IDF15
INTEL DEVELOPER FORUM

The Future of Storage Security

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SSDS004

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experience
what's inside™

Agenda

- A Brief History of Storage Encryption and Options Available
- Inherent Benefits of Self Encrypting Drives (SED)
- Comparison:
  Self Encrypting Drives vs. Software Full Disk Encryption (SW FDE)
- Storage Interface Transition from SATA* to PCI Express®/NVM Express™ and Emergence of Opal
- Benefits of Opal Over Previous Storage Security Standards
- Opal/SED Enhancements Needed to Maintain Parity with Software FDE
- Proposed Solutions and Standardization Efforts
- Summary/Call to Action

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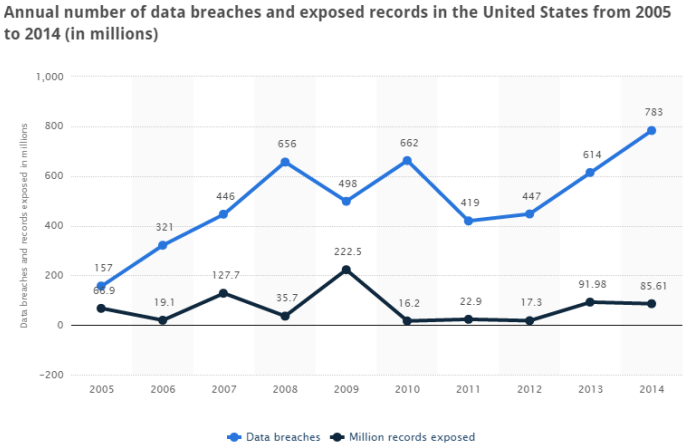
A Brief History of Storage Encryption

- (2002) First law enacted requiring protections on corporate data (SOX)
- (2003) First State law enacted (CA) requiring breach disclosure on unencrypted data (S.B. 1386)
- (2005) Tracking begins on significant data breaches
- (2007) Seagate* introduces first SED (DriveTrust*)
- (2008) Intel IT mandates encryption of all data stored on managed machines
- (2010) Intel releases Intel® Advanced Encryption Standard New Instructions instruction set
- (2011) Intel introduces its first SED SSD
  - (Intel® SSD 320 Series)



Global study at a glance

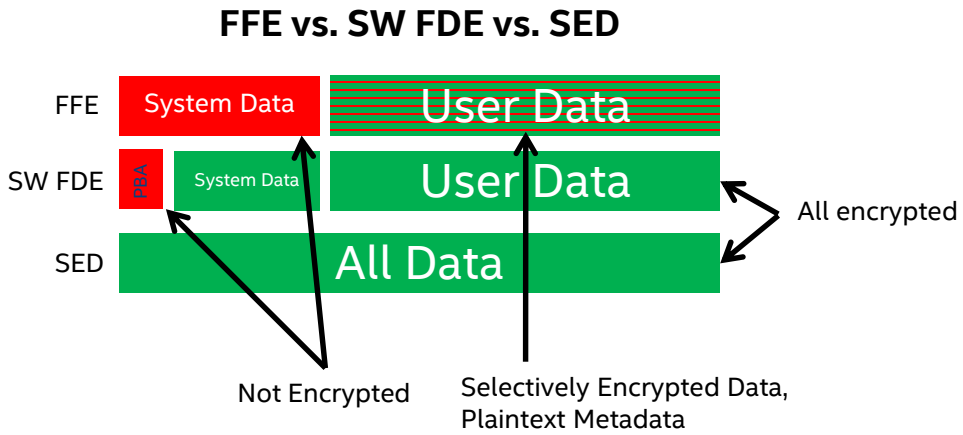
- 350 companies in 11 countries
- $3.79 million is the average total cost of data breach
- 23% increase in total cost of data breach since 2013
- $154 is the average cost per lost or stolen record
- 12% percent increase in per capita cost since 2013

Ponemon Institute May 2015: 2015 Cost of Data Breach Study: Global Analysis

Data Breach Cost and Frequency will continue to increase.
Storage Encryption provides a significant part of the solution!

Storage Encryption Solutions

- File and Folder Encryption (FFE)
  - Selective encryption of user files
  - Typically Enterprise Rights Management based
- Software based Full Disk Encryption (SW FDE)
  - Encryption applied by storage driver on most data
- Self Encrypting Drives (SED)
  - Encrypt all user data all the time



Only SED's Offer Complete User Data Encryption ALL the Time

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Inherent Properties of Self Encrypting Drives

- SEDs encrypt ALL user data ALL the time
- SEDs typically perform encryption that meets/exceeds interface bandwidth
- SEDs integrate encryption, media, and media management into a single device
- Intel® SSDs are designed to execute only signed firmware
- Storage Device Interfaces have a smaller software attack surface than Operating System Interfaces

SEDs Provide a Solid Foundation for Secure Storage

Resultant Benefits of Self Encrypting Drives

- SEDs provide higher assurance that ALL user data is encrypted
  - SW FDE is applied at the storage device driver level which has a larger attack surface than firmware inside a self encrypting drive
- SEDs provide higher assurance that data has been cryptographically erased
  - SW FDE AND File Level Encryption must perform I/O to the storage device to overwrite data for erasure. For SSDs, this issue is exacerbated due to wear leveling.
  - From NIST SP800-88 (Guidelines for Media Sanitization):

2.6 Use of Cryptography and Cryptographic Erase

Many storage manufacturers have released storage devices with integrated encryption and access control capabilities, also known as Self-Encrypting Drives (SEDs). SEDs feature always-on encryption that substantially reduces the likelihood that unencrypted data is inadvertently retained on the device. The end user cannot turn off the encryption capabilitieswhich ensures that all data in the designated areas are encrypted. A significant additional benefit of SEDs is the opportunity to tightly couple the controller and storage media so that the device can directly address the location where any cryptographic keys are stored, whereas solutions that depend only on the abstracted user access interface through software may not be able to directly address those areas.

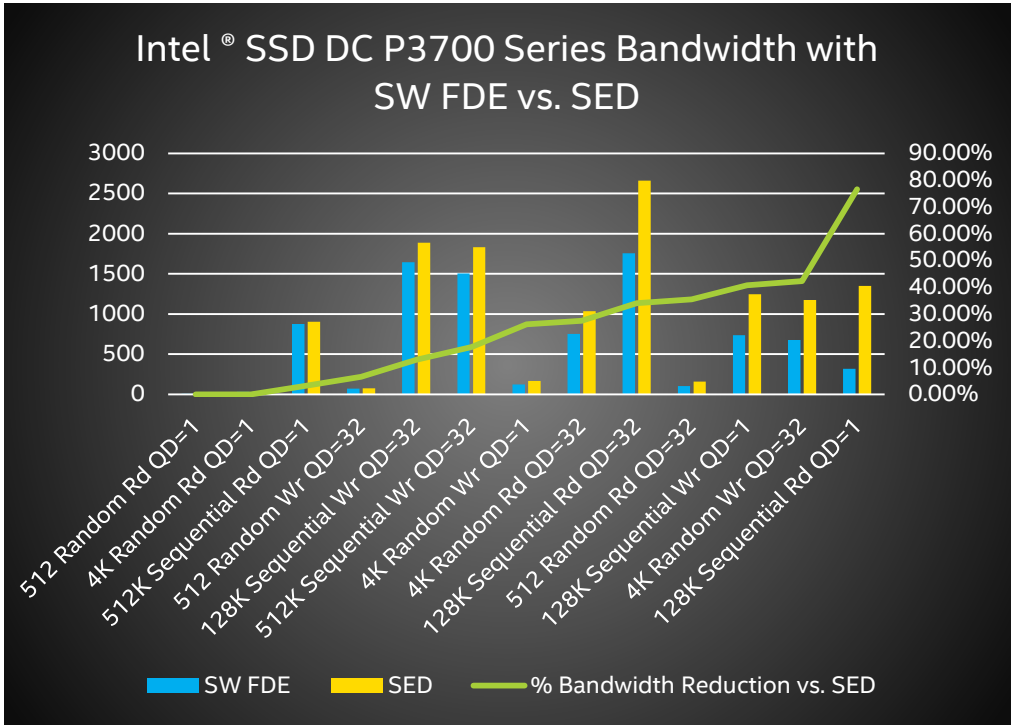
Resultant Benefits of Self Encrypting Drives

- SED key generation/management is less complicated/more secure
  - Currently, SW FDE exposes media encryption keys to other SW/DRAM
- SEDs provide near instant provisioning/setup time
  - SW FDE must perform read/encrypt/write to all user data during initial setup
    - Consumes hours, increases wear
- FIPS certification
  - SEDs are able to achieve higher levels of FIPS certification more easily than SW FDE

2089	**HGST, Inc.** 5601 Great Oaks Parkway	**HGST Ultrastar SSD800/1000/1600 TCG Enterprise SSDs**	Hardware	02/25/2014; 04/03/2014;	***Overall Level:* 2**
1601	**McAfee, Inc.** 27201 Puerta Real, Suite	**McAfee Endpoint Encryption for PCs** (Software Version: 5.2.6)	Software	09/08/2011; 10/04/2011	***Overall Level:* 1**

Resultant Benefits of Self Encrypting Drives

- Performance
  - Intel® Advanced Encryption Standard New Instructions (Intel® AES-NI) is a giant leap forward allowing near full bandwidth crypto for SW FDE
    - uArch performance optimizations continue
    - Software overhead remains, adding extra latency
  - SED AES performance provides low latency and bandwidth at interface speeds



With SW FDE, Consumers Don't Fully Realize the Performance Gains from their Awesome SSD!

Source: Intel. System Configuration: Asus Z97 PRO, Intel® Core™ i5-4670T CPU @2.3 GHz, DRAM 4GB, Intel DC P3700 800GB SSD, Microsoft Windows® 8.1 x64 with and without McAfee EEPC Endpoint Encryption
Results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

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Comparison: Self Encrypting Drives vs. Software Full Disk Encryption†

Category/Feature	Self Encrypting Drive	Software Full Disk Encryption
Run-time Performance	Best	Good
High Assurance that All User Data is Encrypted	Best	Good
High Assurance of Cryptographic Erase	Best	Good
Ease of Regulatory Compliance	Best	Good
Ease of Maintenance	Good	Best
Compatibility	Good	Best
Susceptibility to Attacks (Hot Swap/Password Sniffers)	More Susceptible	Less Susceptible

†Represents Intel's opinion regarding disk encryption features based on a review of publicly available data. For informational purposes only.

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Industry focus Needed to address Compatibility Issues and Add Enhancements to Security Model

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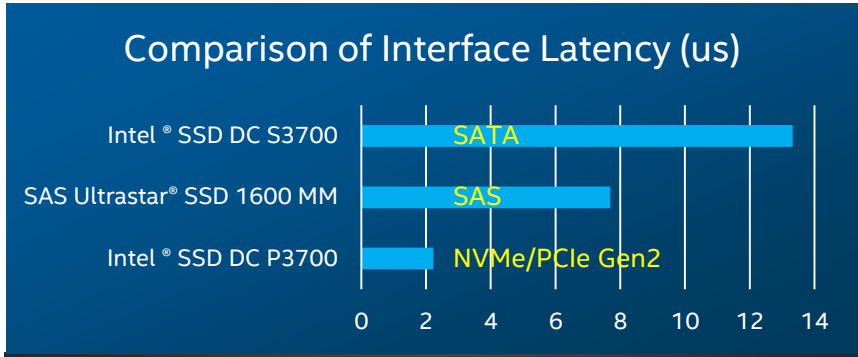
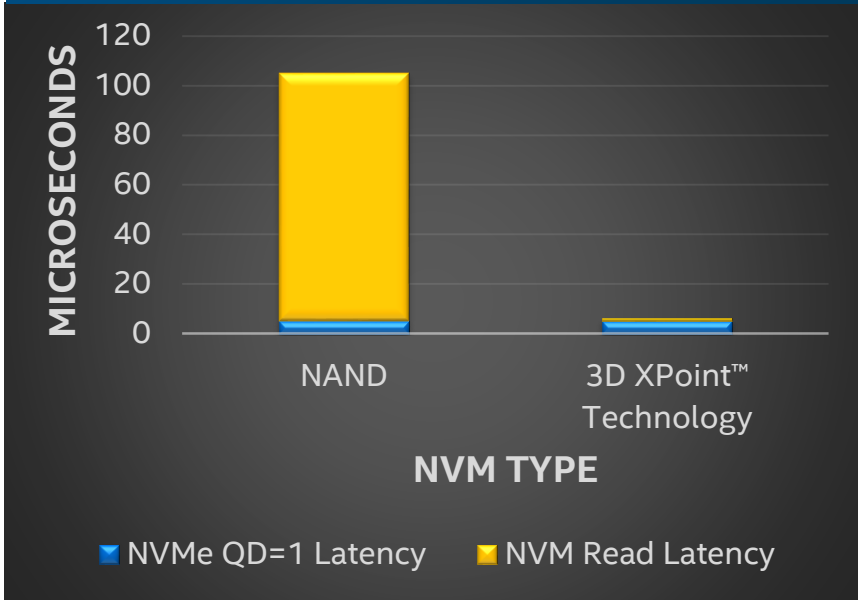
Storage Interface Transition

- Transition occurring from SAS/SATA* to PCIe®/NVMe™
  - Increased bandwidth and reduced latency
  - Multiple hardware and software optimizations merging
- 3D XPoint™ Technology further reduces latencies (>1000x lower latency than NAND)

Technology claims are based on comparisons of latency, density and write cycling metrics amongst memory technologies recorded on published specifications of in-market memory products against internal





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  - Increased bandwidth and reduced latency
  - Multiple hardware and software optimizations merging
- 3D XPoint™ Technology further reduces latencies (>1000x lower latency than NAND)
- Software Full Disk Encryption adds latency and reduces bandwidth

Why increase performance and reduce latency only to give it back with SW FDE?

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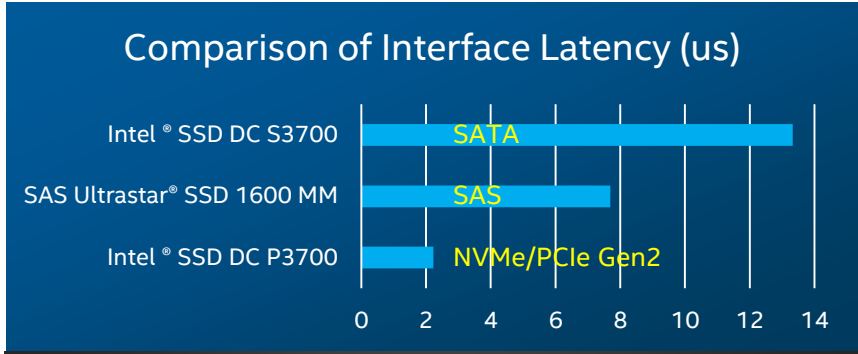
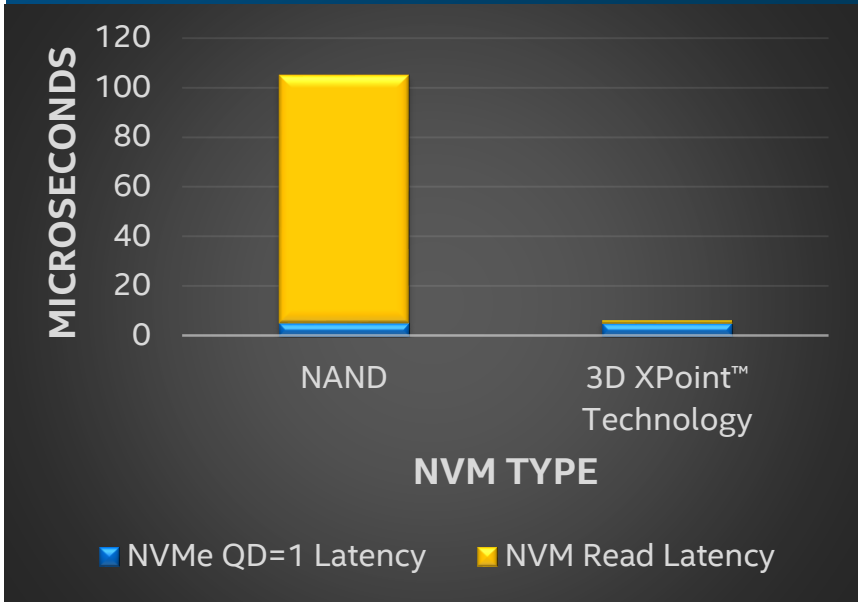
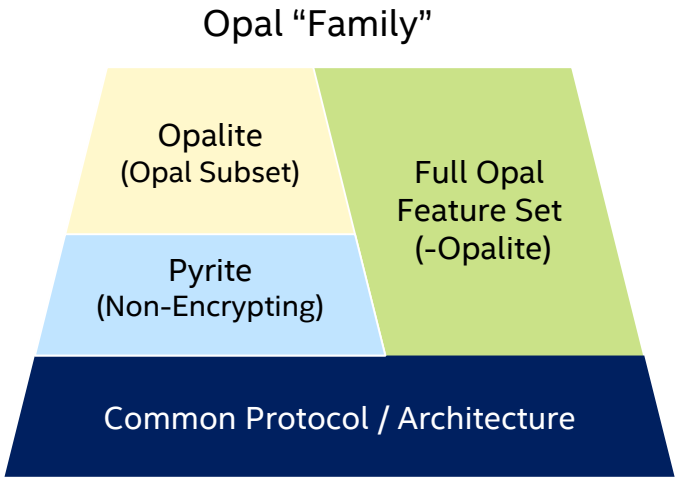




NVM Express™ and Opal

- NVMe™ is leveraging the security expertise of the Trusted Computing Group* (TCG)
- TCG has developed a “family” of specifications to scale across the needs of NVMe in different Client and Enterprise solutions
- SKL Reference BIOS slated to support simple password management via Opal over NVMe



Consumers, enterprise client users, and data centers are able to take advantage of encryption via Opal on NVMe using the same, standardized interface

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Benefits of TCG Opal over Previous Storage Security Standards

- TCG Opal is the only industry standard for storage security that scales to all storage interfaces and usage models
- TCG Opal is actively being developed by an architecture community with focus and knowledge in storage security

Capability	ATA Security	Opal
Guaranteed industry grade AES cipher for data-at-rest protection	✗	✓
Remote management	✗	✓
Interface agnostic	✗	✓
Extensibility to other security usage models	✗	✓
Specified support for Crypto Erase	✗	✓
“Purge” level erase	✗	✓

TCG Opal is the Storage Security Management Interface of the Future

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Opal/SED Enhancements Needed to Maintain Parity with Software FDE: Security

- Classic conflict between User Experience (UX) and Security exists with SEDs
- Unfortunately, platforms containing SEDs are vulnerable when the SED is unlocked and the user is not present
  - I.e. Stolen laptop in S3 state
- This is due to End User Experience (UX) Expectations:
  - Ease of data access (passwords - ugh!)
  - Fast responsiveness (S3 Resume)
- Which led to Tradeoffs: Auto-Unlock SED during…
  - S3 resume (open lid) & Connected Standby/Always on Always Connected
  - S4/S5 resume still requires user password

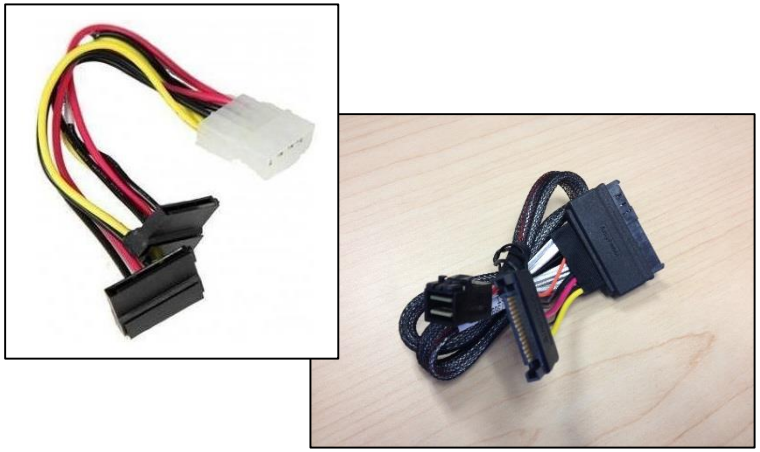
User Experience Favored over Platform Security

Attacks on Self Encrypting Drives

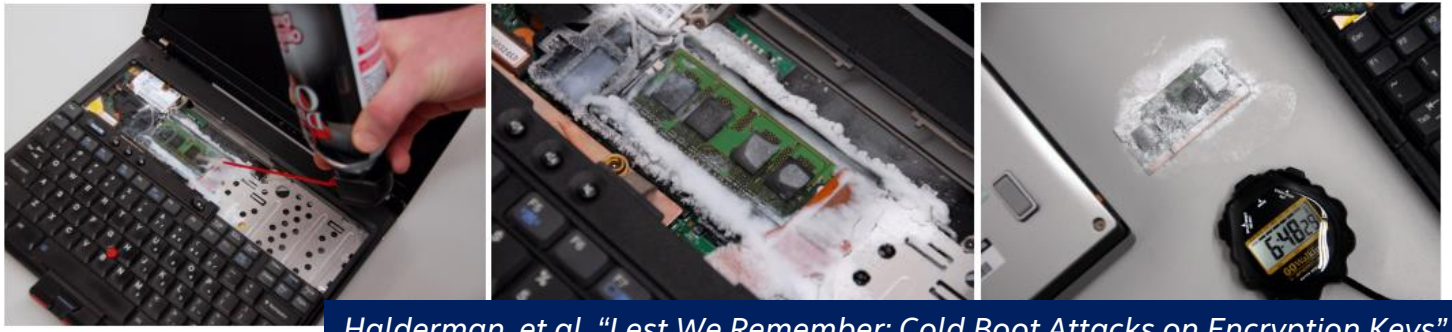
Hot Swap Attack

Overall, only a few SED-based systems withstood more attacks than equivalent software-based FDE systems. The majority of machines is equally vulnerable in both scenarios, and some machines are arguably more vulnerable when using SEDs.

Muller, et al. "Self-Encrypting Disks pose Self-Decrypting Risks"



Cold BootAttack



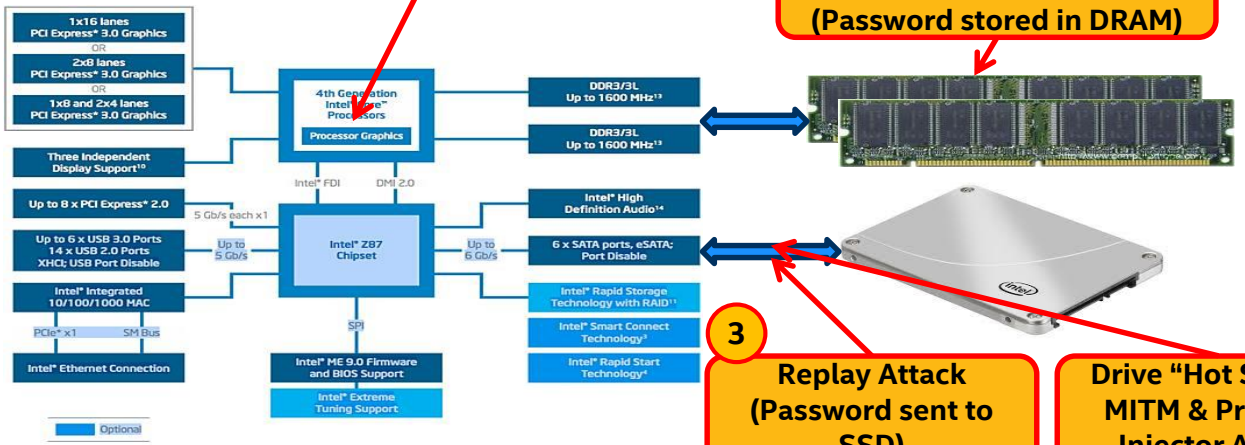
Halderman, et al. "Lest We Remember: Cold Boot Attacks on Encryption Keys"

Exposed Security Gaps

Note: Password is Handled in clear txt

2 Malware Sniff & Ransom Ware Attack on Password (Password used for Auto-Unlock by Host)

1 Cold & Warm Boot Attacks on Password (Password stored in DRAM)



3 Replay Attack (Password sent to SSD)

4 Drive "Hot Swap" / MITM & Protocol Injector Attack

Auto-Unlock Provides UX Benefits, but Opens Data Access Security Gaps!

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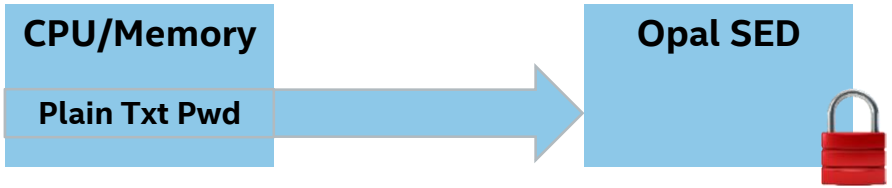
Proposed Solution: Challenge Response Authentication Method (CRAM)

- CRAM introduces a random element into the authentication process
- Prevents sniff/replay of the authentication credential to the drive
- Removes the need to store the password in DRAM
- Signing key can be held securely in a TEE such as Intel® Management Engine (Intel® ME)/Intel® Trusted Platform Module (Intel® TPM)

No CRAM

Resume from S3 Auto-Unlock



CRAM on Pro SSDs

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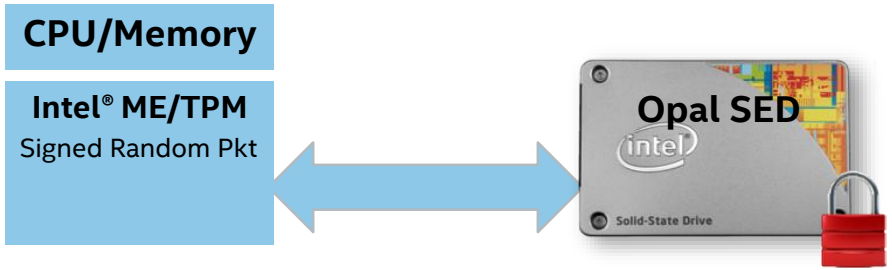

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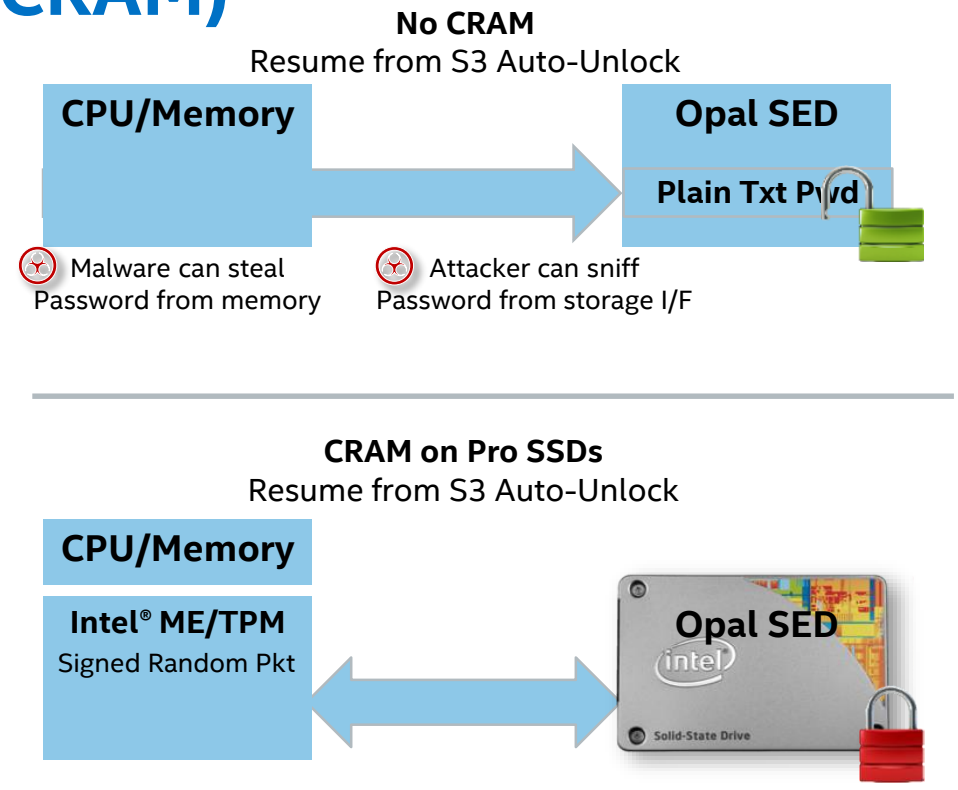

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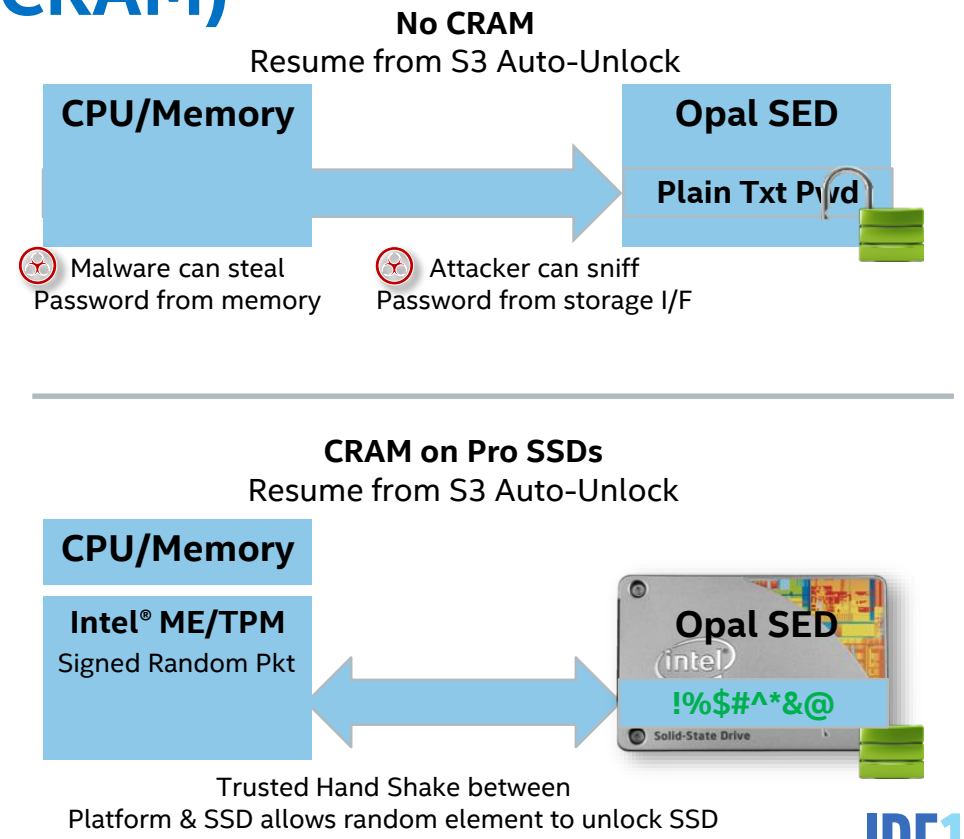
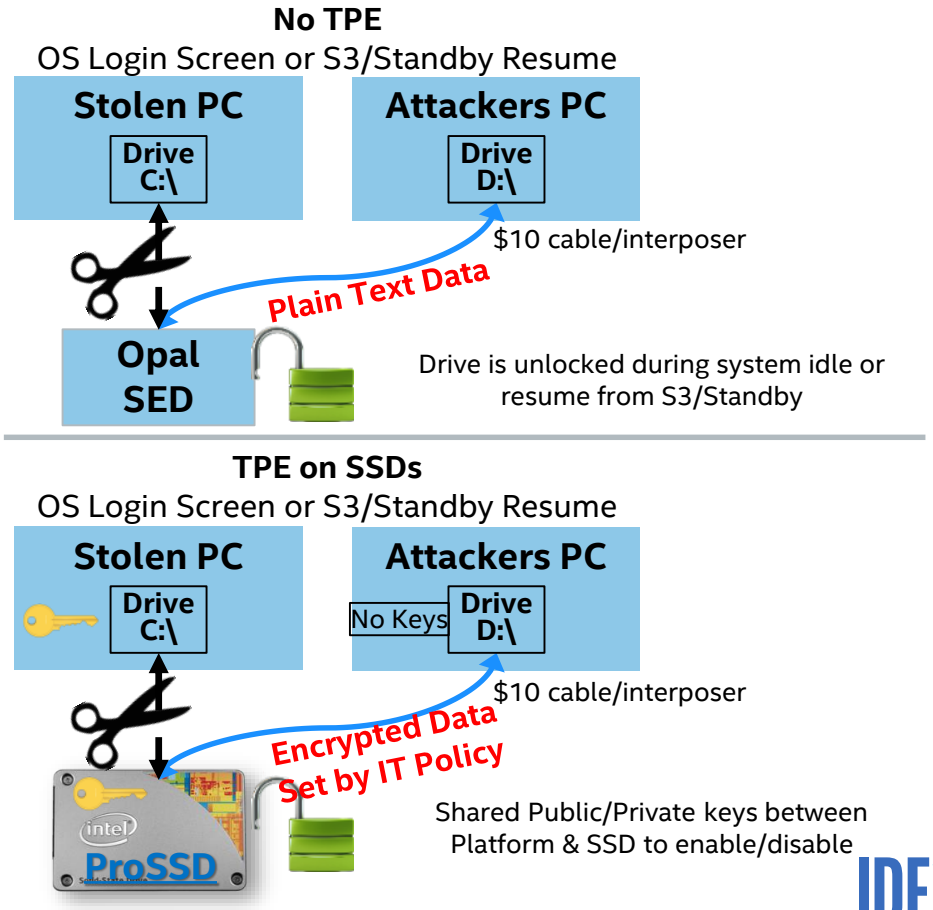
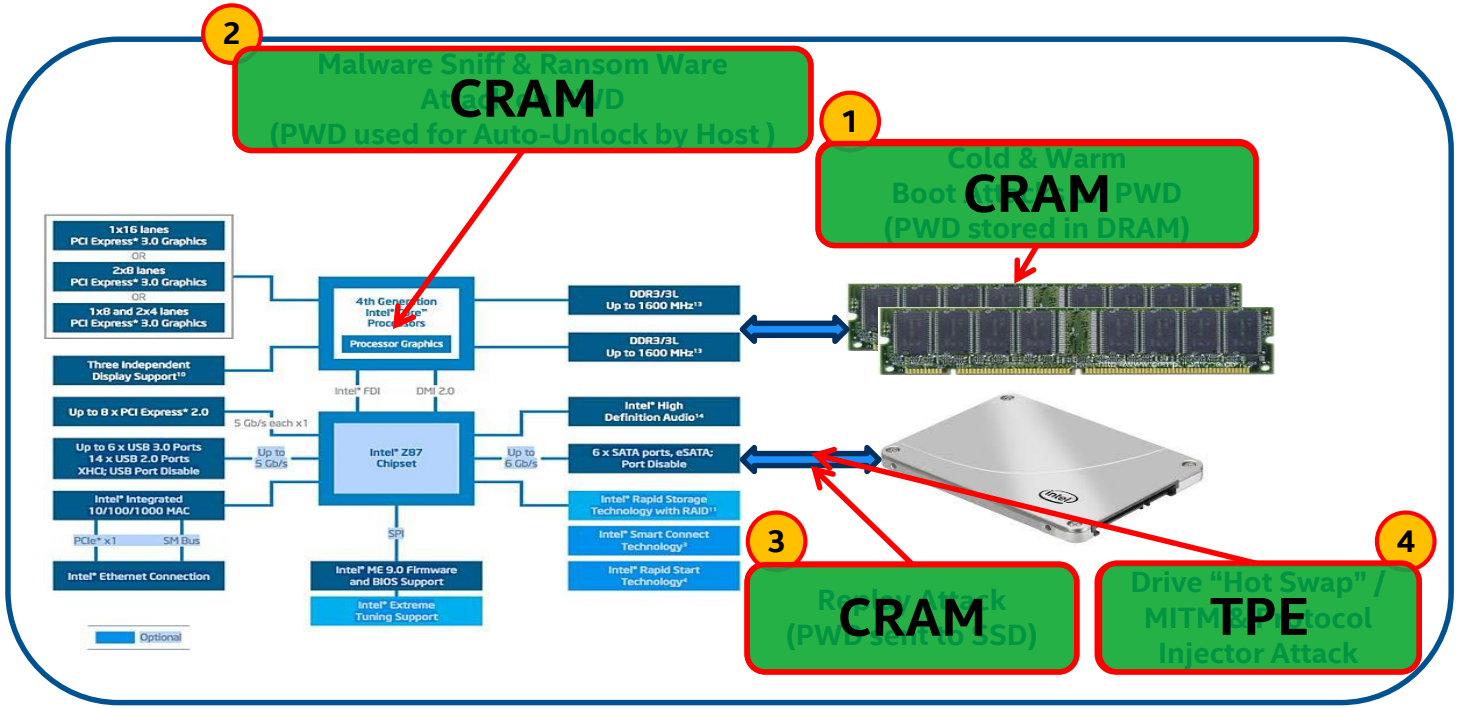


Proposed Solution: Transport Encryption (TPE)

- TPE encrypts all data over the interface in platform “vulnerable states”
- Enable/Disable of TPE requires cryptographic authentication
- Encryption disabled while user is logged in to the OS (maintains performance)
- Encryption enabled at OS lock screen



Gaps Closed!



Proposed Solutions Solve Security Gaps While Introducing Minimal Platform Performance Degradation

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Summary/Call to Action

- Opal SEDs maintain storage performance while providing comprehensive data at rest protection
  - Standards based enhancements are needed to address SED security gaps
- Corporate Consumer?
  - Demand an Opal SED on your next system! (Intel® SSD Preferably)
- Platform or Storage Security Oriented?
  - Join the Trusted Computing Group* (TCG) Storage Workgroup and assist in defining the future of Storage Security through Self Encrypting Drives

The Success of Opal SEDs depends on Consumer Demand and Increased Contributions to SED ecosystem through TCG Opal

Additional Sources of Information

- A PDF of this presentation is available from our Technical Session Catalog: www.intel.com/idfsessionsSF. This URL is also printed on the top of Session Agenda Pages in the Pocket Guide.

- Additional info in the storage security community – https://www.trustedcomputinggroup.org/developers/storage

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