Education

An Introduction to Key Management for Secure Storage

Walt Hubis, LSI Corporation

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Abstract

An Introduction to Key Management for Secure Storage

As secure storage becomes more pervasive throughout the enterprise, the focus quickly moves from implementing encrypting storage devices to establishing effective key management policies. Without the proper generation, distribution, storage, and recovery of key material, valuable data will be eventually compromised. Worse, without proper management of key information, data can be completely lost.

This session explores the fundamental issues and technologies that impact key management for disk, tape, array, and other storage devices. Major issues associated symmetric encryption keys are presented, along with practical advice on effective key management issues and practices.

The Key Management Problem

The Key Management Problem

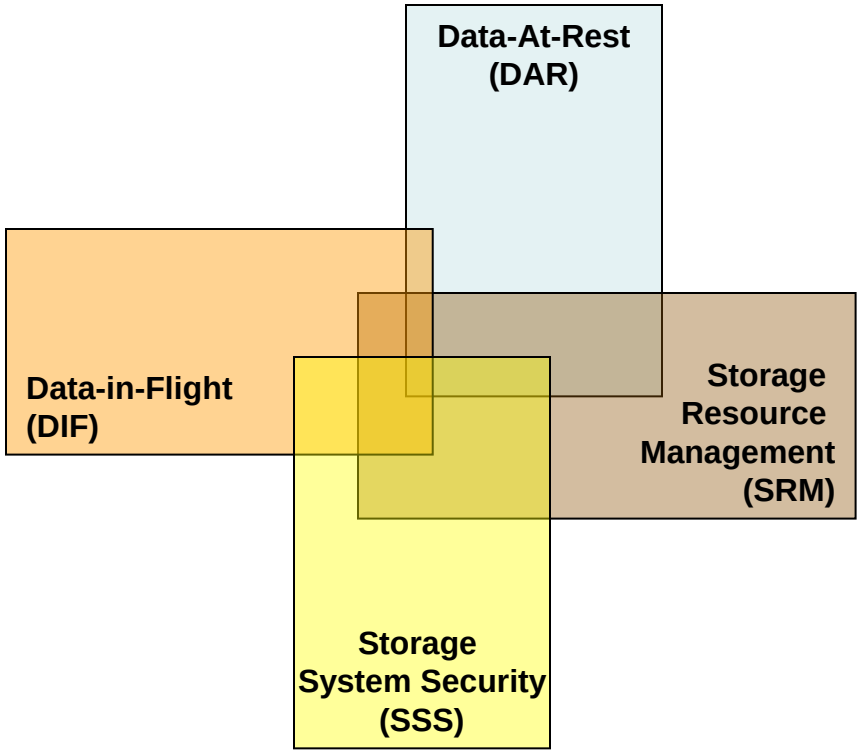
The Key Management Problem

Data At Rest

Data At Rest

- Random Access Devices
  - Disk Drives
- Sequential Access Devices
  - Tape Drives
- Other Media
  - Optical Media
- Data in Flight is Still Important!

Data At Rest



Source: Introduction to Storage Security, A SNIA Security Whitepaper, Oct 14, 2005

Storage Element	Description
Data-At-Rest (DAR)	"Protecting the confidentiality, integrity and/or availability of data residing on servers, storage arrays, NAS appliances and other media"
Storage Resource Management (SRM)	"Securely provisioning, monitoring, tuning, reallocation, and controlling the storage resources so that data may be stored and retrieved."
Storage System Security (SSS)	"Securing embedded operating systems and applications as well as integration with IT and security infrastructure (e.g., external authentication services, centralized logging and firewalls"
Data-in-Flight (DIF)	"Protecting the confidentiality, integrity and/or availability of data as they are transferred across the storage network, the LAN, and the WAN. Also applies to management traffic"

Key Management

Many Key Uses

- Private signature key
- Public signature verification key
- Symmetric authentication key
- Private authentication key
- Public authentication key
- Symmetric data encryption key
- Symmetric key wrapping key
- Symmetric and asymmetric random number generation keys
- Symmetric master key
- Private key transport key
- Public Key Transport Key
- Symmetric Key Agreement Key
- Private Static Key Agreement Key
- Public Static Key Agreement Key
- Private Ephemeral Key Agreement Key
- Public Ephemeral Key Agreement Key
- Symmetric Authorization Key
- Private Authorization Key
- Public Authorization Key

Source: NIST Special Publication 800-57: Recommendation for Key Management

Key Management

- Encryption Algorithms
  - AES
    - 128 Bit Key
    - 192 Bit Key
    - 256 Bit Key
  - DES
    - 56 Bit Key
  - 3DES
    - 168 Bit Key
- Encryption Algorithm Modes
  - Electronic Codebook Mode (ECB)
  - Cipher Block Chaining Mode (CBC)
  - Cipher Feedback Mode (CFB)
  - Output Feedback Mode (OFB)
  - Counter Mode (CTR)
  - Galois/Counter Mode (GCM)
  - LWR Encryption
  - XOR-Encrypt-XOR (XEX)
  - XEX-TCB-CTS (XTS)
  - CBC-Mask-CBC (CMC)
  - ECB-Mask-ECB (EME)

Key Management

- Key and Data Lifetime
  - Forever
    - Assure Access to Data Years from Now
  - For a Limited Time Period
    - Ephemeral – Milliseconds, Seconds
    - Weeks, Months, Years
- What Happens at End of Life?
  - Mandatory Re-Encryption
  - Destruction of Data
  - Destruction of Key

Key Management

- Policies
  - Who Can Establish Keys?
  - Who Can Delete Keys?
  - What is the Lifetime of a Key?
  - Can the Key be Archived?
  - Are the Keys Changed Periodically?
  - Are Keys Automatically Deleted or Archived?
  - Who Else Can Use the Key?

Key Management

- Auditing
  - Track the Key over it's Lifetime
  - Who Created the Key and When?
  - Who Changed the Key and When?
  - Who Created a Copy of the Key and When?
  - Where are the Copies of the Key
  - Who Deleted the Key and When?

Key Management

- Threats
  - Confidentiality
    - Key Disclosure
    - Data Accessible to Anyone
  - Integrity
    - Key has Been Modified
    - Data Accessible by None
  - Archive
    - Key has Been Lost
  - Availability
    - Key Cannot be Accessed

Key Management Goals

- Backup/Restore Key Material
- Archival and Retention of Key Material
- Distribution of Key Material
- Expiration, Deletion, and Destruction of Key Material
- Audit of Key's Life Cycle
- Reporting Events and Alerts

Keying Material

Keys

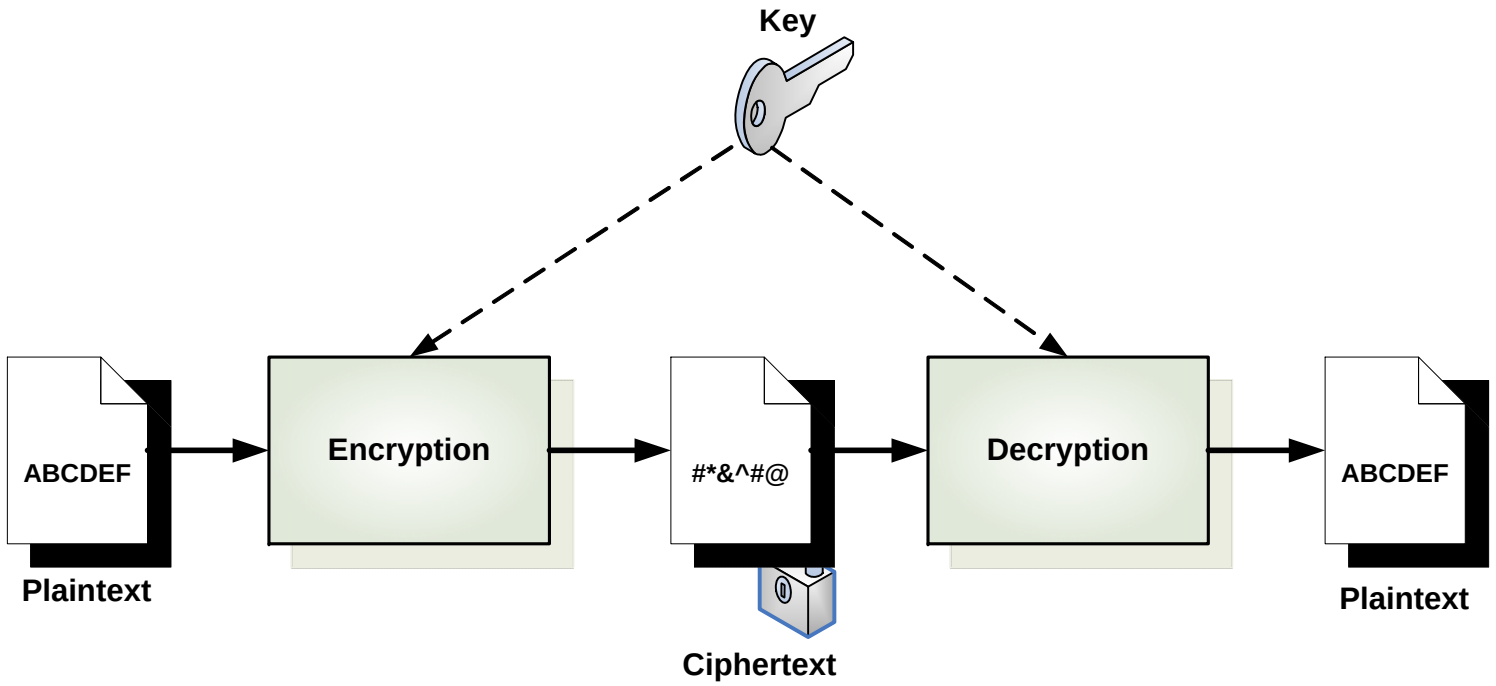
- Two Major Types of Encryption
  - Symmetric Keys
  - Asymmetric Keys
- Storage Systems May Use Both
  - Asymmetric Keys to Exchange Symmetric Keys
  - Symmetric Keys to Encrypt/Decrypt Data

Check out SNIA Tutorial:

ABC's of Data Encryption

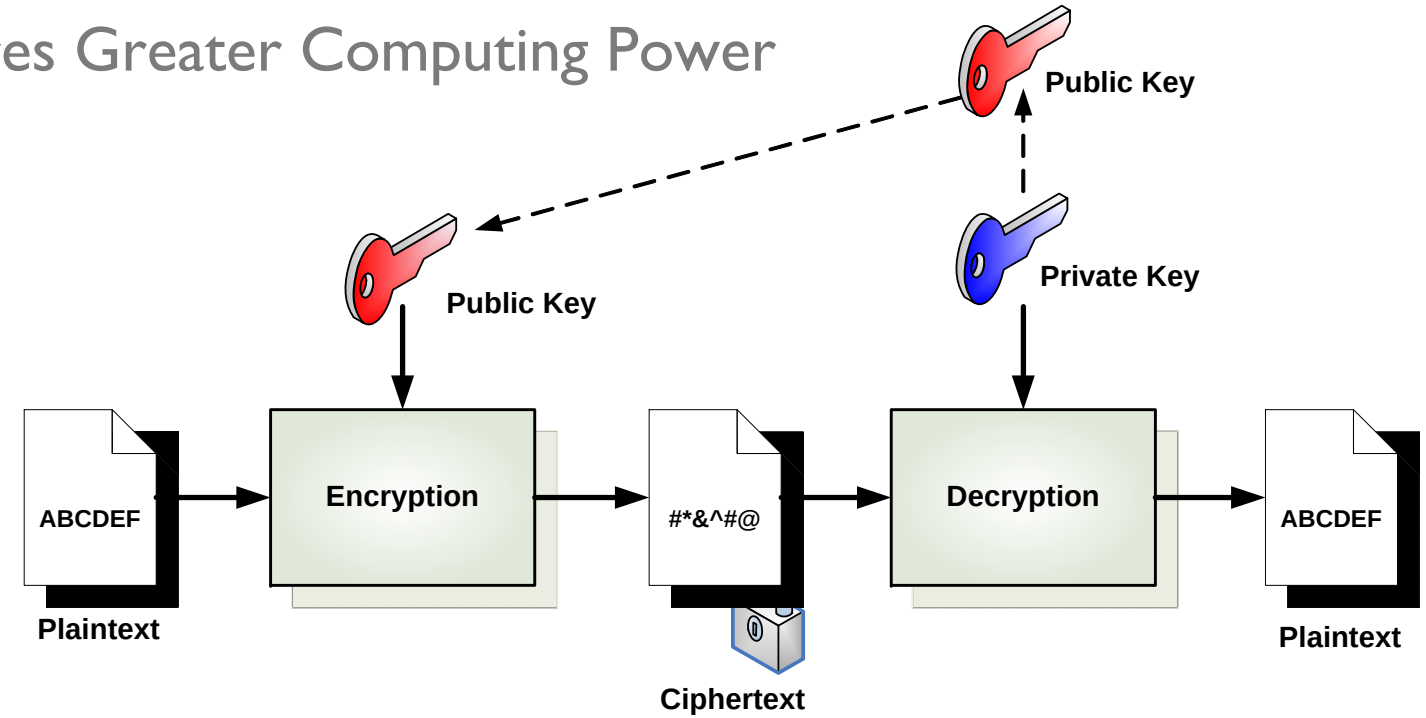
Symmetric Keys

- One Key
  - Used for Both Encryption and Decryption
- Requires Lower Computing Power

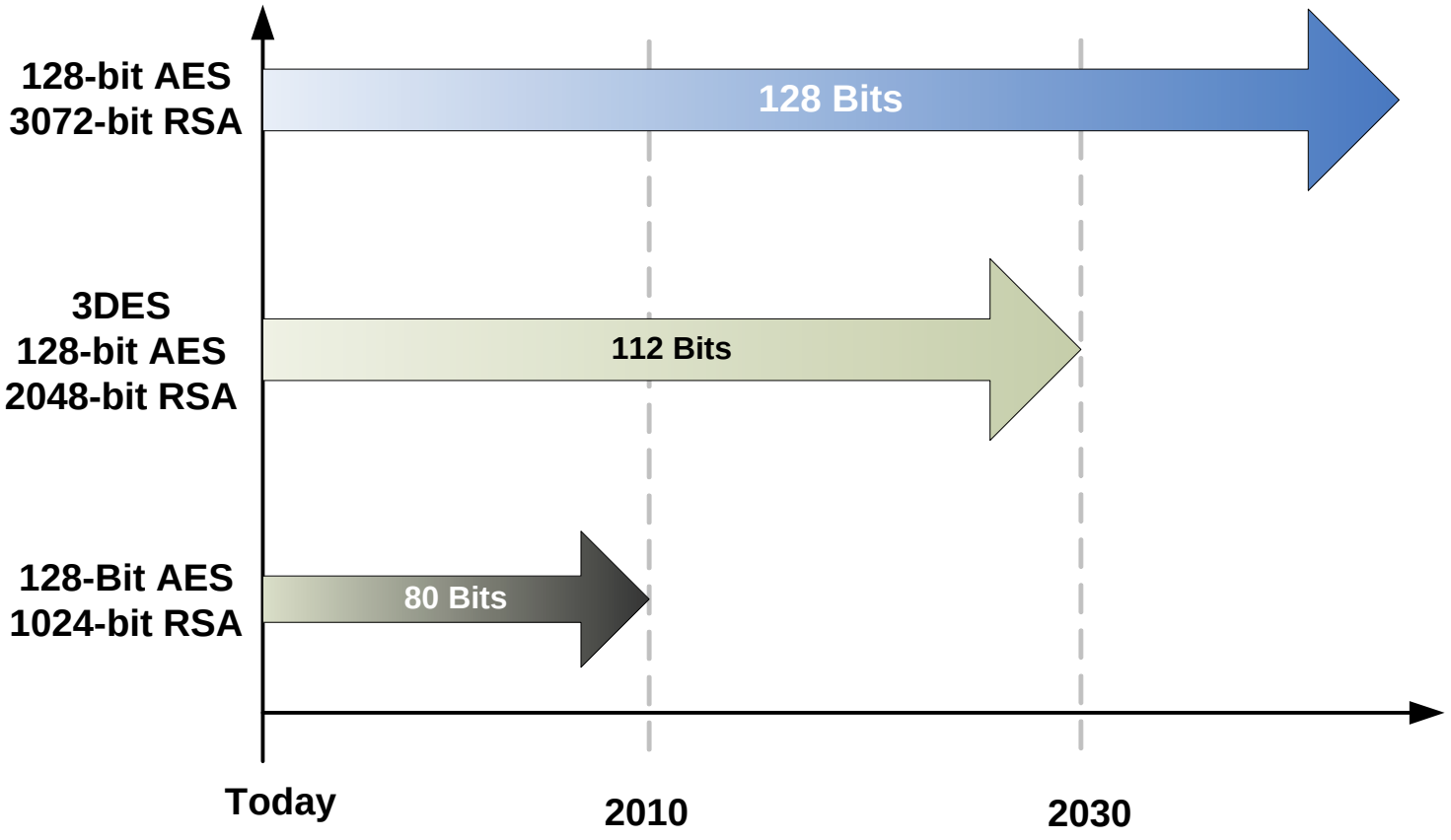


Asymmetric Key

- Uses Private and Public Key Pair
  - Can't be Derived from Each Other
  - Data Encrypted with One Can Only Be Decrypted With the Other
  - Requires Greater Computing Power



Encryption Strength

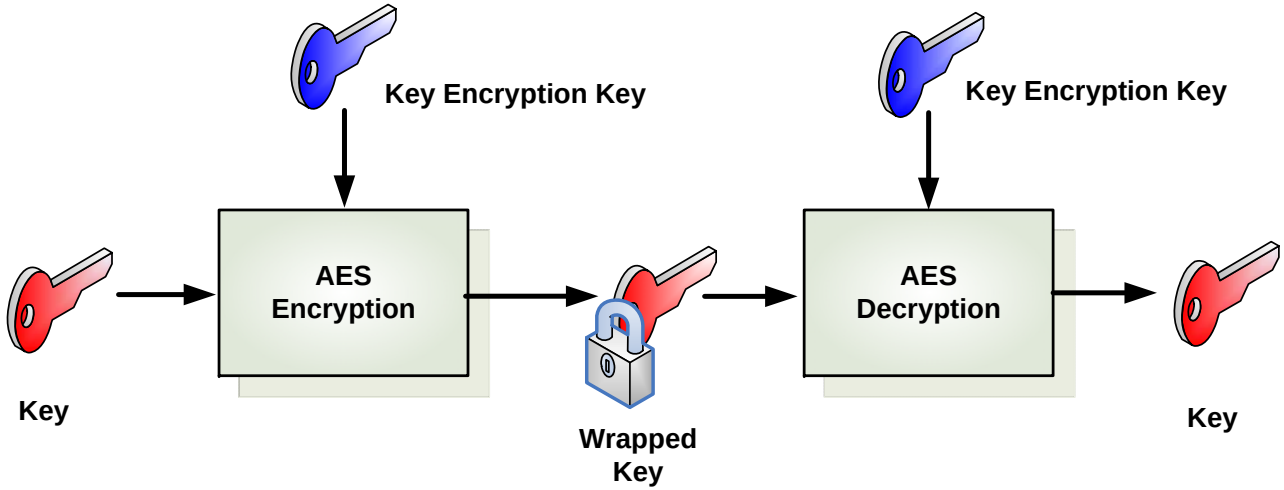


Key Formats

- Key Formats
  - Any and All Key Formats Must Be Managed
  - Keys are Viewed as Objects
- Key Material
  - Key Data
  - Key Information: Metadata
- Storage Generally Uses Symmetric Keys
  - A Secure Key Exchange Assumed
  - Easier to Implement
  - Less Client Resources

Key Wrapping

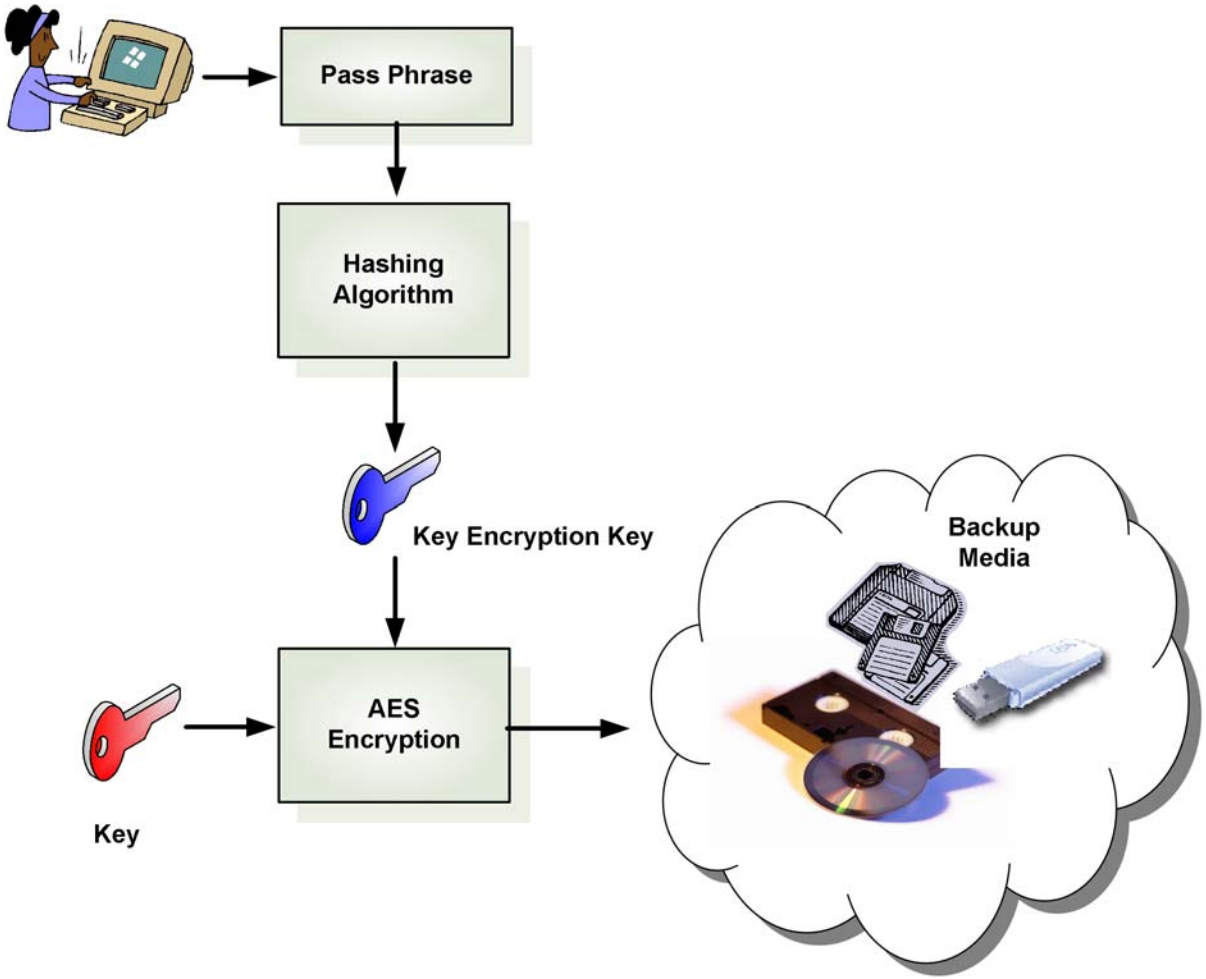
- Used to Move Keys
  - Backup
  - Archiving



Source: AES Key Wrap Specification (http://csrc.nist.gov/CryptoToolkit/kms/key-wrap.pdf)

Pass Phrase

- Used to Generate Key Encryption Key



Basic Key Metadata

- Value
  - The Actual Key
- Unique Identifier (GUID)
  - Unique Within a Domain (Name Space)
    - The Domain May be World Wide Unique
  - May be a Globally Unique Identifier
    - World Wide Unique Name
  - May be a Hierarchy
  - Important for Identifying Keys that are Moved
    - Across Domains
    - Across Companies
    - Across Countries

Optional Key Metadata

- Name
  - User readable name, not necessarily Unique
- Creator name
- Domain name
- Parent GUID
- Previous version GUID
- Version string

Optional Key Metadata

- Timestamps
  - Creation
  - Modified
  - Valid Time
  - Expiration Time
- Policies
  - Use of key
  - Key type
- Access rights - who can:
  - Access
  - Modify
  - Disable
  - Destroy
- Vendor-Specific Metadata

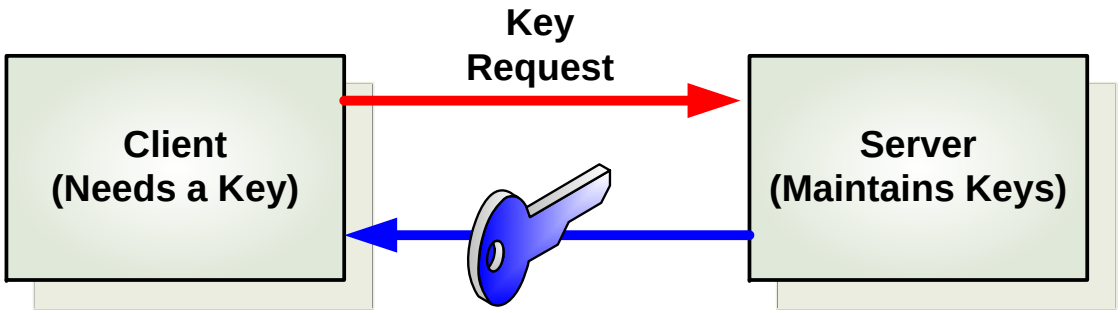
Key Management Components

Key Management Components

- Client-Server View
- The Key
- The Key Server
- The Key Transport Channel
  - Secure Channel
  - Authentication
- Key Exchange Protocol

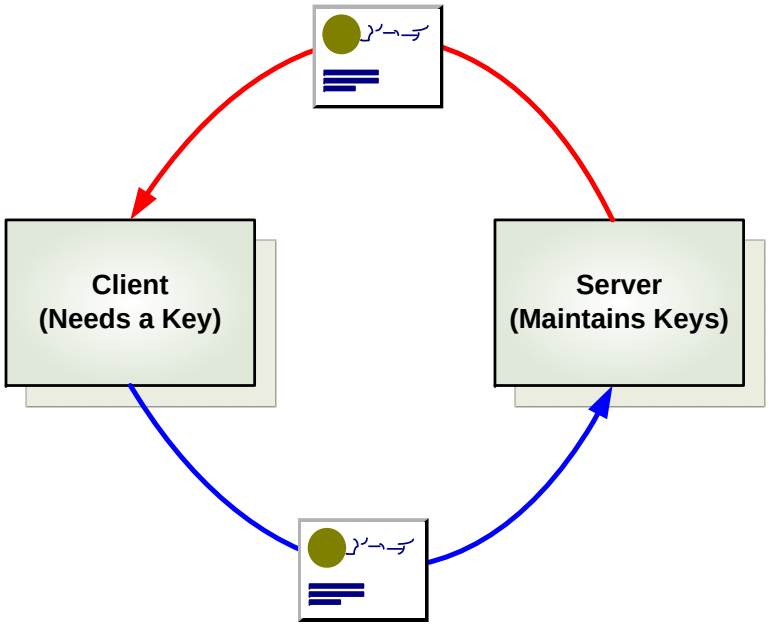
Client-Server View

- Client
  - User or Consumer of Keys
- Server
  - Provider of Keys



Client-Server Authentication

- Client and Server Must Authenticate
  - Assures Identity
  - Secrets or Certificates
  - Pre-Shared Keys or PKI
- Communications are Secure
  - Channel Encryption



Key Clients - Lightweight

- Limited Resources
  - Limited Computational Requirements
  - Limited Memory Requirements
- Communication
  - Network Based: Out of Band
  - Host Based: In Band
- Applications
  - Disk Drives
  - Tape Drives, Libraries
  - Array Controllers
- Simple Protocol
  - Fixed Fields and Values
  - Similar to SCSI CDBs

Key Clients - Complex

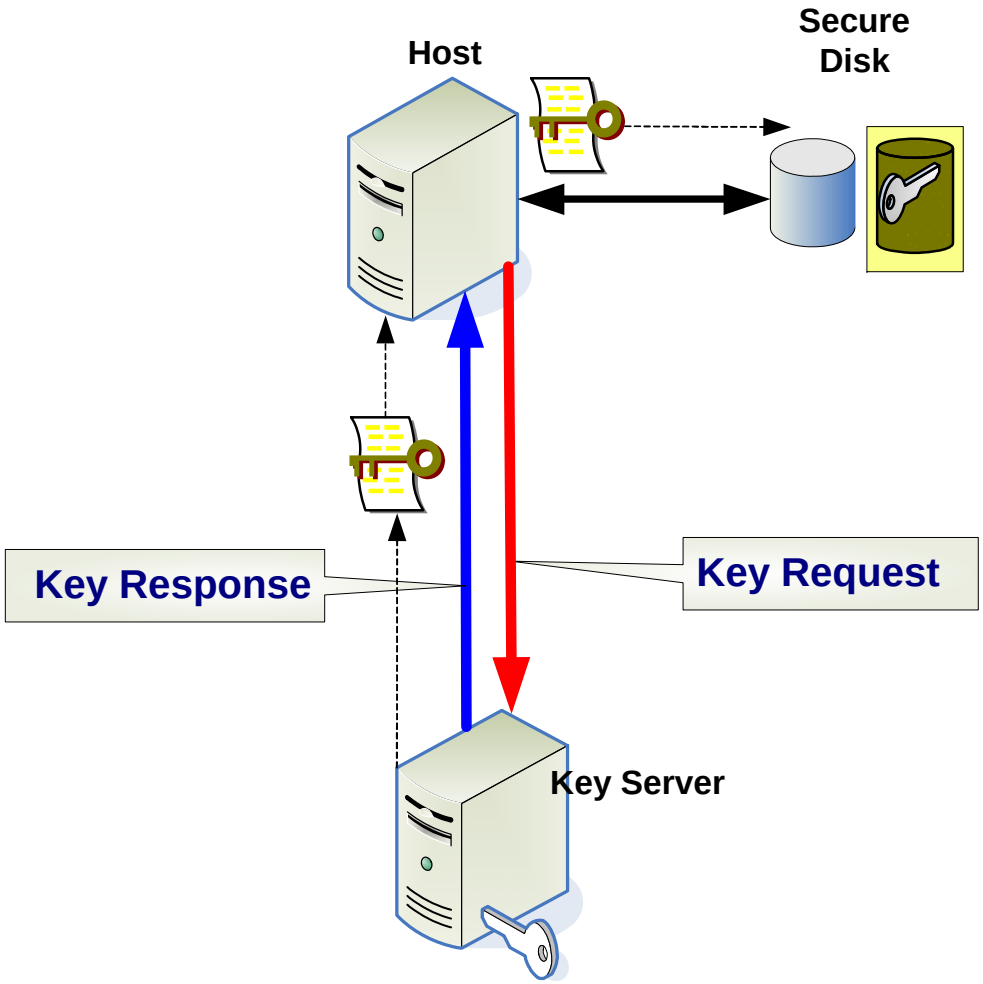
- Unlimited Resources
- Applications
  - Key Servers
  - Data Bases
  - Objects
  - File Servers
- May Use a Complex Protocol
  - Requires Complex Protocol Parser

Key Server

- Key Server
  - Software Application
    - Generic Hardware Platform
  - Dedicated Hardware Servers
    - Hardened
- Multiple Key Servers
  - Key Management Between Servers
- Policy Management
  - Accounting
  - Validation
- Backup

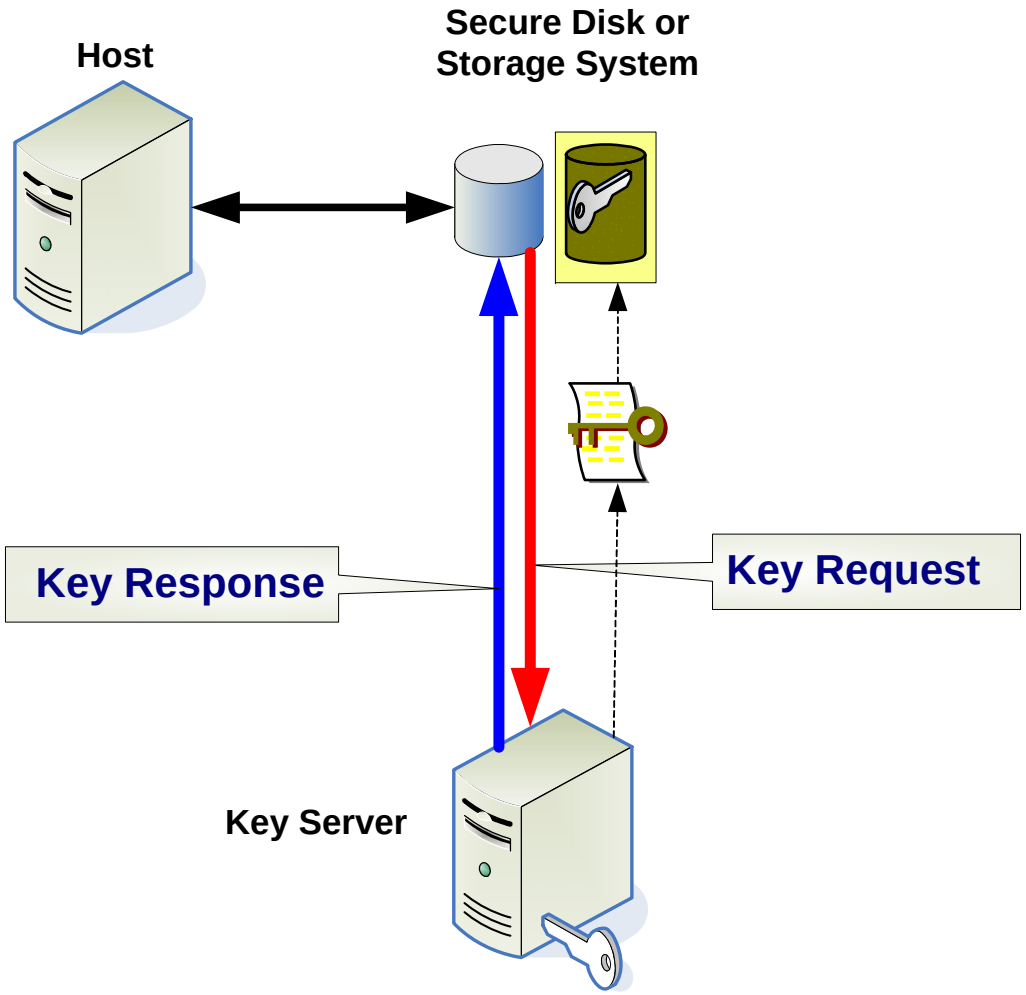
Key Clients and Servers - Disk

- Typical KM Scenario
  - Client: Host PC
  - Passes Key to Drive



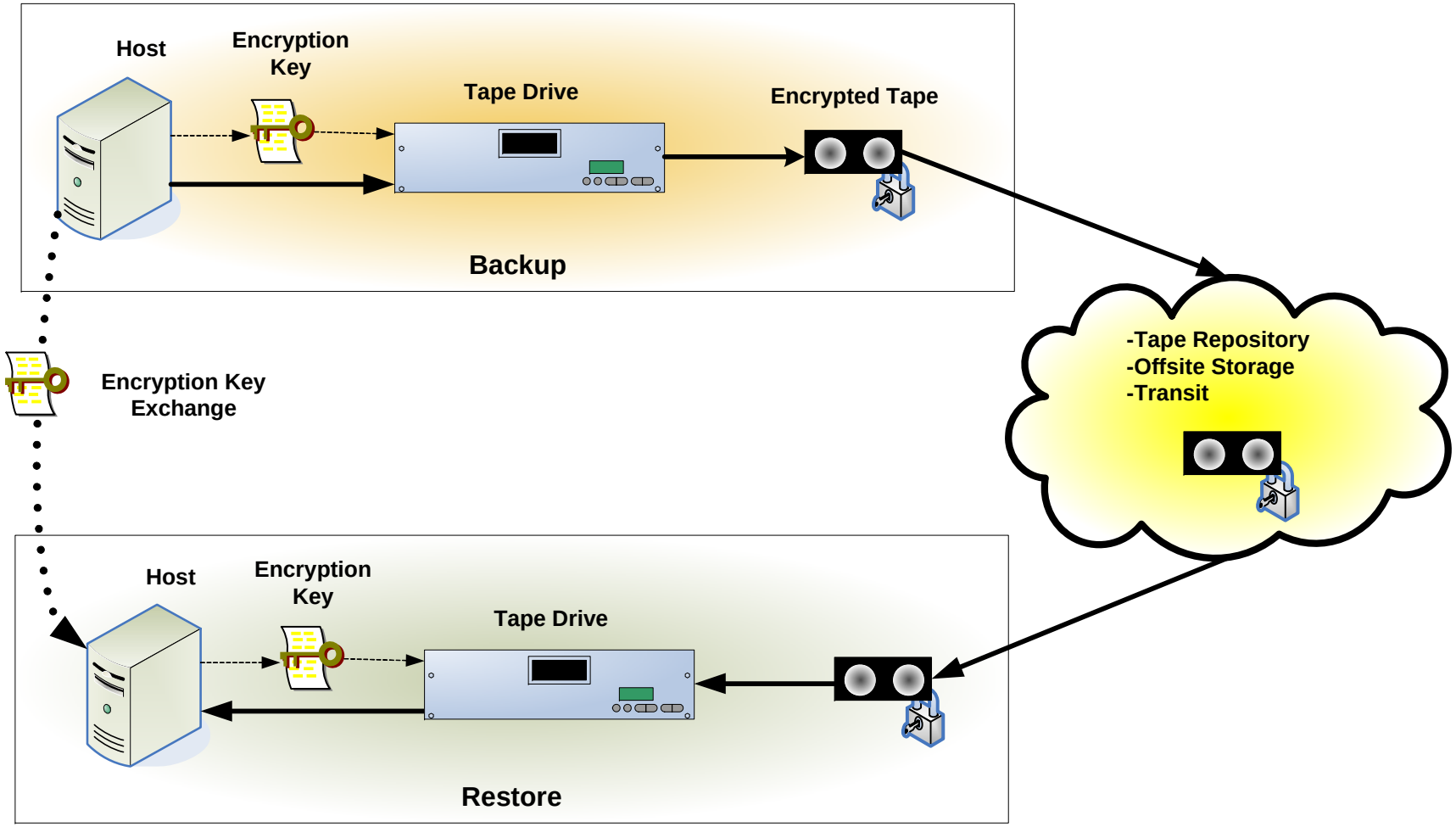
Key Clients and Servers - Disk

- Client is the Drive
  - Drive or Subsystem
  - Requests Key Directly from Server



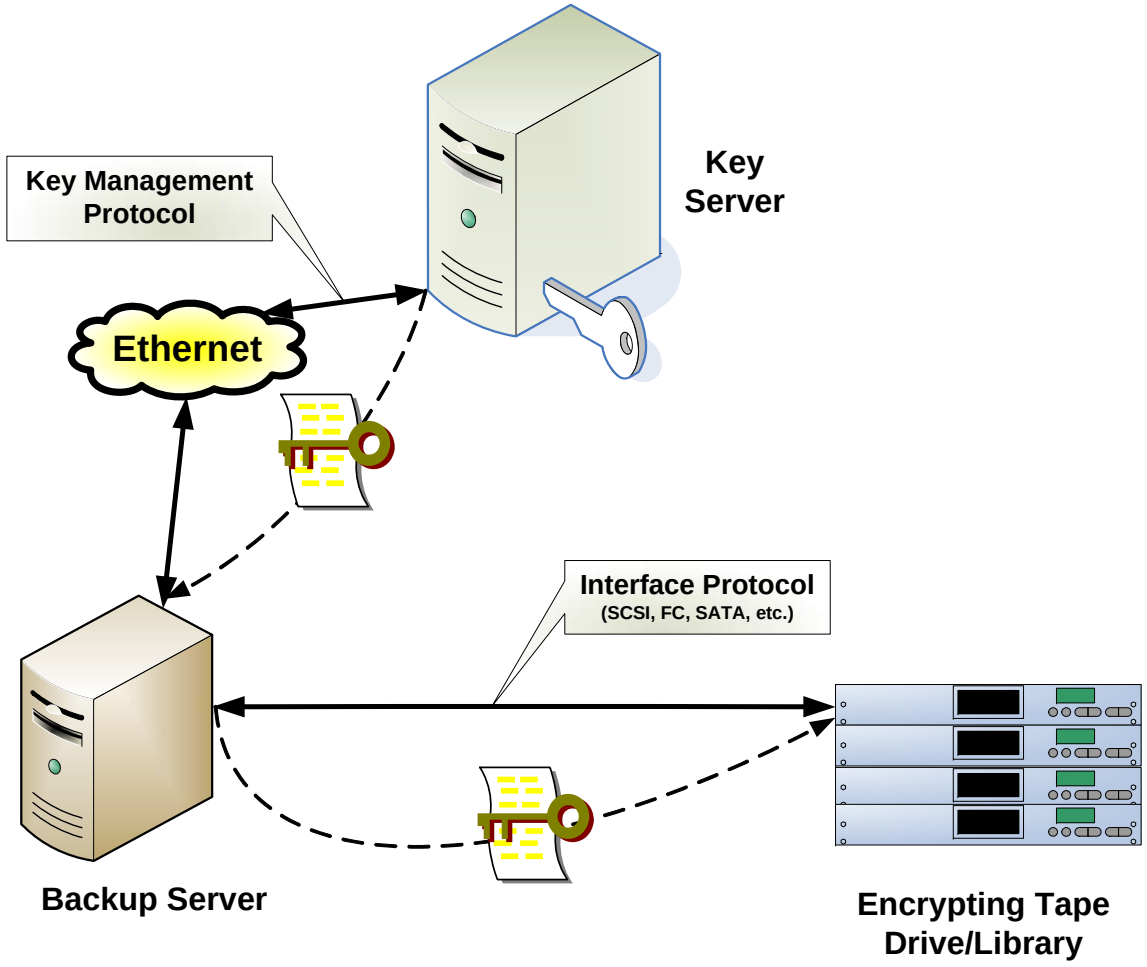
Key Clients and Servers - Tape

Manual Key Management



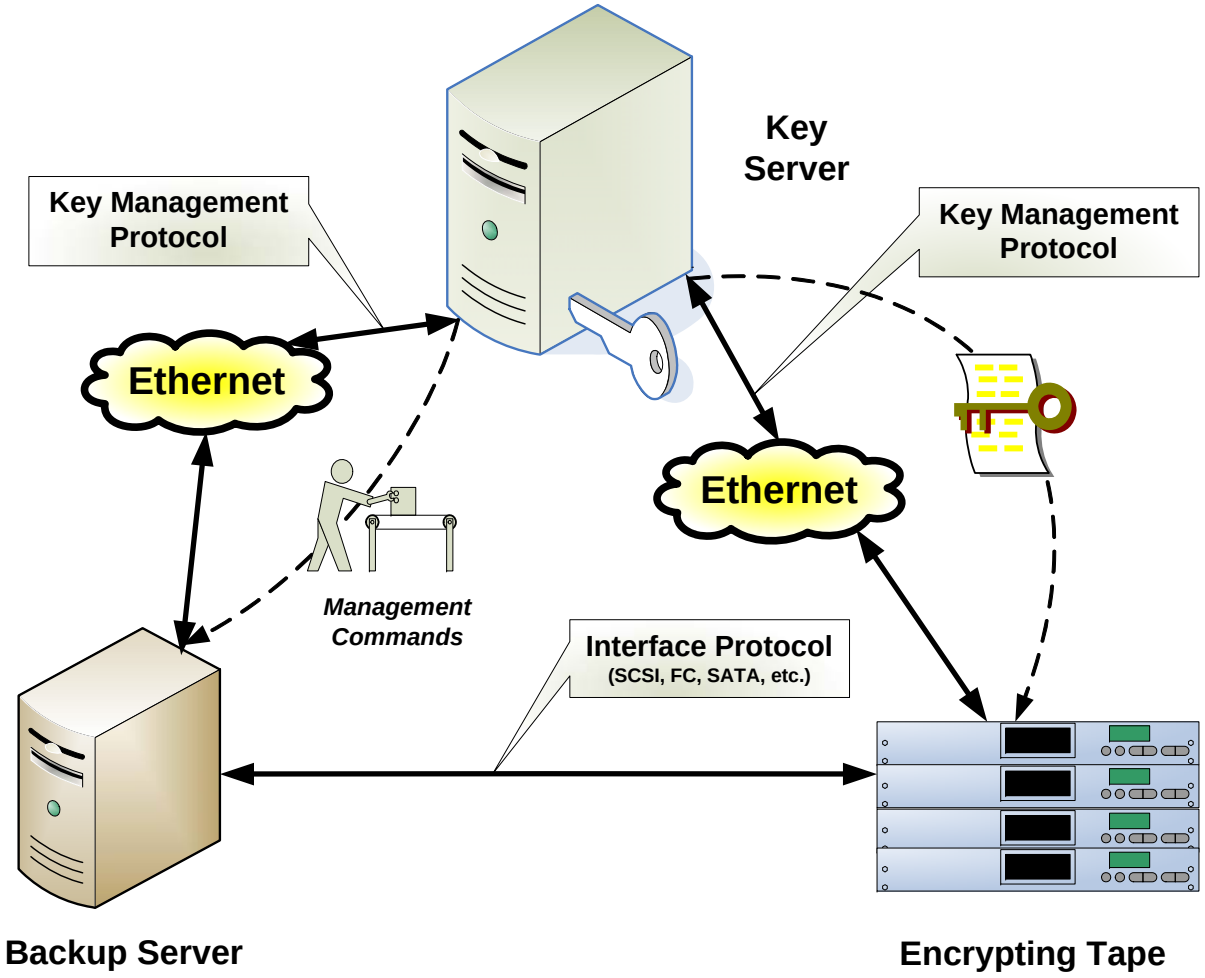
Key Clients and Servers - Tape

- Automated Key Management

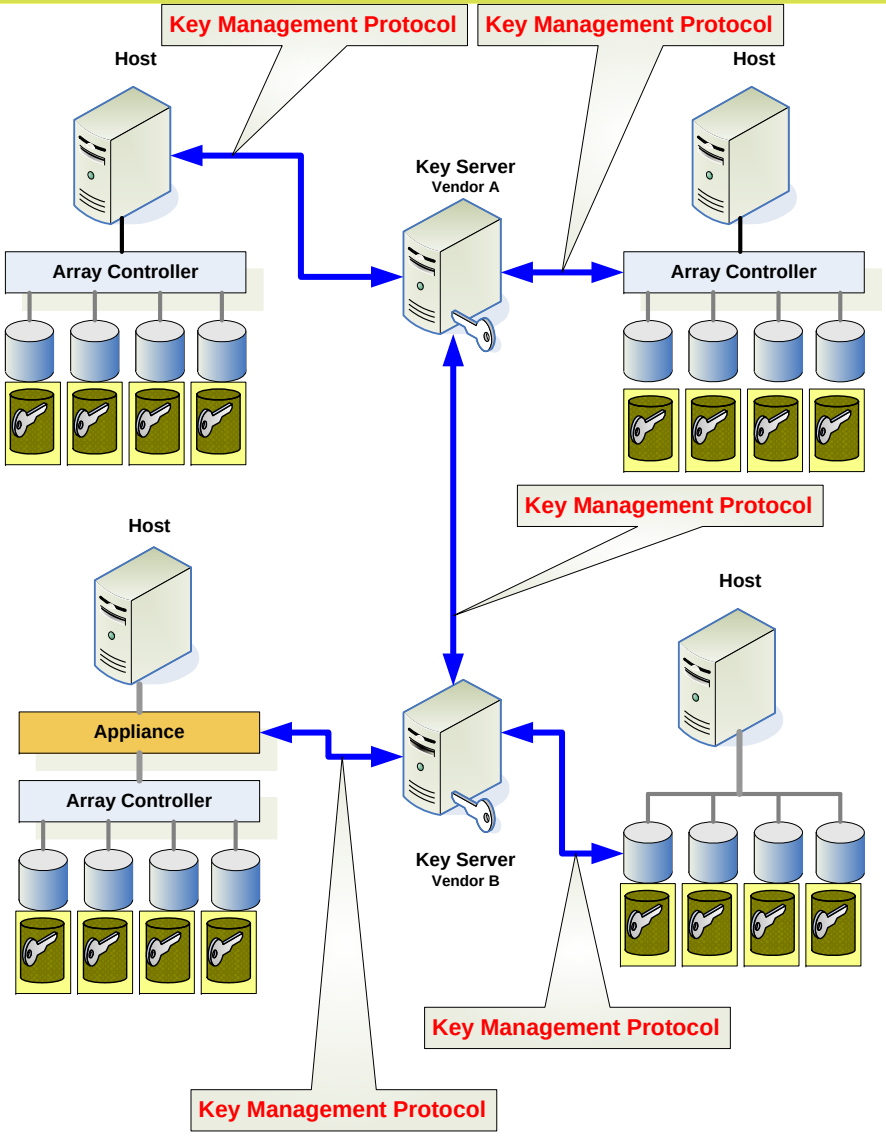


Key Clients and Servers - Tape

- Automated Key Management



Key Clients and Servers - Enterprise



KMS Protocol

- Two Primary Operations
  - Set key
    - Server ⇨Client
  - Get key
    - Client ⇦Server
- Optional Operations
  - Find key
  - Update key
  - Replicate key
  - Disable key
  - Destroy key
  - Access rights
  - Get service info
  - Audit log functions

Key Management Best Practices

Important Key Properties

- **Use a Cryptographic Key for Only One Purpose**
  - Do Not use Key-Encrypting Keys or Wrapping Keys to Encrypt Data
  - Do Not use Data-Encrypting Keys to encrypt other keys
- **Use Randomly Chosen Keys from the Entire Key Space**
  - Use Computer-Generated Keys Whenever Possible
  - Enforce a Broad Range of Entries in the Key Space
- **Avoid Weak Keys**
  - "00000000" or "FFFFFFF" or even "DEADBEEF"
  - Dictionary Attacks (e,g., "password")
- **Avoid Plain Text Keys**
  - Always Encrypt Keys for Transfer
  - Prevent Observation of Plaintext Keys

Key Management Safety

- **Automate Key Management Whenever Possible**
  - Authentication
  - Key Generation
- **Observe and Enforce Cryptoperiod**
  - Also, Limit Keys to Maximum Amount of Data
- **Limit Keys with Long Lifetime**
  - Archived Keys Only
- **Separate Key Functions**
  - Don't Mix Key Encryption and Data Encryption Keys

Key Management Safety

- **Document Objectives**
  - Authorization Objectives
  - Protection Objectives
  - Key Management Services Objectives
  - Key Material Destruction
- **Enforce Strict Access Controls**
  - Limit User Capabilities
  - Segregate Duties
    - Audit
    - User
    - Management

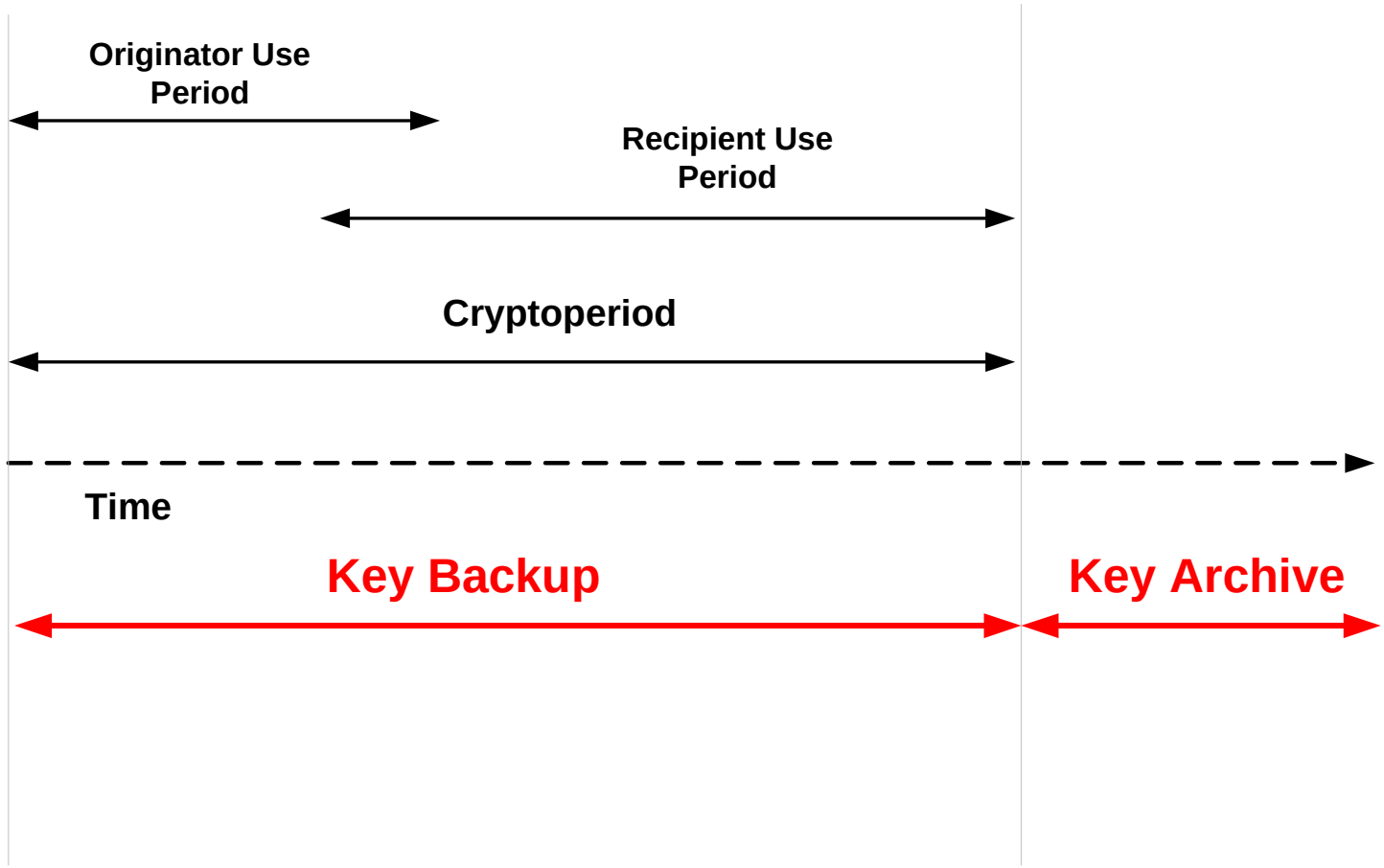
Establish Keys Securely

- **Symmetric Keys**
  - Use an Approved Random Number Generator
  - Use an Approved Key Update Procedure
  - Use an Approved Key Derivation Function from a Master Key
  - Don't Concatenate Split Keys to Generate Keys
- **Limit Distribution of Data Encryption Keys**
  - No Gratuitous Distribution
  - Limit to Backups
  - Limit to Authorized Entities
- **Protect Keys**
  - Wrap Keys Before Distribution
  - Use Appropriate Physical Security

Operational Use

- **Secure Devices and Processes**
  - Insure that Installation does not Result in Key Leakage
  - Insure that Device or Process Meets Key Best Practices
- **Secure Key Storage**
  - Cryptographic Security (e.g., Wrapping)
  - Physical Security
- **Integrity**
  - Employ Methods to Detect Modifications
  - Ability to Restore Key Material when Unauthorized Modifications Occur
- **Backup and Archive**
  - Backup Keys During the Key's Cryptoperiod
  - Archive Keys after the Cryptoperiod has Expired – *As Needed*.

Key Backup and Archive



Operational Use

Change Keys

- When a Compromise is Detected
- When the Key's Cryptoperiod Nears Expiration
- When the Key's Data Limit Approaches

Destroy Keys

- Remove Keys from Backups when Not Needed for Operational Use
- Destroy Keys When No Longer needed for Backup or Archive

Other Issues

- **Import and Export Controls**
  - Understand and Obey Government Import and Export Regulations
- **Plan for Problems**
  - Have a Recovery Plan in Place for a Key Compromise Event
- **Plan for Disaster**
  - Have a Recovery Plan in Place for Catastrophic Events
  - Consider an Escrow Plan to Protect Mission Critical Information
  - *Archives May Need to Last for a Very Long Time*

Archive Security

Active Archive

- Contains *Some* Data Subject to Retention Policies
- Retention Policies Driven by Governmental Compliance Requirements

Long Term Archive

- Data Life Exceeds the Life Span of Formats and Storage Mechanisms
- Preserve Data Long Periods of Time
- Wills, Land Records, Medical Data, Criminal Case Files, etc.

Active Archive Security

- **Active Archive Security**
  - Ensure Read-Only Enforcement is Adequate
  - Ensure Data Privacy
    - Access Controls
    - Encryption
  - Provide Appropriate Index and Search Capabilities
  - Prepare for a Disaster
  - Enforce Role and Access Policies
- **Governance and Compliance**
  - Data Retention Requirements
  - Data Disposition Requirements
  - Preserve Evidentiary Nature of the Data
    - Rigorous Authenticity Checks
    - Chain of Custody (Audits)

Long-Term Archive

- **Policies**
  - Establish Type of Data to be Accepted
  - Determine Preservation Period
  - Define Archived Data Object Maintenance Policy
  - Establish Authorization Policy
  - Specify the Preservation Activities
  - Define a Cryptographic Maintenance Policy
- **Security**
  - Access Control Mechanisms Must be Appropriate to the Lifespan
  - Perform Periodic Data Conversions and Revalidations
  - Address Long-Term Non-Repudiation of Digitally Signed Data

For More Information

- NIST Special Publication 800-57: Recommendation for Key Management (http://csrc.nist.gov/publications/nistpubs/800-57/sp800-57-Part1-revised2_Mar08-2007.pdf)
- ISO/IEC 11770 Parts 1-3: Information technology - Security techniques - Key management
- FIPS 140-2: SECURITY REQUIREMENTS MODULES (http://csrc.nist.gov/publications/fips/fips140-2/fips1402.pdf)
- Trusted Computing Group (https://www.trustedcomputinggroup.org/home)
- IEEE P1619.3: Security in Storage Workgroup (SISWG) Key Management Subcommittee (http://siswg.net/)
- OASIS Enterprise Key Management Infrastructure (EKMI) Technical Committee (http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=ekmi)
- IETF: Provisioning of Symmetric Keys (KEYPROV) (http://www.ietf.org/html.charters/keyprov-charter.html)

Q&A / Feedback

- Please send any questions or comments on this presentation to SNIA: tracksecurity@snia.org

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SNIA Education Committee

Larry Hofer CISSP
Eric Hibbard CISSP
Mark Nossokoff
Blair Semple
SNIA SSIF
SNIA Security TWG