Key Management Interoperability Protocol (KMIP)

Storage Developer’s Introduction
SNIA Fall 2009
Gordon Arnold, garnold@us.ibm.com
Chair, Storage Security Industry Forum
Abstract

Data in networked storage environments is significantly more vulnerable to unauthorized access, theft, or misuse than data stored in direct-attached storage. Encrypting data-at-rest can mitigate threats and allow data security, but widespread use of encryption is complicated by inconsistencies and duplication in key management systems supporting encryption environments. An emerging standard, Key Management Interoperability Protocol (KMIP), promises to greatly reduce OPEX and improve compliance visibility, and this session provides a developer’s perspective on its implementation.

Learning Objectives:
- How KMIP addresses standardizing communication between encryption systems that need to consume keys and the key management systems that create and manage those keys.
- How KMIP is used with encrypted storage, low-end devices, and certificate distribution
- How enterprises will be able to deploy a single enterprise key management infrastructure to manage keys for all encryption systems in the enterprise that require symmetric keys, asymmetric keys pairs, certificates and other security objects.
- An interactive discussion on KMIP implementation suggestions for storage developers
Agenda

- The Need for Interoperable Key Management
- KMIP Overview
- KMIP Specification
- KMIP Use Cases
- Storage specific guidance
The Need for Interoperable Key Management

- Today’s enterprises operate in increasingly complex, multi-vendor environments.
- Enterprises need to deploy better encryption across the enterprise.
- A key hurdle in IT managers deploying encryption is their ability to recover the encrypted data.
- Today, many companies deploy separate encryption systems for different business uses – laptops, storage, databases and applications – resulting in:
  - Cumbersome, often manual efforts to manage encryption keys
  - Increased costs for IT
  - Challenges meeting audit and compliance requirements
  - Lost data
Often, Each Cryptographic Environment Has Its Own Key Management System

Enterprise Cryptographic Environments

- Key Management System
- Key Management System
- Key Management System
- Key Management System
- Key Management System
- Key Management System
- Key Management System

- Production Database
- CRM
- Staging
- Replica
- Email
- Collaboration & Content Mgmt Systems
- LAN
- WAN
- Disk Arrays
- File Server
- Backup System
- Backup Disk
- Backup Tape
- eCommerce Applications
- Business Analytics
- Dev/Test Obfuscation

- Portals
- Enterprise Applications
- VPN
Often, Each Cryptographic Environment Has Its Own Protocol

Enterprise Cryptographic Environments

Disparate, Often Proprietary Protocols

Key Management System

CRM

Production Database

Email

Replica

Portals

Collaboration & Content Mgmt Systems

File Server

Disk Arrays

Backup System

Backup Disk

Backup Tape

Dev/Test Obfuscation

WAN

LAN

VPN

VPN

VPN

VPN

VPN

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email

Email
KMIP Overview
What is KMIP

- The Key Management Interoperability Protocol (KMIP) enables key lifecycle management. KMIP supports legacy and new encryption applications, supporting symmetric keys, asymmetric keys, digital certificates, and other "shared secrets." KMIP offers developers templates to simplify the development and use of KMIP-enabled applications.

- KMIP defines the protocol for encryption client and key-management server communication. Supported key-lifecycle operations include generation, submission, retrieval, and deletion of cryptographic keys. Vendors will deliver KMIP-enabled encryption applications that support communication with compatible KMIP key-management servers.
KMIP: Single Protocol Supporting Enterprise Cryptographic Environments

Key Management Interoperability Protocol

Enterprise Key Management
KMIP: Symmetric Encryption Keys

Key Management Interoperability Protocol

Enterprise Key Manager

Application

Application

Application

Server

SAN

Tape Library

Storage Array
KMIP: Asymmetric Keys
KMIP: Digital Certificates

KMIP to Commercial Meter

KMIP to low-end Residential Meter

KMIP to Industrial Meter
KMIP Request / Response Model

Enter the Enterprise Key Manager

Request Header | Get | Unique Identifier

Response Header | Symmetric Key | Unique Identifier | Key Value

Unencrypted data

Name: XYZ
SSN: 1234567890
Acct No: 45YT-658
Status: Gold

Encrypted Storage

Encrypted data
Supporting Multiple Operations per Request

Enterprise Key Manager

<table>
<thead>
<tr>
<th>Request Header</th>
<th>Locate</th>
<th>Name</th>
<th>Get</th>
<th>ID Placeholder</th>
</tr>
</thead>
</table>

Response Header | Symmetric Key | Unique Identifier | Key Value

Name: XYZ
SSN: 1234567890
Acct No: 45YT-658
Status: Gold

Unencrypted data

Encrypting Storage

Encrypted data
Messages in TTLV Format

Tag  Type  Len  Value  Tag  Type  Len  Value  ...

...  Value  Len  Type  Tag  Value  Len  Type  Tag
Transport-Level Encoding

Key Client

API

Internal representation

KMIP Encode

KMIP Decode

Transport

KMIP

Key Server

API

Internal representation

KMIP Encode

KMIP Decode

Transport

KMIP
OASIS KMIP Technical Committee

- OASIS (Organization for the Advancement of Structured Information Standards) is a not-for-profit consortium that drives the development, convergence and adoption of open standards for the global information society.

- KMIP Technical Committee chartered in March 2009
  - “The KMIP TC will develop specification(s) for the interoperability of Enterprise Key Management (EKM) services with EKM clients. The specifications will address anticipated customer requirements for key lifecycle management (generation, refresh, distribution, tracking of use, life-cycle policies including states, archive, and destruction), key sharing, and long-term availability of cryptographic objects of all types (public/private keys and certificates, symmetric keys, and other forms of “shared secrets”) and related areas.”

- KMIP TC IPR mode is Royalty Free on RAND
KMIP Specification

http://xml.coverpages.org/KMIP/KMIP-v0.98-final.pdf
KMIP defines a set of Operations that apply to Managed Objects that consist of Attributes and possibly cryptographic material.

### Protocol Operations
- Create
- Create Key Pair
- Register
- Re-key
- Derive Key
- Certify
- Re-certify
- Locate
- Check
- Get
- Get Attributes
- Get Attribute List
- Add Attribute
- Modify Attribute
- Delete Attribute
- Obtain Lease
- Get Usage Allocation
- Activate
- Revoke
- Destroy
- Archive
- Recover
- Validate
- Query
- Cancel
- Poll
- Notify
- Put

### Managed Objects
- Certificate
- Symmetric Key
- Public Key
- Private Key
- Split Key
- Template
- Policy Template
- Secret Data
- Opaque Object
- Key Block (for keys) or Value (for certificates)

### Object Attributes
- Unique Identifier
- Name
- Object Type
- Cryptographic Algorithm
- Cryptographic Length
- Cryptographic Parameters
- Certificate Type
- Certificate Issuer
- Certificate Subject
- Digest
- Operation Policy Name
- Cryptographic Usage Mask
- Lease Time
- Usage Limits
- State
- Initial Date
- Activation Date
- Process Start Date
- Protect Stop Date
- Deactivation Date
- Destroy Date
- Compromise Occurrence Date
- Compromise Date
- Revocation Reason
- Archive Date
- Object Group
- Link
- Application Specific ID
- Contact Information
- Last Change Date
- Custom Attribute
KMIP Base Objects

- Base Objects are:
  - Components of Managed Objects:
    - Attribute, identified by its Attribute Name
    - Key Block, containing the Key Value, either
      - in the clear, either in raw format, or as a transparent structure
      - or “wrapped” using Encrypt, MAC/Sign, or combinations thereof
      - possibly together with some attribute values
  - Elements of protocol messages:
    - Credential, used in protocol messages
  - Parameters of operations:
    - Template-Attribute, containing template names and/or attribute values, used in operations
KMIP Managed Objects

- Managed Cryptographic Objects
  - Certificate, with type and value
  - Symmetric Key, with Key Block
  - Public Key, with Key Block
  - Private Key, with Key Block
  - Split Key, with parts and Key Block
  - Secret Data, with type and Key Block

- Managed Objects
  - Template and Policy Template:
    - Template has a subset of Attributes that indicate **what an object** created from such a template **is**
    - Policy Template has a subset of Attributes that indicate **how an object** created from such a template **can be used**
    - Note that (Policy) Templates have nothing except Attributes: for convenience these Attributes are included in the (Policy) Template structure too.
  - Opaque Object, without Key Block
KMIP Attributes

- Attributes contain the “meta data” of a Managed Object
  - Its Unique Identifier, State, etc
  - Attributes can be searched with the Locate operation, as opposed to the content of the Managed Object

- Setting/modifying/deleting Attributes
  - Only some of the Attributes are set with specific values at object creation, depending on the object type
    - For instance, the Certificate Type Attribute only exists for Certificate objects
  - Some Attributes are implicitly set by certain operations
    - Certificate Type is implicitly set by Register, Certify, and Re-certify
  - Client can set explicitly some of the Attributes
    - Certificate Type cannot be set by the client
  - Not all Attributes can be added, or subsequently modified or deleted once set
    - Certificate Type cannot be added, modified or deleted
  - Some Attributes can have multiple values (or instances) organized with indices
    - For instance, a Symmetric Key object may belong to multiple groups, hence its Object Group Attribute will have multiple values
31 Attributes defined

Describes what “is” the object

- Unique Identifier
- Name
- Object Type
- Cryptographic Algorithm
- Cryptographic Length
- Cryptographic Parameters
- Certificate Type
- Certificate Issuer
- Certificate Subject
- Digest
- Operation Policy Name
- Cryptographic Usage Mask
- Lease Time
- Usage Limits
- State
- Initial Date
- Activation Date
- Process Start Date
- Protect Stop Date
- Deactivation Date
- Destroy Date
- Compromise Occurrence Date
- Compromise Date
- Revocation Reason
- Archive Date
- Object Group
- Link
- Application Specific ID
- Contact Information
- Last Change Date
- Custom Attribute

Describes how to “use” the object

Describes other features of the object
Key Lifecycle States and Transitions

1. Pre-Active
2. Active
3. Compromised
4. Deactivated
5. Destroyed
6. Destroyed Compromised
7. Pre-Active
8. Active
9. Compromised
10. Destroyed

Transition States:
- 1 → 2
- 2 → 4
- 4 → 6
- 6 → 8
- 8 → 10
- 3 → 1
- 5 → 3
- 7 → 1
- 10 → 3
Illustration of the Lifecycle Dates

Symmetric key:

Asymmetric key pair:

Private key for decryption
Public key for digital signature

Public key for encryption
Private key for digital signature

Process Start Date = Activation Date
Protect Stop Date = Deactivation Date
Illustrations of the Link Attribute

Derivation:

- Symmetric Key 1
- Symmetric Key 2
- Symmetric Key 3
- Secret Data
- Base Object

Re-key or re-certify:

- Object 1
- Object 2
- Object 3
- Replacement Object
- Replaced Object

Public/Private/Cert:

- Certificate 1
- Certificate 2
- Certificate 3
- Public Key
- Private Key
Client-to-server Operations

- Operation consists of a request from client followed by server response
- Multiple operations can be batched in a single request-response pair
  - ID Placeholder can be used to propagate the value of the object’s Unique Identifier among operations in the same batch
- Requests may contain Template-Attribute structures with the desired values of certain attributes
- Responses contain the attribute values that have been set differently than as requested by the client
26 client-to-server operations defined

- Generate objects
- Search and obtain objects
- Set/get attributes
- Use the objects
- Support of optional operations
- Support for asynchronous responses

Server-to-client operations:
- Create
- Create Key Pair
- Register
- Re-key
- Derive Key
- Certify
- Re-certify
- Locate
- Check
- Get
- Get Attributes
- Get Attribute List
- Add Attribute
- Modify Attribute
- Delete Attribute
- Obtain Lease
- Get Usage Allocation
- Activate
- Revoke
- Destroy
- Archive
- Recover
- Validate (optional)
- Query
- Cancel (optional)
- Poll (optional)
- Notify (optional)
- Put (optional)
Server-to-client Operations

- Unsolicited messages from the server to the client with the following operations:
  - Notify operation, used by server to inform client about attribute-value changes
  - Push operation, used by server to provide an object and attributes to client, indicating whether the new object is replacing an existing object or not
  - Batching can be used
  - Support is optional
Message Contents and Format

- Protocol messages consist of requests and responses, each with a header and one or more batch items with operation payloads and message extensions.

- **Header:**
  - Protocol version
  - Maximum response size (optional, in request)
  - Time Stamp (optional in request, required in response)
  - Authentication (optional)
  - Asynchronous Indicator (optional, in request, no support for asynchronous response is default)
  - Asynchronous Correlation Value (optional, in response). Used later on for asynchronous polling
  - Result Status: Success, Pending, Undone, Failure (required, in response)
  - Result Reason (required in response if Failure, optional otherwise)
  - Result Message (optional, in response)
  - Batch Order Option (optional, in request, in-order processing is default). Support at server is optional
  - Batch Error Continuation Option: Undo, Stop, Continue. Stop (optional, in request, Stop is default). Support at server is optional
  - Batch Count

- **Batch Item:**
  - Operation (enumeration)
  - Unique Message ID (required if more than one batch item in message)
  - Payload (the actual operation request or response)
  - Message Extension (optional, for vendor-specific extensions)
Message Encoding

- Example of TTLV encoding of the Application Specific ID Attribute
  - Attribute identified by its name “Application Specific ID”
  - Shows value at index 2

<table>
<thead>
<tr>
<th>Tag</th>
<th>Type</th>
<th>Length</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute</td>
<td>Structure</td>
<td>&lt;varies&gt;</td>
<td></td>
</tr>
<tr>
<td>Attribute Name</td>
<td>String</td>
<td>&lt;varies&gt;</td>
<td>“Application Specific ID”</td>
</tr>
<tr>
<td>Attribute Index</td>
<td>Integer</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Attribute Value</td>
<td>Structure</td>
<td>&lt;varies&gt;</td>
<td></td>
</tr>
<tr>
<td>App. Name</td>
<td>String</td>
<td>&lt;varies&gt;</td>
<td>“ssl”</td>
</tr>
<tr>
<td>App. ID</td>
<td>String</td>
<td>&lt;varies&gt;</td>
<td>“www.example.com”</td>
</tr>
</tbody>
</table>
In a TTLV-encoded message, Attributes are identified either by tag value or by their name (see previous slide), depending on the context:

- When the operation lists the attribute name among the objects part of the request/response (such as Unique Identifier), its tag is used in the encoded message.
- When the operation does not list the attribute name explicitly, but instead includes Template-Attribute (such as in the Create operation) or Attribute (such as in Add Attribute) objects as part of the request/response, its name is used in the encoded message.

```
operation 04 4 0000000A
Unique Identifier 06 24 1f165d65-cbbd-4bd6-9867-80e0b390acf9
```
Authentication

- Authentication is external to the protocol
- All servers should support at least
  - SSL/TLS
  - https
- Authentication message field contains the Credential Base Object
  - Client or server certificate in the case of SSL/TLS or https
KMIP
Use Cases

http://xml.coverpages.org/KMIP/KMIP-UseCases-v0.98-final.pdf
KMIP Use Cases

- Purpose: provide examples of message exchanges for common use cases

- Categories
  - basic functionality (create, get, register, delete of sym. keys and templates)
  - life-cycle support (key states)
  - auditing and reporting
  - key exchange
  - asymmetric keys
  - key roll-over
  - archival
  - vendor-specific message extensions

- Details of the message composition and TTLV encoding (encoded bytes included)
Storage Specific guidance

- Establishment of trust
  - Between the storage device and the key management server
- How and when are keys generated
  - Client, server
- How are keys associated with storage units
  - Implied or explicit and what requirements does that put on the storage device?
Establishment of Trust

- Digital certificates used for SSL/TLS session
  - Authentication for session establishment
- How are certificates distributed and installed?
  - During manufacturing
    - Certificate to use to verify device added key management server prior to ship
  - Client could generate and register with server
  - Server can generate and request
How and when are keys generated

3 possible scenarios

1. Client generates key when required – sends to the server for backup/recovery
2. Server generates the key when requested by the client
3. Server pre-generates groups of keys, when client requests a key it gets assigned a key from the group

Comparison of the approaches

1. Storage device may have special functions for key generation
2. Storage device can take advantage of special functions for key generation in the server
3. Reduces the need for backup and synchronization of keystores
How are keys associated with storage units

- 3 major approaches

1. Generate a key identifier or label which is stored with the storage unit – used to read previously used key – sent to server and a database lookup occurs

2. Have a method of identifying the storage unit and associating the key with the storage unit’s identifier

3. Storage an encrypted wrapped copy of the key with the storage unit – have to interact with authentication or the key management server to unwrap the key
Conclusion
KMIP: enabling enterprise key management through standard protocol
Q&A