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Abstract

SELF-ENCRYPTING STORAGE

Data security is top of mind for most businesses trying to respond to the constant barrage of news highlighting data theft and security breaches. Combined with litigation risks, compliance issues and pending legislation, companies face a myriad of technology and products that all claim to protect data-at-rest on storage devices.

The disk drive industry has standardized and is now deploying innovative, simple and powerful technology intended to secure data where it lives – in storage. This tutorial will give storage users and managers a look at emerging drive-level self-encryption technology (both HDD and SSD) from notebook PCs to the data center that provide a more secure storage foundation and compare that technology with alternate storage encryption methods, including: host-based, appliance, network fabric, and controller-based.
IT Security Today

• Corporations spend millions to protect their networks, devices & data…
  • Physical security, firewalls, intrusion detection, etc…

• …But don’t always understand the risk posed by internal misplacement, re-purposing, and disposal processes.
Since 2005, over 345,124,400 records containing sensitive personal information have been involved in security breaches.

In 2008, the average cost of a data breach was $6.65 million per affected corporation ($202 per record).

$6.65 Million Per Incident

Reported Data Breaches Since February 2005 to Now

Source: Privacy Rights Clearinghouse

http://www.privacyrights.org/ar/ChronDataBreaches.htm
Since 2005, over 345,124,400 records containing sensitive personal information have been involved in security breaches.

In 2008, the average cost of a data breach was $6.65 million per affected corporation ($202 per record).

Legal
Financial
Reputation

http://www.privacyrights.org/ar/ChronDataBreaches.htm
Who is demanding a solution...?

6 new bills on security breach, privacy, theft

(Requires FIPS-140 Compliance)

44+ states have passed breach notification laws w/ encryption safe harbors

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

June 23, 2006

M-06-16

MEMORANDUM FOR THE HEADS OF DEPARTMENTS AND AGENCIES

FROM: Clay Johnson III
Deputy Director for Management

SUBJECT: Protection of Sensitive Agency Information
Why Encrypt Data-At-Rest?

- **Compliance**
  - 44+ states have data privacy laws with encryption safe harbors
  - New data breach bills have explicit encryption safe harbors

- Data center and laptop drives are mobile (HDD, SSD)

- Exposure of data loss is expensive ($6.65 Million on average per incident\(^1\))

- Obsolete, Failed, Stolen, Misplaced…
  - Nearly ALL drives leave the security of the data center
  - The vast majority of decommissioned drives are still readable

*Threat scenario: stored data leaves the owner’s control – lost, stolen, re-purposed, repaired, end-of-life, …*

\(^1\) Ponemon Institute, Fourth Annual US Cost of Data Breach Study – Jan 2009  [www.ponemon.org](http://www.ponemon.org)
Encryption can be done in a number of places...

- Host middleware
- Host HBA (h/w adapter)
- Application
- Switch
- “Bump in the wire” appliance
- Array controller
- Drive (HDD, SSD)
Encryption can be done in a number of places...

- Host middleware
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- Application
- Switch
- “Bump in the wire” appliance
- Array controller
- Drive (HDD, SSD)
Encryption upstream can affect other processes

Data Compression
Data Deduplication
Data Loss Prevention (DLP)
3 Simple reasons

- **Storage for secrets with strong access control**
  - Inaccessible using traditional storage access
  - Arbitrarily large memory space
  - Gated by access control

- **Unobservable cryptographic processing**
  - Processing unit “welded” to storage unit
  - “Closed”, controlled environment

- **Custom logic: faster, more secure operations**
  - Inexpensive implementation of cryptographic functions
  - Complex security operations are feasible
Self-Encrypting Drives

- Simplified Management
- Robust Security
- Compliance “Safe Harbor”
- Cuts Disposal Costs

- Scalable
- Interoperable
- Integrated
- Transparent

“Many organizations are considering drive-level security for its simplicity in helping secure sensitive data through the hardware lifecycle from initial setup, to upgrade transitions and disposal”

Eric Ouellet
Research Vice President
Gartner
Self-Encrypting Drives Solve…

Purpose

• Protect data from exposure due to equipment loss
• Enable instant, secure erase of HDD/SSD *(delete on-board key)*

Closed encryption device

• Dedicated engine for full interface speed encryption
• Key generated by true RNG in drive
• Encryption cannot be turned off
• Encryption Key never leaves the drive
• Drive exposes an open interface for management of encryption & credentials
• Only signed firmware can be loaded onto drive

2 Architectures

• Client (laptops, desktops) 3rd party software manages encryption
• Enterprise (arrays) Storage System manages encryption
Trusted Platform with Trusted Storage
- Multi-factor authentication: password, biometrics, dongles
- Secure/hardware storage of credentials, confidential financial/medical data
- Trusted life cycle management of personal information
- Integrity-checking of application software
- Cryptographic functions directly in storage
- Trusted/secure computation of high-value functions (protection from viruses/etc)

Home Banking
(or Remote Medical, or … )
Breadth of Applications

Trusted Platform with Trusted Storage

- Multi-factor authentication: password, biometrics, dongles
- Secure/hardware storage of credentials, confidential financial/medical data
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- Cryptographic functions directly in storage
- Trusted/secure computation of high-value functions (protection from viruses/etc)
Trusted Storage Standardization

TRUSTED COMPUTING GROUP™

Published Storage Specifications
Joint Work – T10 (SCSI) and T13 (ATA)

TRUSTED SEND/IN
(Protocol ID = xxxx  …..)

TRUSTED RECEIVE/OUT

T10/T13 defined the “container commands”
TCG/Storage defining the “TCG payload”

Protocol IDs assigned to TCG, T10/T13, or reserved
Implementation Overview

TRUSTED STORAGE

- (Partitioned) Hidden Memory
- Security firmware/hardware
- Trusted Send/Receive Commands
- Assign Hidden Memory to Applications

TCG/T10/T13

ATA or SCSI

Firmware/hardware enhancements for security and cryptography Firmware

Hidden Storage

Security Providers

Controller Storage

ISV Application (on the Host)

Assign Hidden Memory to Applications

SED CHIP

Self-Encrypting Storage
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Trusted Storage with Trusted Platform

Life Cycle: Manufacture, Own, Enroll, PowerUp, Connect, Use, …
Trusted Storage with Trusted Platform

Life Cycle: Manufacture, Own, Enroll, PowerUp, Connect, Use, …
Enterprise Management of Self-Encrypting Drives

- **Enterprise Server:**
  - Key generation and distribution
  - Key/Password archive, backup and recovery

- **Laptop (Application):**
  - Master/User passwords, multi-factor authentication, TPM support
  - Secure log-in, “Rapid Erase”

- **Self-Encrypting Drive:**
  - Disk or sector encryption, sensitive credential store, drive locking
Client Security: Pre-Boot Authentication

- Transparency: Master boot record and OS are unmodified
- Protected from malicious software: Authentication occurs before OS (and any malicious software) is loaded
- The master boot record can’t be corrupted: The entire drive, including the master boot record, is encrypted

1. BIOS attempts MBR read; drive redirects to pre-boot area
2. Drive loads pre-boot OS
3. User enters authentication credentials for drive to verify
4. If authentication successful, drive loads original MBR
5. Normal operation commences
Self-Encrypting Drive Basics

The drive LOCKS automatically when powered OFF

The drive remains LOCKED when it is powered back ON

Authentication Key (Password) **Unlocks** the drive

Write and Read data normally while drive is unlocked

Authentication Key source

un-encrypted text

Write

Read

100% performance encryption engine in the drive

Data protected from loss, disclosure
Authentication in the Drive

1. Correct AK?
2. Clear AK decrypts DEK
3. DEK encrypts and decrypts User Data

Storage Server

Hash AK

Hashed AK

Encrypted DEK

Encrypted User Data

Correct AK?

No

Yes

Unlock HDD

Chip

Clear Data

Disc

AK
Authentication Key
DEK
Data Encryption Key

Hashed AK

Data responds to No Read or Write Request

Self-Encrypting Storage
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Cryptographic Erase

**Description**
- Cryptographic erase changes the drive encryption key
- Data encrypted with previous key, unintelligible when **DEcrypted** with new key

**Benefits**
- Instantaneous “rapid” erase for secure disposal or re-purposing
Client SED Deployment

Drive Manufacturer

- Encryption key created
- Encryption turned on
- User password Not Initialized

Drive Sold

System Manufacturer

- Optional cryptographic erase (generate new encryption key)
- Optionally integrate management software

System sold

SED Managers

End User

- User powers on, enters PWD
- User changes PWD
- Uses system normally
- User returns system to IT for erase

IT department

- Change master password(s)
- Optional crypto erase before re-image
- Set a default User password
- Save new passwords

Customer

- Generate new encryption key to erase drive

Self-Encrypting Storage
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### ‘Hurdles’ to Implementing Encryption...

| Key management / data loss | • Tracking and managing encryption keys  
|                          | • Tracking and managing authentication keys (passwords for unlocking drives) |
| Complexity               | • Data classification  
|                          | • Impact on OS, applications, databases  
|                          | • Interoperability |
| Performance              | • Performance degradation; scalability |
| Cost                     | • Initial acquisition costs  
|                          | • Deployment costs |
No Performance Degradation

Scales Linearly, Automatically

The encryption engine is in the controller ASIC

Encryption engine speed
Matches
Port’s max speed

All data will be encrypted, with no performance degradation
IT Retires Drives Constantly

- All Drives are Eventually Retired
  - End of Life
  - Returned for Expired Lease
  - Returned for Repair / Warranty
  - Repurposed

- 50,000 drives leave data centers daily

- Exposure of data is expensive - $6.65 million on average

- 90% of retired drives are still readable
  (IBM study\(^1\))

Needed: A simple, efficient, secure way to make retired drive data unreadable

How the Drive Retirement Process Works

People make mistakes

“Because of the volume of information we handle and the fact people are involved, we have occasionally made mistakes.”

which lost a tape with 150,000 Social Security numbers stored at an Iron Mountain warehouse, October 2007¹

Retirement Options

- Overwriting takes days and there is no notification of completion from drive
- Hard to ensure degauss strength matched drive type
- Shredding is environmentally hazardous
- Not always as secure as shredding, but more fun

99% of Shuttle Columbia’s hard drive data recovered from crash site

Data recovery specialists at Kroll Ontrack Inc. retrieved 99% of the information stored on the charred Seagate hard drive’s platters over a two day period.

- May 7, 2008 (Computerworld)

How the Drive Retirement Process Works

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- May 7, 2008 (Computerworld)

Drive Retirement is:

Expensive

Time-consuming

Error-prone

People make mistakes which lost a tape with 150,000 Social Security numbers stored at an Iron Mountain warehouse, October 2007

Drive Retirement: Self-Encrypting Drives

Self-Encrypting Drives

- Retire Drive
  - Replace
  - Repair
  - Repurpose
- Remove ALL drives
- Send even "dead" drives through secure area
- Queue in secure area
- Transport Offsite
- Queue in secure area

Power Off = Locked and Encrypted = Secure

- Reduces IT operating expense
  - Eliminates the need to overwrite or destroy drive
  - Secures warranty and expired lease returns
  - Enables drives to be repurposed securely
- Provides safe harbor for most data privacy laws
Encryption key never leaves the drive. No need to track or manage ... BUT, YOU STILL MANAGE THE AUTHENTICATION KEYS (drive locking), to protect against loss or theft (for just crypto erase, no authentication key needed)

- To recover data from a drive:
  - Only need the Authentication Key and the drive
  - Don’t need to escrow the encryption key to maintain data recoverability
  - Don’t need to track encryption key storage separate from data storage
  - Don’t need to be concerned with interoperability of encryption key storage and data
Reducing Complexity for IT

Encrypting outside the drive:
- Application Developers: May need to change applications
- OS: May change if encrypting in a driver
- Encryption engine: May need separate hardware
- Network: Heavyweight encryption can impact performance
- Key Manager: Installed on existing server
- Storage System: Data compression & de-duplication affected

Encrypting inside the drive:
- Key Manager: Installed on existing server
- Storage System: Upgrade per schedule
Storage System Operations

At Initialization:
- Bring in new volume
- Set up Authentication Key

Power-up:
- Authenticate with the key source
- Pass key to the disk drive

After Power-up:
The storage system virtualizes the drives and provides:
- Data protection through RAID and copy services
- Availability through redundancy, failover drivers, robust error handling
- Capacity sharing through partitioning and network connectivity
- Management reporting
- Data compression and deduplication best applied BEFORE encryption
Reducing Security Costs

- **Initial acquisition costs:**
  - Integrated into standard products
  - Implemented per regular storage upgrade schedule
  - Standards-based, and all drive vendors are participating in TCG
  - The drive industry has long demonstrated standards promote competition which drives cost
  - Economies of scale enable incremental logic in the ASICs to remain a small portion of drive material costs

- **Reduce drive decommissioning and insurance costs**
- **Maintain ability to compress and deduplicate data**
- **Preserve drive hardware value**
  - Service, warranty, expired lease returns enabled
  - Drive repurposing enabled
Hardware-Based Self-Encryption versus Software Encryption

- **Transparency**: SEDs come from factory with encryption key already generated

- **Ease of management**: No encrypting key to manage

- **Life-cycle costs**: The cost of an SED is pro-rated into the initial drive cost; software has continuing life cycle costs

- **Disposal or re-purposing cost**: With an SED, erase on-board encryption key

- **Re-encryption**: With SED, there is no need to ever re-encrypt the data

- **Performance**: No degradation in SED performance

- **Standardization**: Whole drive industry is building to the TCG/SED Specs

- **No interference** with upstream processes

**ISSUE**: Hardware acquisition (part of normal replacement cycle)
### Addressing the Hurdles…

| Simplifies key management to prevent data loss | ✓ Encryption key does not leave the drive; it does not need to be escrowed, tracked, or managed |
| Simplifies Planning and Management | ✓ Standards-based for optimal manageability and interoperability  
|  | ✓ Transparent to application developers and database administrators. No change to OS, applications, databases  
|  | ✓ Data classification not needed to maintain performance |
| Solves Performance | ✓ No performance degradation  
|  | ✓ Automatically scales linearly  
|  | ✓ Can change keys without re-encrypting data |
| Reduces Cost | ✓ Standards enables competition and drive cost down  
|  | ✓ Compression and de-duplication maintained  
|  | ✓ Simplifies decommissioning and preserves hardware value for returns, repurposing |
The Future: Self-Encrypting Drives

- **Encryption everywhere!**
  - Data center/branch office to the USB drive

- **Standards-based**
  - Multiple vendors; interoperability

- **Unified key management**
  - Authentication key management handles all forms of storage

- **Simplified key management**
  - Encryption keys never leave the drive. No need to track or manage.

- **Transparent**
  - Transparent to OS, applications, application developers, databases, database administrators

- **Automatic performance scaling**
  - Granular data classification not needed
Thank You!
SNIA Security: Get Involved!

✦ SNIA Security Technical Work Group (TWG)
  - Focus: Requirements, architectures, interfaces, practices, technology, educational materials, and terminology for storage networking.
  - [http://www.snia.org/tech_activities/workgroups](http://www.snia.org/tech_activities/workgroups)

✦ Storage Security Industry Forum (SSIF)
  - Focus: Marketing collateral, educational materials, customer needs, whitepapers including the BCPs & Encryption of Data At-Rest (a Step-by-Step Checklist)
  - [http://www.snia.org/forums/ssif](http://www.snia.org/forums/ssif)
Q&A / Feedback

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

Many thanks to the following individuals for their contributions to this tutorial.
- SNIA Education Committee

Gianna DaGiau
Eric A. Hibbard, CISSP, CISA
SNIA SSIF
Jason Cox
Self-Encrypting Drive

- Laptop Loss or Theft
- Re-Purposing
- End of Life
- Rapid Erase

Drive Locking/Drive Pairing

On-board Crypto Key Management

ALL Encrypted

Crypto Chip

Personal Video Recorders

Forensic Logging

DRM Building Blocks
- **SPs** (Security Providers)
  - Logical Groupings of Features
  - SP = Tables + Methods + Access Controls

- **Tables**
  - Like “registers”, primitive storage and control

- **Methods**
  - Get, Set – Commands kept simple with many possible functions

- **Access Control** over Methods on Tables
SPs (Security Providers)
- Logical Groupings of Features
- SP = Tables + Methods + Access Controls

Tables
- Like “registers” for primitive storage and control

Methods
- Get, Set – Commands kept simple with many possible functions

Access Control over Methods on Tables