialization vector adds 16 bytes to each encrypted column. By default, the encryption process uses an initialization vector. Specify init_vector null on create encryption key to omit the initialization vector.
- The length of the plain text data. If the column type is char, varchar, binary, or varbinary, the data is prefixed with 2 bytes before encryption. These 2 bytes denote the length of the plain text data. No extra space is used by the encrypted column unless the additional 2 bytes result in the cipher text occupying an extra block.
- A sentinel byte, which is a byte appended to the cipher text to safeguard against the database system trimming trailing zeros.

In Table 5-1, the lengths in the Maximum encrypted data length columns reflect the value in sycolumns.encrlen for a column of the specified type and length.

Table 5-1: datatype length for encrypted columns

User-specified column type	Input data length	Encrypted column type	Maximum encrypted data length (no init vector)	Actual encrypted data length (no init vector)	Maximum encrypted data length (with init vector)	Actual encrypted data length (with init vector)
bigint	8	varbinary	17	17	33	33
unsigned bigint	8	varbinary	17	17	33	33
tinyint, smallint, or int (signed or unsigned)	1, 2, or 4	varbinary	17	17	33	33
tinyint, smallint, or int (signed or unsigned)	0 (null)	varbinary	17	0	33	0
float, float(4), real	4	varbinary	17	17	33	33
float, float(4), real	0 (null)	varbinary	17	0	33	0
float(8), double	8	varbinary	17	17	33	33
float(8), double	0 (null)	varbinary	17	0	33	0
numeric(10,2)	3	varbinary	17	17	33	33
numeric (38,2)	18	varbinary	33	33	49	49
numeric (38,2)	0 (null)	varbinary	33	0	49	0
char, varchar (100)	1	varbinary	113	17	129	33
char, varchar(100)	14	varbinary	113	17	129	33

User-specified column type	Input data length	Encrypted column type	Maximum encrypted data length (no init vector)	Actual encrypted data length (no init vector)	Maximum encrypted data length (with init vector)	Actual encrypted data length (with init vector)
char, varchar(100)	15	varbinary	113	33	129	49
char, varchar(100)	31	varbinary	113	49	129	65
char, varchar(100)	0 (null)	varbinary	113	0	129	0
binary, varbinary(100)	1	varbinary	113	17	129	33
binary, varbinary(100)	14	varbinary	113	17	129	33
binary, varbinary(100)	15	varbinary	113	33	129	49
binary, varbinary(100)	31	varbinary	113	49	129	65
binary, varbinary(100)	0 (null)	varbinary	113	0	65	0
unichar(10)	2 (1 unichar character)	varbinary	33	17	49	33
unichar(10)	20 (10 unichar characters)	varbinary	33	33	49	49
univarchar(20)	20 (10 unichar characters)	varbinary	49	33	65	49
date	4	varbinary	17	17	33	33
time	4	varbinary	17	17	33	33
time	null	varbinary	17	0	33	0
smalldatetime	4	varbinary	17	17	33	33
datetime	8	varbinary	17	17	33	33
smallmoney	4	varbinary	17	17	33	33
money	8	varbinary	17	17	33	33
money	null	varbinary	17	0	33	0
bit	1	varbinary	17	17	33	33

Note

- The timestamp datatype is not supported by Adaptive Server.
- char and binary are treated as variable-length datatypes and are stripped of blanks and zero padding before encryption. Any blank or zero padding is applied when the data is decrypted.
- The column length on disk increases for encrypted columns, but the increases are invisible to tools and commands. For example, sp_help shows only the original size.

CHAPTER 6

Accessing Encrypted Data

Adaptive Server automatically performs encryption and decryption when you process data in encrypted columns. Adaptive Server encrypts data when you update or insert data into an encrypted column, and decrypts data when you select it or use it in a where clause.

Processing encrypted columns

When you issue a select, insert, update, or delete command against an encrypted column, Adaptive Server automatically encrypts or decrypts the data using the encryption key associated with the encrypted column.

- When you issue an insert or update on an encrypted column:
  - If you do not have insert or update permission on the encrypted column, the command fails.
  - If the column is encrypted by a key with a user-specified password, Adaptive Server expects the password to be available. If the user-specified password has not been set, the command fails. See “Accessing encrypted data with user password” on page 73
  - Adaptive Server decrypts the encryption key.
  - Adaptive Server encrypts the data using the column’s encryption key.
  - Adaptive Server inserts the varbinary cipher text data into the table.

    - After the insert or update, Adaptive Server clears the memory holding the plain text. At the end of the statement, it clears the memory holding the raw encryption keys.
- When you issue a select command on data from an encrypted column:
    - The command fails if you do not have select permission on the encrypted column.
    - If the encryption key is associated with a column encrypted with a user-specified password, Adaptive Server expects the password to be available. If the user-specified password has not been set, the select statement fails. See "Accessing encrypted data with user password" on page 73. Otherwise, Adaptive Server decrypts the encryption key.
    - The decryption of the selected data succeeds if you have decrypt permission on the column, and Adaptive Server returns plain text data to the user.
    - If a decrypt default has been declared on the encrypted column and if you do not have decrypt permission on the column, Adaptive Server returns the decrypt default value.
- When you include encrypted columns in a where clause:
    - If you do not have decrypt permission on the column, and the column includes a decrypt default, the where clause predicate evaluates to false. See "Decrypt default columns and query qualifications" on page 51.
    - When possible, Adaptive Server makes the comparison without decrypting the data if:
        - The where clause joins an encrypted column with another column encrypted by the same key without use of an initialization vector or random pad
        - The column data is being matched with an equality or an inequality condition to a constant value

      See "Performance Considerations" on page 89.

Permissions for decryption

To see or process decrypted data, users must have:

- select and decrypt permissions on the column used in the target list and in where, having, order by, group by, and other such clauses
- A password used to encrypt the key if you use the passwd *password_phrase* clause with the create or alter encryption key commands. See Chapter 7, “Protecting Data Privacy from the Administrator.”

Configuring Adaptive Server for restricted decrypt permission restricts implicit decrypt permissions. You must explicitly grant table owners decrypt permission to enable them to select from an encrypted column on tables that they own. Users cannot expect that execute permission on a stored procedure or select permission on a view does not explicitly grant users decrypt permission against the underlying table. The user must also have explicit decrypt permission on the base table.

Dropping encryption

If you are a table owner, you can use alter table with the decrypt option to drop encryption on a column.

For example, to drop encryption on the creditcard column in the customer table, enter:

```
alter table customer modify creditcard decrypt
```

If the creditcard column was encrypted by a key with an explicit user password, you would need to set that password first.

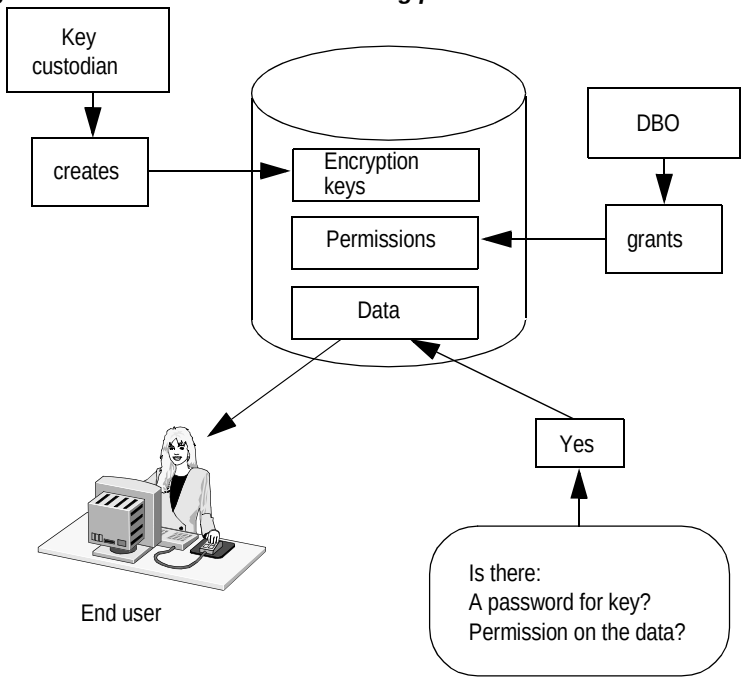
CHAPTER 7

Protecting Data Privacy from the Administrator

Role of the key custodian

The key custodian, who must be assigned the keycustodian_role, maintains encryption keys. Using the keycustodian_role role allows you to separate the duties for administering confidential data by ensuring that no administrator has implicit access to data. Figure 7-1 illustrates that the database owner, as the schema owner, controls permissions for accessing the data, but has no access without knowledge of the key's password. The key custodian, however, administers keys and their passwords, but has no permissions on the data. Only the qualified end user, with permissions on the data and knowledge of the encryption key's password, can access the data.

Figure 7-1: Database owner controlling permissions for data



The system administrator and database owner do not have implicit key management responsibilities. Adaptive Server provides the system role keycustodian_role so that the SSO need not assume all encryption responsibity. The key custodian owns the encryption keys, but should have no explicit or implicit permissions on the data. The database owner grants users access to data through column permissions, and the key custodian allows users access to the key's password. keycustodian_role is automatically granted to sso_role and can be granted by a user with the sso_role.

The key custodian can:

- Create and alter encryption keys.
- Assign as the database default key a key he or she owns, as long as he or she also owns the current default key, if one exists.
- Set up key copies for designated users, allowing each user access to the key through a chosen password or a login password.
- Share key encryption passwords with end users.
- Grant schema owners select access to encryption keys on keys owned by the key custodian.

- Create the master key or set the system encryption password.
- Recover encryption keys.
- Drop his or her own encryption keys.
- Change ownership of keys he or she owns.

You can have multiple key custodians, who each own a set of keys. The key custodian grants the schema owner permission to use the keys on create table, alter table, and select into, and may disclose the key password to privileged users or allow users to associate key copies with a personal password or a login password. The key custodian can work with a "key recoverer" to recover keys in the event of a lost password or disaster. If the key custodian leaves the company, the SSO can use the alter encryption key command to change key ownership to a new key custodian.

Users, roles, and data access

User-specified passwords on encryption keys ensure that data privacy is protected from the system administrator. Table 7-1 explains how:

- The key custodian can own the keys, but not see the data.
- The database owner can own the schema, but not the data.
- A user can see and process the data because of:
  - Key access, granted by the key custodian
  - Data access, granted by the table owner

Table 7-1: Permissions for users and roles on encrypted columns

Role	Can create encryption key?	Can use key in a schema definition?	Can decrypt encrypted data?
sso_role	Yes	No, requires create table permission	No. User with role may have knowledge of password, but requires select permission on table (SSO has implicit decrypt permission).
sa_role	No, requires create encryption key permission	Yes, but must be granted select permission on the key	No, requires knowledge of password
keycustodian_role	Yes	No, requires create table permission	No. User with role may have knowledge of password, but requires decrypt and select permission on table or column.

Role	Can create encryption key?	Can use key in a schema definition?	Can decrypt encrypted data?
database owner or schema owner	No, requires create encryption key permission	Yes, but must be granted select permission on the key	No, requires knowledge of password.
User	No	No	Yes, but must be granted decrypt or select permission and have knowledge of key's password.

Key protection using user-specified passwords

Use create encryption key to associate a password with a key:

```
create encryption key [[db.][owner].]keyname  [as default]
    [for algorithm_name]
    [with {[keylength num_bits]
    [passwd 'password_phrase']
    [init_vector {NULL | random}]
    [pad {NULL | random}]}]
```

Where *password_phrase* is a quoted alphanumeric string of up to 255 bytes in length that Adaptive Server uses to generate thekey encryption key (KEK).

Adaptive Server does not save the user-specified password. It saves a string of validating bytes known as the "salt" in sysencryptkeys.eksalt, which allows Adaptive Server to recognize whether a password used on a subsequent encryption or decryption operation is legitimate for a key. You must supply the password to Adaptive Server before you can access any column encrypted by keyname.

When you create an encryption key, its entry in the sysencryptkeys table is known as the base key. For some users and applications, the **base key**, encrypted by either the master key, the system encryption password, or an explicit password, is sufficient. Any explicit password is shared among users requiring access to the key. Additionally, you can create **key copies** for different users and applications. Each key copy can be encrypted by an individual password and is stored as a separate row in sysencryptkeys. An encryption key is always represented by one base key and zero or more key copies.

This example shows how to use passwords on keys, and the key custodian's function in setting up encryption. The password on the key is shared among all users who have a business need to process encrypted data.

1 Key custodian “razi” creates an encryption key:

```
create encryption key key1
     with passwd 'Worlds1Biggest6Secret'
```

2 “razi” distributes the password to all users who need access to encrypted data.

3 Each user enters the password before processing tables with encrypted columns:

```
set encryption passwd 'Worlds1Biggest6Secret'
     for key razi.key1
```

4 If the key is compromised because an unauthorized user gained access to the password, “razi” alters the key to change the password.

Changing a key’s protection method

You can use the alter encryption key command to change the protection method for an encryption key:

alter encryption key [[*database*.database][*owner*].] *keyname*
[with {passwd {'old_passwd' | system_encr_passwd
| login_passwd} | master key}]
modify encryption
[with [{passwd {'old_passwd' | system_encr_passwd | login_passwd}
| master key}] [[no] dual_control]]

where:

- *keyname* – identifies a column encryption key.
- with passwd '*old_password*' – specifies the user-defined password previously specified to encrypt the base key or the key copy with a create encryption key or alter encryption key statement. The password can be up to 255 bytes long. If you do not specify with passwd on the base key, the default is the master key or the system encryption password.
- with passwd '*new_password*' – specifies the new password Adaptive Server uses to encrypt the column encryption key or key copy. The password can be up to 255 bytes long. If you do not specify with passwd and you are encrypting the base key, the default is system_encr_passwd.

- system_encr_passwd – is the default encryption password. You cannot modify the base key to be encrypted with the system encryption password if one or more key copies already exist. This restriction prevents the key custodian from inadvertently exposing an encryption key to access by an administrator after the key custodian has set up the key for restricted use by individual users. You cannot modify key copies to encrypt using the system encryption password.
- *login_passwd* – is the login password of the current session. You cannot modify the base key to use *login_password* for encryption. A user can modify his own key copy to encrypt with his login password.

  See "Application transparency using login passwords on key copies" on page 75 for alternatives to encrypting key copies with a user's login password that do not require the key copy assignee to execute alter encryption key.
- master key – in the first instance indicates that the current encryption uses the master key. In the second instance, it indicates that the CEK must be re-encrypted with the master key.

Example 1: In this example, the key custodian alters the base key because the password was compromised or a user who knew the password left the company.

1 Key custodian "razi" creates an encryption key:

```
create encryption key key1
     with passwd 'MotherOfSecrets'
```

2 "razi" shares the password on the base key with "joe" and "bill", who need to process the encrypted data (no key copies are involved).

3 "joe" leaves the company.

4 "razi" alters the password on the encryption key and then shares it with "bill", and "pete", who replaces is "joe." The data does not need to be reencrypted because the underlying key has not changed, just the way the key is protected. The following statement decrypts key1 using the old password and reencrypts it with the new password:

```
alter encryption key key1
    with passwd 'MotherOfSecrets'
    modify encryption
    with passwd 'FatherOfSecrets'
```

Example 2: Use the master key to encrypt an existing CEK "k2":

```
alter encryption key k2
```

```
        with passwd 'goodbye'
        modify encryption
        with master key
```

Example 3: Re-encrypt an existing CEK “k3” that is currently encrypted by the master key, to use dual control:

```
alter encryption key k3
        modify encryption
        with master key
        dual_control
```

Note You can omit with master key in this example to achieve the same encryption.

Example 4: Re-encrypt an existing CEK “k4” that is currently encrypted by the master key and password “k4_password”, to remove dual control. The CEK and all its key copies are controlled by a single key derived from “k4_new_password”:

```
alter encryption key k4
        with passwd 'k4_password'
        modify encryption
        with passwd 'k4_new_password'
        no dual_control
```

Example 5: Encrypt an existing CEK “k5” that is currently encrypted by the master key, for dual control encrypted by the master key and password “k5_password”:

```
alter encryption key k5
        modify encryption
        with passwd 'k5_password'
        dual_control
```

Example 6: Encrypt a CEK for dual control by the master key and password “k6_password”:

```
create encryption key k6
        with passwd 'k6_password'
        dual_control
```

For user “ned”, encrypt his existing key copy of CEK “k6” that is currently encrypted with dual control by the master key and password “k6_password”, for dual control by the master key and password “k6_ned_password”:

```
alter encryption key k6
        with passwd 'k6_password'
```

```
        add encryption
        with passwd 'k6_ned_password'
        for user ned
```

Note User “ned” cannot change the dual control property of his key copy.

Example 7: Encrypt a CEK “k7” currently encrypted by the master and dual master key, to use the system encryption password:

```
alter encryption key k7
        modify encryption
        with passwd system_encr_passwd
        no dual control
```

Creating key copies

The key custodian may need to make a copy of the key temporarily available to an administrator or an operator who must load data into encrypted columns. Because this operator does not otherwise have permission to access encrypted data, he should not have permanent access to a key.

You can make key copies available to individual users as follows:

- The key custodian uses create encryption key to create a key with a user-defined password. This key is known as the base key.
- The key custodian uses alter encryption key to assign a copy of the base key to an individual user with an individual password.

This syntax shows how to add a key encrypted using an explicit password for a designated user:

```
alter encryption key [database.[ owner ].]key
        with passwd 'base_key_password'
        add encryption with passwd 'key_copy_password'
        for user_name "
```

where:

- *base_key_password* – is the password used to encrypt the base key, and may be known only by the key custodian. The password can be upto 255 bytes in length. Adaptive Server uses the first password to decrypt the base column-encryption key.

- *key_copy_password* – the password used to encrypt the key copy. The password cannot be longer than 255 bytes. Adaptive Server makes a copy of the decrypted base key, encrypts it with a key encryption key derived from the *key_copy_password*, and saves the encrypted base key copy as a new row in sysencryptkeys.
- *user_name* – identifies the user for whom the key copy is made. For a given key, sysencryptkeys includes a row for each user who has a copy of the key, identified by their user ID (uid).
- The key custodian adds as many key copies as there are users who require access through a private password.
- Users can alter their copy of the encryption key to encrypt it with a different password.

The following example illustrates how to set up and use key copies with an encrypted column:

1 Key custodian "razi" creates the base encryption key with a user-specified password:

```
create encryption key key1 with passwd 'WorldsBiggestSecret'
```

2 "razi" grants select permission on key1 to database owner for schema creation:

```
grant select on key key1 to dbo
```

3 database owner creates schema and grants table and column-level access to "bill":

```
create table employee (empname char(50), emp_salary money encrypt with
     razi.key1, emp_address varchar(200))
     grant select on employee to bill
     grant decrypt on employee(emp_salary) to bill
```

4 Key custodian creates a key copy for "bill" and gives "bill" the password to his key copy. Only the key custodian and "bill" know this password.

```
alter encryption key key1 with passwd 'WorldsBiggestSecret'
     add encryption with passwd 'justforBill'
     for user 'bill'
```

5 When "bill" accesses employee.emp_salary, he first supplies his password:

```
set encryption passwd 'justforBill' for key razi.key1
     select empname, emp_salary from dbo.employee
```

When Adaptive Server accesses the key for the user, it looks up that user's key copy. If no copy exists for a given user, Adaptive Server assumes the user intends to access the base key.

Changing passwords on key copies

Once a user has been assigned a key copy, he or she can use alter encryption key to modify the key copy's password.

This example shows how a user assigned a key copy alters the copy to access data through his or her personal password:

- Key custodian "razi" sets up a key copy on an existing key for "bill" and encrypts it with a temporary password:

```
alter encryption key key1 with passwd 'MotherOfSecrets'
     add encryption with passwd 'just4bill' for user bill
```

- "razi" sends "bill" his password for access to data through key1.
- "bill" assigns a private password to his key copy:

```
alter encryption key razi.key1 with passwd 'just4bill'
     modify encryption with passwd 'billswifesname'
```

Only "bill" can change the password on his key copy. When "bill" enters the command above, Adaptive Server verifies that a key copy exists for "bill". If no key copy exists for "bill", Adaptive Server assumes the user is attempting to modify the password on the base key and issues an error message:

```
Only the owner of object '<keyname>' or a user with
     sso_role can run this command.
```

You cannot create key copies for user "guest" for login association. Encrypting a key copy with a login password requires two-steps.

Accessing encrypted data with user password

You must supply the encryption key's password to encrypt or decrypt data on an insert, update, delete, select, alter table, or select into statement. If the system encryption password protects the encryption key, you need not supply the system encryption password because Adaptive Server can already access it. Similarly, if your key copy is encrypted with your login password, Adaptive Server can access this password while you remain logged in to the server (see "Application transparency using login passwords on key copies" on page 75). For keys encrypted with an explicit password, you must set the password in your session before executing any command that encrypts or decrypts an encrypted column with this syntax:

```
set encryption passwd 'password_phrase'
    for {key | column} {keyname | column_name}
```

where:

- *password_phrase* – is the explicit password specified with the create encryption key or alter encryption key command to protect the key.
- key – indicates that Adaptive Server uses this password to decrypt the key when accessing any column encrypted by the named key
- *keyname* – may be supplied as a fully qualified name. For example:

  [[*database*.][*owner*.]*keyname*
- column – specifies that Adaptive Server use this password only in the context of encrypting or decrypting the named column. End users do not necessarily know the name of the key that encrypts a given column.
- *column_name* – name of the column on which you are setting an encryption password. Supply *column_name* as:

  [[*database*.][*owner*].]*table_name*.*column_name*

Each user who requires access to a key encrypted by an explicit password must supply the password. Adaptive Server saves the password in encrypted form in the user session's internal context. Adaptive Server removes the key from memory at the end of the session by overwriting the memory with zeros.

This example illustrates how Adaptive Server determines the password when it must encrypt or decrypt data. It assumes that the ssn column in the employee and payroll tables is encrypted with key1, as shown in these simplified schema creation statements:

```
create encryption key key1 with passwd "Ynot387"
create table employee (ssn char (11) encrypt with key1, ename char(50))
create table payroll (ssn char(11) encrypt with key1, base_salary float)
```

1. The key custodian shares the password required to access employee.ssn with “susan”. He does not need to disclose the name of the key to do this.
2. If “susan” has select and decrypt permission on employee, she can select employee data using the password given to her for employee.ssn:

```
set encryption passwd "Ynot387" for column employee.ssn
     select ename from employee where ssn = '111-22-3456'

ename
----------------------
Priscilla Kramnik
```

3. If “susan” attempts to select data from payroll without specifying the password for payroll.ssn, the following select fails (even if “susan” has select and decrypt permission on payroll):

```
select base_salary from payroll where ssn = '111-22-3456'

You cannot execute 'SELECT' command because the user encryption password
has not been set.
```

To avoid this error, “susan” must first enter:

```
set encryption passwd "Ynot387" for column payroll.ssn
```

The key custodian may choose to share passwords on a column-name basis and not on a key-name basis to avoid users hard-coding key names in application code, which can make it difficult for the database owner to change the keys used to encrypt the data. However, if one key is used to encrypt several columns, it may be convenient to enter the password once. For example:

```
set encryption passwd "Ynot387" for key key1
select base_salary from payroll p, employee e
     where p.ssn = e.ssn
        and e.ename = "Priscilla Kramnik"
```

If one key is used to encrypt several columns and the user is setting a password for the column, the user needs to set password for all the columns they want to process. For example:

```
set encryption passwd 'Ynot387' for column payroll.ssn
set encryption passwd 'Ynot387' for column employee.ssn
select base_salary from payroll  p, employee e
     where p.ssn = e.ssn
     and e.ename = 'Priscilla Kramnik'
```

If a password is set for a column and then set at the key level for the key that encrypts the column, Adaptive Server discards the password associated with the column and retains the password at the key level. If two successive entries for the same key or column are entered, Adaptive Server retains only the latest. For example:

1 If a user mistypes the password for the column employee.ssn as "Unot387" instead of the correct "Ynot387":

```
set encryption passwd "Unot387"
     for column employee.snn
```

2 And then the user reenters the correct password, Adaptive Server retains only the second entry:

```
set encryption passwd "Ynot387"
     for column employee.ssn
```

3 If the user now enters the same password at the key level, Adaptive Server retains only this last entry:

```
set encryption passwd "Ynot387" for key key1
```

4 If the user now enters the same password at the column level, Adaptive Server discards this entry because it already has this password at the key level:

```
set encryption passwd "Ynot387"
     for column payroll.ssn
```

If a stored procedure or a trigger references a column encrypted by a user specified password, you must set the encryption password before executing the procedure or the statement that fires the trigger.

Note Sybase recommends that you do not place the set encryption passwd statement inside a trigger or procedure; this could lead to unintentional exposure of the password through sp_helptext. Additionally, hard-coded passwords require you to change the procedure or trigger when a password is changed.

Application transparency using login passwords on key copies

The key custodian can set up key copies for encryption with a user's login password, and thereby provide:

- Ease of use – users whose login password is associated with a key can access encrypted data without supplying a password.
- Better security – users have fewer passwords to track, and are less likely to write them down.
- Lower administrative overhead for key custodian – the key custodian need not manually distribute temporary passwords to each user who requires key access through a private password.
- Application transparency – applications need not prompt for a password to process encrypted data. Existing applications can take advantage of the measures to protect data privacy from the power of the administrator.

To encrypt a key copy with a user's login password, use:

```
alter encryption key [[database.][owner].]keyname
    with passwd 'base_key_password'
    add encryption for user 'user_name' for login_association
```

where login_association tells Adaptive Server to create a key copy for the named user, which it later encrypts with the user's login password. Encrypting a key copy with a login password requires:

1 Using alter encryption key, the key custodian creates a key copy for each user who requires key access via a login password. Adaptive Server attaches information to the key copy to securely associate the key copy with a given user. The identifying information and key are temporarily encrypted using a key derived from the master key or—if no master key exists—the system encryption password. The key copy is saved in sysencryptkeys.

2 When a user processes a column requiring a key lookup, Adaptive Server notes that a copy of the encryption key identified for this user is ready for login password association. Using the master key or the system encryption password to decrypt the information in the key copy, Adaptive Server validates the user information associated with the key copy against the user's login credentials, and encrypts the key copy with a KEK derived from the user's login password, which has been supplied to the session.

When adding a key copy with alter encryption key key for login_association, the master key or the system encryption password must be available for encryption of the key copy. The system encryption password must still be available for Adaptive Server to decrypt the key copy when the user logs in. After Adaptive Server has reencrypted the key copy with the user's login password, the system encryption password is no longer required.

The following example encrypts a user's copy of the encryption key, key1, with the user's login password:

1 Key custodian "razi" creates an encryption key:

```
create encryption key key1 for AES
     with passwd 'MotherofSecrets'
```

2 "razi" creates a copy of key1 for user "bill", initially encrypted with the master key or the system encryption password, but eventually to be encrypted by "bill"'s login password:

```
alter encryption key key1 with
     passwd 'MotherofSecrets'
     add encryption
     for user 'bill'
     for login_association
```

3 Adaptive Server uses the master key or the system encryption password to encrypt a combination of the key and information identifying the key copy for "bill", and stores the result in sysencryptkeys.

4 "bill" logs in to Adaptive Server and processes data, requiring the use of key1. For example, if emp.ssn is encrypted by key1:

```
select * from emp
```

Adaptive Server recognizes that it must encrypt "bill"'s copy of key1 with his login password. Adaptive Server uses the master key or the system encryption password to decrypt the key value data saved in step 4. It validates the information against the current login credentials, then encrypts key1's key value with a KEK generated from "bill"'s login password.

5 During future logins when "bill" processes columns encrypted by key1, Adaptive Server accesses key1 directly by decrypting it with "bill"'s login password, which is available to Adaptive Server through "bill"'s internal session context.

Users who are aliased to "bill" cannot access the data encrypted by key1 because their own login passwords cannot decrypt key1.

6 When "bill" loses authority to process confidential data, the key custodian drops "bill"'s access to the key:

```
alter encryption key key1
     drop encryption
     for user 'bill'
```

A user can encrypt a key copy directly with a login password with alter encryption key using the with passwd login_passwd clause. However, the disadvantages of using this method over the login association are:

- The key custodian must communicate the key copy's first assigned password to the user.
- The user must issue alter encryption key to reencrypt the key copy with a login password.

For example:

- "razi" adds a key copy for user "bill" encrypted by an explicit password:

```
alter encryption key key1
     with passwd 'MotherofSecrets'
add encryption with passwd 'just4bill'
     for user bill
```

- "razi" shares the key copy's password with "bill".
- "bill" decides to encrypt his key copy with his login password for his own convenience:

```
alter encryption key key1 with passwd "just4bill"
modify encryption with passwd login_passwd
```

- Now, when "bill" processes encrypted columns, Adaptive Server accesses "bill"'s key copy through his login password.

Login password change and key copies

If you hold a key copy encrypted by a login password on one or more keys, you need not modify the key copies after you have changed your login password. As part of changing the login password, sp_password decrypts your key copies with your old login password and reencrypts them using the new login password.

If the SSO uses sp_password to change your password without supplying your old password, sp_password drops your key copies. This prevents an administrator from gaining access to a key through a known password. After a mandatory password change of this kind, the key custodian must use alter encryption key to add a key copy for login_association for the user whose password is changed. sp_password ignores offline databases and, for keys stored in offline databases, the key custodian follows the steps for recovering a lost key copy password when the database comes back online. See "Loss of login password" on page 82.

The key custodian may also need to perform these steps when a user's password is changed after the server is started using the -p flag. If the SSO, who uses the -p flag also has access to keys through key copies encrypted with his or her login password, then the key custodian must drop and re-create the SSO's key copies.

Dropping a key copy

When a user changes jobs or leaves the company, the key custodian should drop the user's key copy:

alter encryption key *keyname*
drop encryption for user *user_name*

For example, if user "bill" leaves the company, the key owner can prevent "bill"'s access to key1 by dropping his key copy:

```
alter encryption key key1
    drop encryption for user bill
```

Adaptive Server does not require a password for this command because no key decryption is required.

drop encryption key drops the base key and all its copies.

CHAPTER 8

Recovering Keys from Lost Passwords

Loss of password on key copy

If a user loses a password for the encryption key, the key custodian must drop the user's copy of the encryption key and issues to the user another copy of the encryption key with a new password.

In this example, the key custodian assigned a copy of key1 to "bill", and "bill" changed his password on key1 to a password known only to him. After losing his password, "bill" requests a new key copy from the key custodian.

1 The key custodian deletes Bill's copy of the key:

```
alter encryption key key1
     drop encryption for user bill
```

2 The key custodian makes a new copy of key1 for user "bill" and gives "bill" the password:

```
alter encryption key key1
     with passwd 'MotherofSecrets'
     add encryption with passwd 'over2bill'
     for user bill
```

3 "bill" automatically has permission to alter his own copy of key1:

```
alter encryption key key1
```

```
with passwd 'over2bill'
modify encryption
with passwd 'billsnupasswd'
```

Loss of login password

If user “bill”, who has key copies encrypted by his login password, loses his login password, you can recover his access to encryption keys with these steps:

1 The SSO uses sp_password to issue “bill” a new login password. Adaptive Server drops any key copies assigned to “bill” for login association or key copies already encrypted by “bill”’s login password.

2 The key custodian follows the regular procedure for setting up key encryption by login association. He verifies that the the master key or the system encryption password was set, and creates “bill”’s key copy:

```
alter encryption key k1
     with passwd 'masterofsecrets'
     add encryption for bill
     for login_association
```

This step assumes the key custodian still knows the base key’s password. If the key’s encryption password is unknown, the key custodian must first follow the key recovery procedure. See “Loss of password on base key” on page 82 for more information.

3 The next time “bill” accesses data encrypted by k1, Adaptive Server reencrypts “bill”'s key copy using “bill”'s new login password. For example, if emp_salary is encrypted by key k1, the following statement automatically reencrypts “bill”’s key copy with his login password:

```
select emp_salary from emp
     where name like 'Prisicilla%'
```

Loss of password on base key

Key custodians can use key recovery if the base key password is lost. Key recovery is vital because, without the password, the key custodian cannot change the key’s password or add key copies.

If all users share access to data through the base key and a user forgets the password, he or she can get the password from another user or the key custodian. If no one remembers the password, all access to the data is lost. Because of this, Adaptive Server recommends that you back up keys by creating a copy of the base key that you can use for recovery. This copy is called the key recovery copy.

The key custodian should:

1 Appoint one user as the key recoverer. The key recoverer's responsibility is to remember the password to the key recovery copy.

2 Make a copy of the base key for the key recoverer. Every key that requires recovery after a disaster must have a key recovery copy.

Key recovery commands

Adaptive Server does not allow access to data through the recovery key copy. A key recovery copy exists only to provide a backup for accessing the base key.

Set up a recovery key copy using:

```
alter encryption key keyname with passwd base_key_passwd
add encryption with passwd recovery_passwd
for user key_recovery_user for recovery
```

where:

- *base_key_passwd* – is the password the key custodian assigned to the base key.
- *recovery_passwd* – is the password used to protect the key recovery copy.
- *key_recovery_user* – user assigned the responsibility for remembering a password for key recovery.

After setting the key recovery copy, the key custodian shares the password with the key recovery user, who can alter the password using:

```
alter encryption key keyname with passwd old_recovery_passwd
    modify encryption with passwd new_recovery_passwd for recovery
```

During key recovery, the key recovery user tells the key custodian the password of the key recovery copy. The key custodian restores access to the base key using:

alter encryption key *keyname* with passwd *recovery_key_passwd*
recover encryption with passwd *new_base_key_passwd*

where:

- *recovery_key_passwd* – is the password associated with the key recovery copy, shared with the key custodian by the recovery key user. Adaptive Server uses the *recovery_key_passwd* to decrypt the key recovery copy to access the raw key.
- *new_base_key_passwd* – is the password used to encrypt the raw key. Adaptive Server updates the base key row in sysencryptkeys with the result.

You may also need to change ownership of the key to another key custodian. See "Changing ownership of encryption keys" on page 85.

This example shows how to set up the recovery key copy and use it for key recovery after losing a password:

1 The key custodian creates a new encryption key protected by a password.

```
create encryption key key1 for AES
     passwd 'loseitl8ter'
```

2 The key custodian adds a encryption key recovery copy for key1 for "charlie".

```
alter encryption key key1 with passwd 'loseitl8ter'
     add encryption
     with passwd 'temppasswd'
     for user charlie
     for recovery
```

3 "charlie" assigns a different password to the recovery copy and saves this password in a locked drawer:

```
alter encryption key key1
     with passwd 'temppasswd'
     modify encryption
     with passwd 'finditl8ter'
     for recovery
```

4 If the key custodian loses the password for base key, he can obtain the password from "charlie" and recover the base key from the recovery copy using:

```
alter encryption key key1
     with passwd 'finditl8ter'
     recover encryption
     with passwd 'newpasswd'
```

The key custodian now shares access to key1 with other users by sharing the base key's password, or by dropping and adding key copies where changes in personnel have occurred.

Changing ownership of encryption keys

Changing ownership may occur in the normal course of business, or as part of key recovery. This command, when executed by the SSO, transfers key ownership to a named user:

alter encryption key [[*database*.][*owner*].]*keyname*
modify owner *user_name*

Where *user_name* is the name of the new key owner. This user must already be a user in the database where the key was created.

For example, if "razi" is the key custodian, and owns the key encr_key, but is being replaced by a new key custodian named "tinnap", change the key ownership using:

```
alter encryption key encr_key modify owner tinnap
```

Only the SSO or the key owner can run this command.

If the new owner already has a copy of the key, you see:

```
A copy of key encr_key already exists for user tinnap
```

A user who already has a regular key copy or a recovery key copy cannot become the new owner of the key. Adaptive Server does not allow a key copy to be made for a key owner.

If the previous key owner had granted any permissions on the key, the grantor uid in sysprotects system table is changed to the uid of the new owner of the key. The ownership change is effective immediately; the new owner need not log in again for the change to take effect.

CHAPTER 9

Auditing Encrypted Columns

Auditing options

See “Auditing” in the *Security Administration Guide* for encrypted columns auditing information (specifically Table 18-5, which lists the values in the event and extrainfo columns).

Audit values

See “Auditing” in the *Security Administration Guide* for values that appear in the event column of sysaudits (specifically Table 18-2, which lists auditing options, requirements, and examples).

Event names and numbers

You can query the audit trail for specific audit events. Use audit_event_name with *event id* as a parameter.

audit_event_name(*event_id*)

See “Auditing” in the *Security Administration Guide* for values that appear in the event column of sysaudits (specifically Table 18-6, which lists the audit event values).

Masking passwords in command text auditing

Passwords are masked in audit records. For example, if the SSO has enabled command text auditing (that is, auditing all actions of a particular user) for user “alan” in database db1:

```
sp_audit "cmdtext", "alan", "db1", "on"
```

And “alan” issues this command:

```
create encryption key key1 with passwd "bigsecret"
```

Adaptive Server writes the following SQL text to the extrainfo column of the audit table:

```
"create encryption key key1 with passwd "xxxxxx"
```

Auditing actions of the key custodian

To audit all actions in which keycustodian_role is active, use:

```
sp_audit "all", "keycustodian_role", "all", "on"
```

CHAPTER 10

Performance Considerations

Encryption is a CPU-intensive operation that may introduce a performance overhead to your application in terms of CPU usage and the elapsed time of commands that use encrypted columns. The amount of overhead depends on the number of CPUs and Adaptive Server engines, the load on the system, the number of concurrent sessions accessing the encrypted data, and the number of encrypted columns referenced in a query. The encryption key size and the length of the encrypted data are also factors. In general, the larger the key size and the wider the data, the higher the CPU usage in the encryption operation.

The elapsed time depends on whether the Adaptive Server optimizer can make use of an encrypted column.

Indexes on encrypted columns

You can create an index on an encrypted column if the column's encryption key does not specify the use of an initialization vector or random padding. Using an initialization vector or random padding results in identical data encrypting to different patterns of cipher text, which prevents an index from enforcing uniqueness and from performing equality matching of data in cipher text form.

Indexes on encrypted data are useful for equality and nonequality matching of data but not for data ordering, range searches, or finding minimum and maximum values. If Adaptive Server is performing an order-dependent search on an encrypted column, it cannot execute an indexed lookup on encrypted data. Instead, the encrypted column in each row must be decrypted and then searched. This slows data processing.

Sort orders and encrypted columns

If you use a case-insensitive sort order, Adaptive Server cannot use an index on an encrypted char or varchar column when performing a join with another column or a search based on a constant value. This is also true of an accent-insensitive sort order.

For example, For example, in a case-insensitive search, the string `abc` matches all strings in the following range: `abc`, `Abc`, `ABc`, `ABC`, `AbC`, `aBC`, `aBc`, `abC`. Adaptive Server must compare `abc` against this range of values. By contrast, a case-sensitive comparison of the string `abc` to the column data matches only identical column values, that is, columns containing `abc`. The main difference between case-insensitive and case-sensitive column lookups is that case-insensitive matching requires Adaptive Server to perform a range search whereas case-sensitive matching requires an equality search.

An index on a nonencrypted character column orders the data according to the defined sort order. For encrypted columns, the index orders the data according to the cipher text values, which bears no relationship to the ordering of plain text values. Therefore, an index on an encrypted column is useful only for equality and non-equality matching and not for searching a range of values. `abc` and `Abc` encrypt to different cipher text values and are not stored adjacently in an index.

When Adaptive Server uses an index on an encrypted column, it compares column data in cipher text form. For case sensitive data, you do not want `abc` to match `Abc`, and the cipher text join or search based on equality matching works well. Adaptive Server can join columns based on cipher text values and can efficiently match where clause values. In this example, the maidenname column is encrypted:

```
select account_id from customer
     where cname = 'Peter Jones'
     and maidenname = 'McCarthy'
```

Providing that maidenname has been encrypted without use of an initialization vector or random padding, Adaptive Server encrypts `McCarthy` and performs a cipher text search of maidenname. If there is an index on maidenname, the search uses of the index.

Joins on encrypted columns

Adaptive Server optimizes the joining of two encrypted columns by performing cipher text comparisons if:

- The joining columns have the same datatype. For cipher text comparisons, char and varchar are considered to be the same datatypes, as are binary and varbinary.
- For int and float types, the columns have the same length. For numeric and decimal types, the columns must have the same precision and scale.
- The joining columns are encrypted with the same key.
- The joining columns are not part of an expression. For example, you cannot perform a cipher text join on a join where t.encr_col1 = s.encr_col1 +1.
- The encryption key was created with init_vector and pad set to NULL.
- The join operator is '=' or '<>'.
- The data uses the default sort order.

This example sets a schema to join on cipher text:

```
create encryption key new_cc_key for AES
        with init_vector NULL
create table customer
        (custid int,
        creditcard char(16) encrypt with new_cc_key)
create table daily_xacts
       (cust_id int, creditcard char(16) encrypt with
        new_cc_key, amount money........)
```

You can also set up indexes on the joining columns:

```
create index cust_cc on customer(creditcard)

create index daily_cc on daily_xacts(creditcard)
```

Adaptive Server executes the following select statement to total a customer's daily charges on a credit card without decrypting the creditcard column in either the customer or the daily_xacts table.

```
select sum(d.amount) from daily_xacts d, customer c
     where d.creditcard = c.creditcard and
     c.custid = 17936
```

Search arguments and encrypted columns

For equality and non-equality comparison of an encrypted column to a constant value, Adaptive Server optimizes the column scan by encrypting the constant value once, rather than decrypting the encrypted column for each row of the table. The same restrictions listed in "Joins on encrypted columns" on page 91 apply.

For example:

```
select sum(d.amount) from daily_xacts d
     where creditcard = '123-456-7890'
```

Adaptive Server cannot use an index to perform a range search on an encrypted column; it must decrypt each row before performing data comparisons. If a query contains other predicates, Adaptive Server selects the most efficient join order, which often leaves searches against encrypted columns until last, on the smallest data set.

If your query has more than one range search without a useful index, write the query so that the range search against the encrypted column is last. This example which searches for the Social Security Numbers of taxpayers earning more than $100,000 in Rhode Island positions the zipcode column before the range search of the encrypted adjusted gross income column:

```
select ss_num from taxpayers
       where zipcode like '02%' and
       agi_enc > 100000
```

Referential integrity searches

Referential integrity probes match at the cipher text level if both the following are true:

- The datatypes of the primary key and foreign key match according to the rules described above.
- The encryption of the primary and foreign keys meets the key requirements for joining columns.

Movement of encrypted data as cipher text

As much as possible, Adaptive Server optimizes the copying of encrypted data by copying cipher text instead of decrypting and reencrypting data. This applies to select into commands, bulk copying, and replication.

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