Protecting Confidential Data on Personal Computers with Storage Capsules

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Problem: Malicious Software

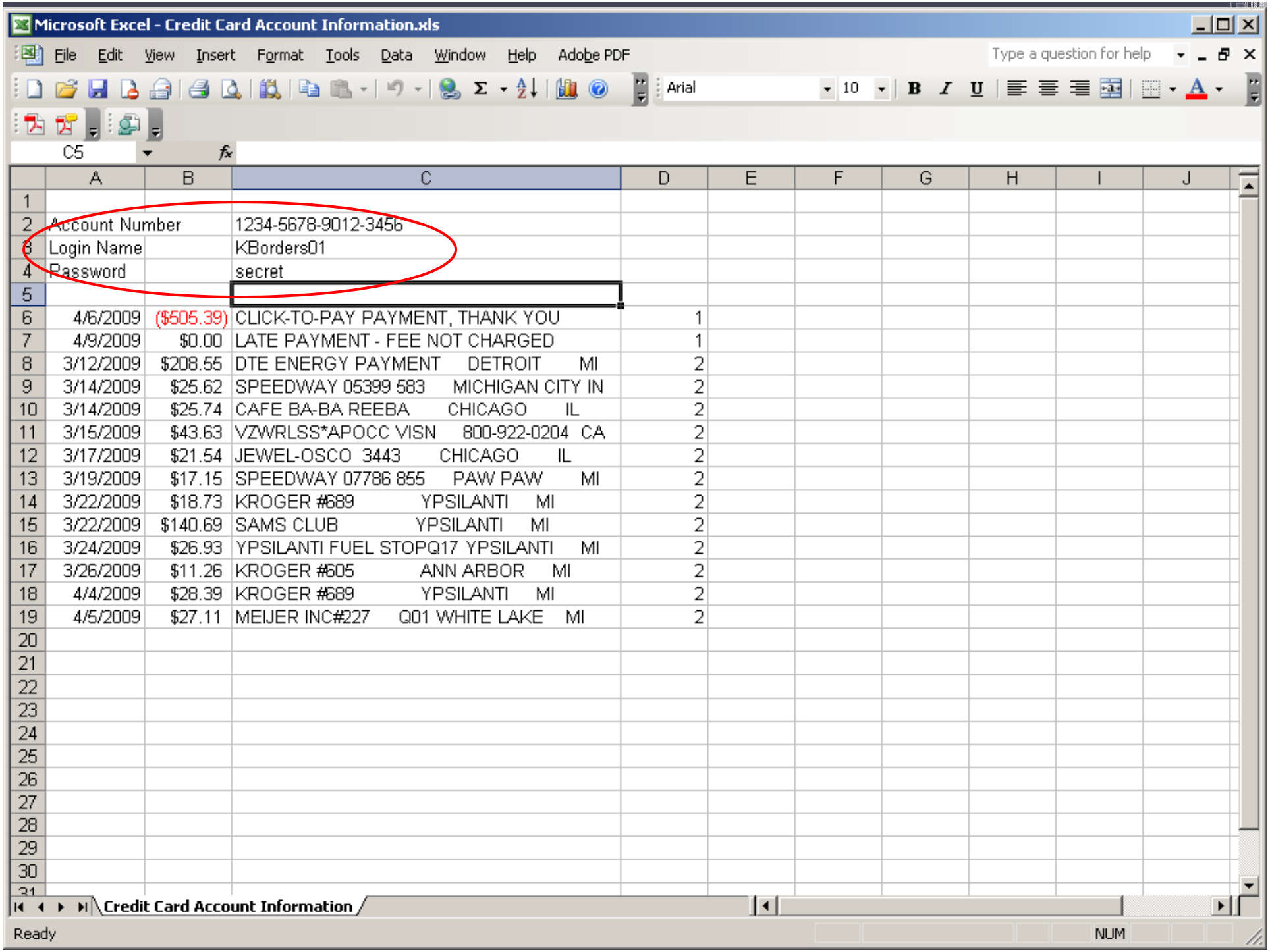
- Computing becomes pervasive, so is malware
  - Over 23 million computers cleansed in 2008 [1]

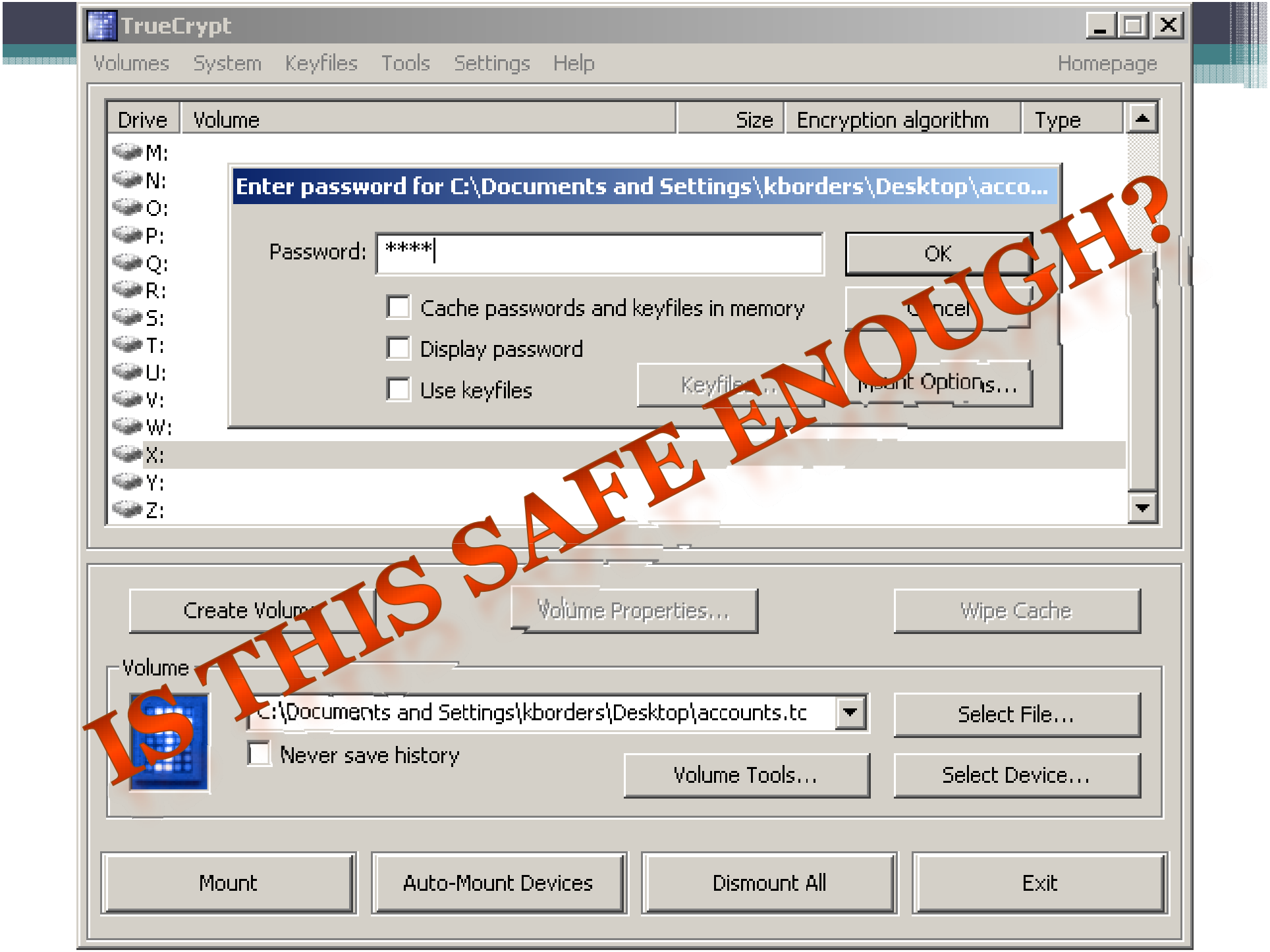
- Consequences are severe:
  - Financial loss
  - Identity theft
  - Fraud

[1] Microsoft Security Intelligence Report Volume 5

Scenario

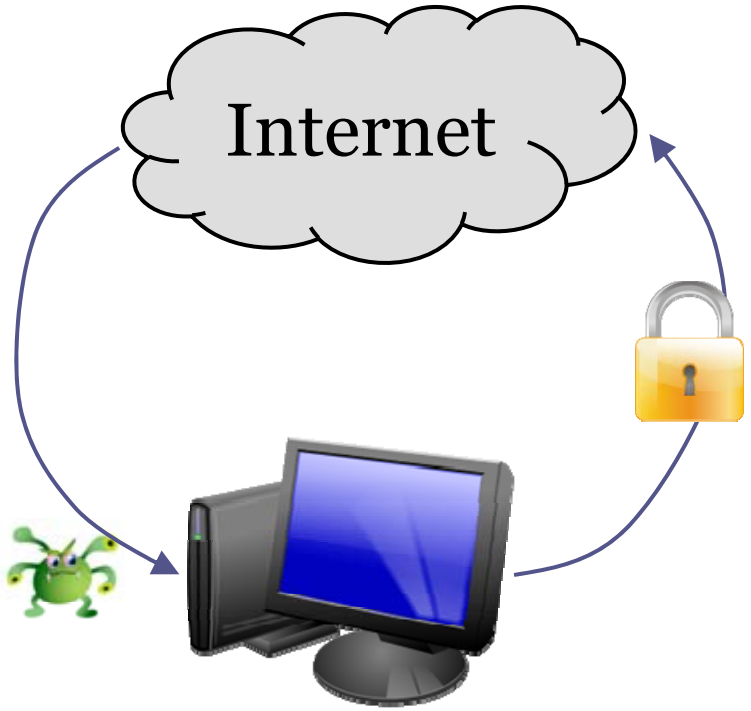
- Tasks that require confidentiality protection
  - Perform financial analysis of credit card expenditure
  - Writing journal containing controversial political beliefs
  - Writing business proposal


Microsoft Excel - Credit Card Account Information.xls
File Edit View Insert Format Tools Data Window Help Adobe PDF
Type a question for help
Arial 10
C5
Account Number 1234-5678-9012-3456
Login Name KBorders01
Password secret
4/6/2009 ($505.39) CLICK-TO-PAY PAYMENT, THANK YOU 1
4/9/2009 $0.00 LATE PAYMENT - FEE NOT CHARGED 1
3/12/2009 $208.55 DTE ENERGY PAYMENT DETROIT MI 2
3/14/2009 $25.62 SPEEDWAY 05399 583 MICHIGAN CITY IN 2
3/14/2009 $25.74 CAFE BA-BA REEBA CHICAGO IL 2
3/15/2009 $43.63 VZWRLSS*APOCC VISN 800-922-0204 CA 2
3/17/2009 $21.54 JEWEL-OSCO 3443 CHICAGO IL 2
3/19/2009 $17.15 SPEEDWAY 07786 855 PAW PAW MI 2
3/22/2009 $18.73 KROGER #689 YPSILANTI MI 2
3/22/2009 $140.69 SAMS CLUB YPSILANTI MI 2
3/24/2009 $26.93 YPSILANTI FUEL STOPQ17 YPSILANTI MI 2
3/26/2009 $11.26 KROGER #605 ANN ARBOR MI 2
4/4/2009 $28.39 KROGER #689 YPSILANTI MI 2
4/5/2009 $27.11 MEIJER INC#227 Q01 WHITE LAKE MI 2
Credit Card Account Information
Ready
NUM

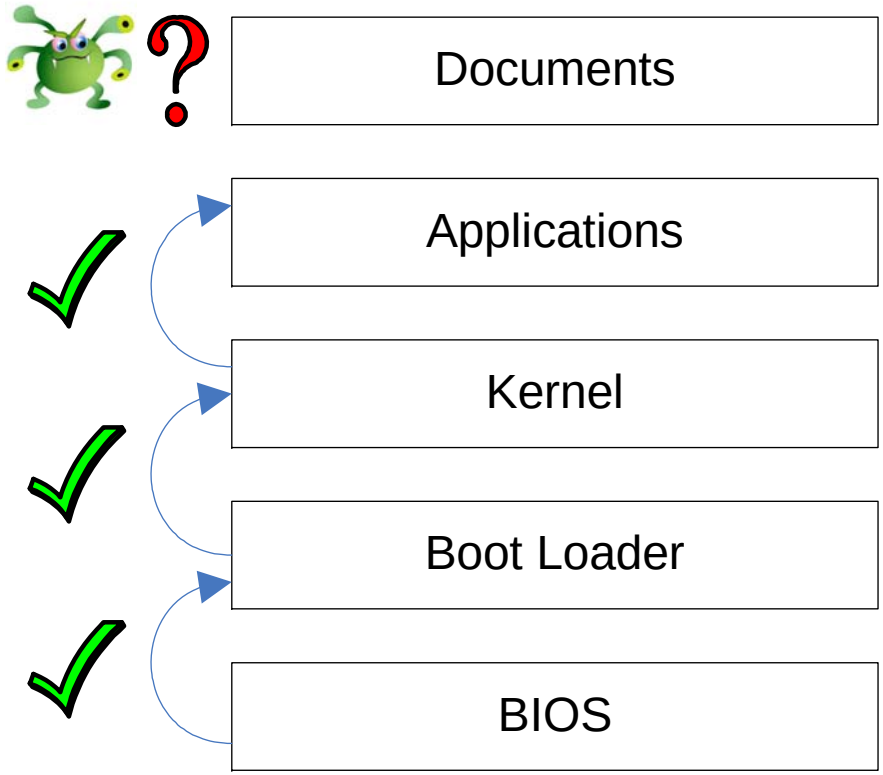

TrueCrypt
Volumes System Keyfiles Tools Settings Help Homepage
Drive Volume Size Encryption algorithm Type
M:
N:
O:
P:
Q:
R:
S:
T:
U:
V:
W:
X:
Y:
Z:
Enter password for C:\Documents and Settings\kborders\Desktop\acco...
Password: ****
OK
Cancel
Cache passwords and keyfiles in memory
Display password
Use keyfiles
Keyfiles...
Mount Options...
IS THIS SAFE ENOUGH?
Create Volume
Volume Properties...
Wipe Cache
Volume
C:\Documents and Settings\kborders\Desktop\accounts.tc
Never save history
Select File...
Volume Tools...
Select Device...
Mount
Auto-Mount Devices
Dismount All
Exit

Goals

Provide confidentiality for local sensitive files against malicious software

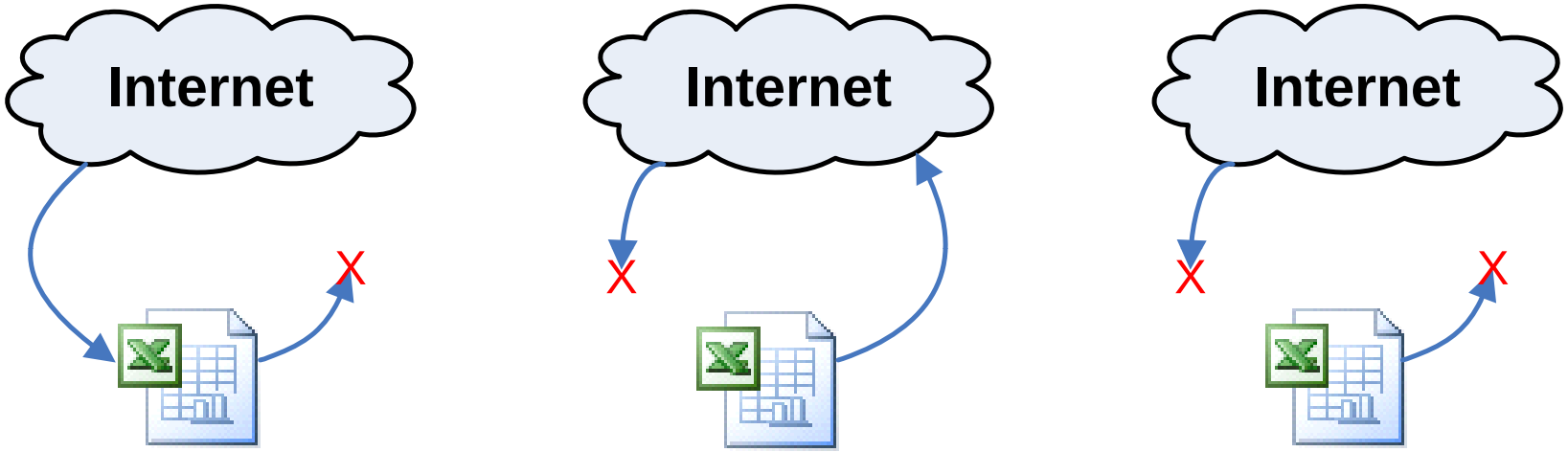


Related Work: Trusted Boot



- Not 100% safe
- Need to verify all software prior to installation
  - Hard
- Verify documents
  - Even harder!!

Related Work: Strict Inter-Process Flow Control



Mandatory Access Control A

Mandatory Access Control B

Air Gap

- Mandatory Access Control with strict control flow policy = Limited Usability
- Air gap greatly limits utility

Contribution – Storage Capsules

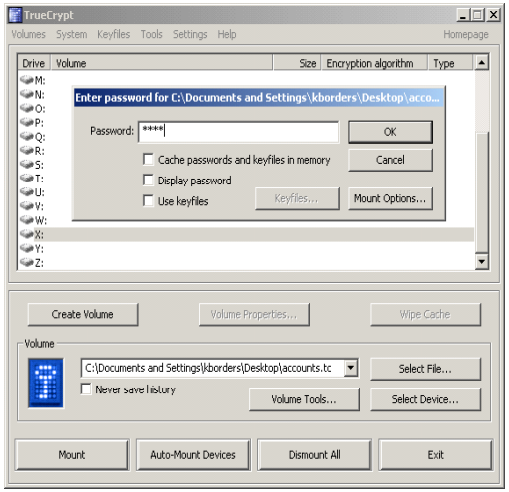
- A system that can securely access confidential information from a compromised commodity OS

Approach

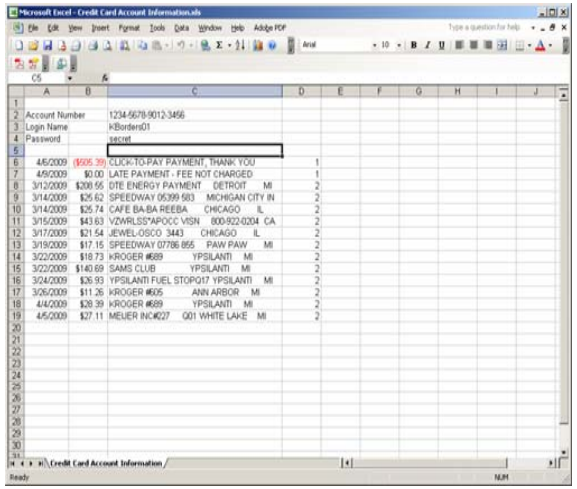
- Allow normal OS and standard applications to access sensitive data
- Two modes of operation:

Normal Mode	Secure Mode
• No restrictions	• Prevent network output
• Perform non-sensitive operations	• Edit sensitive documents
• No storage protection	• Encrypt changes to Storage Capsules

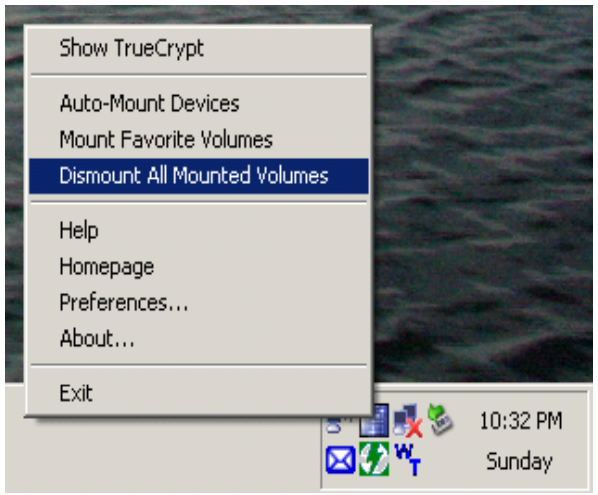
From the User's Perspective



1. Open Container



2. Edit Document

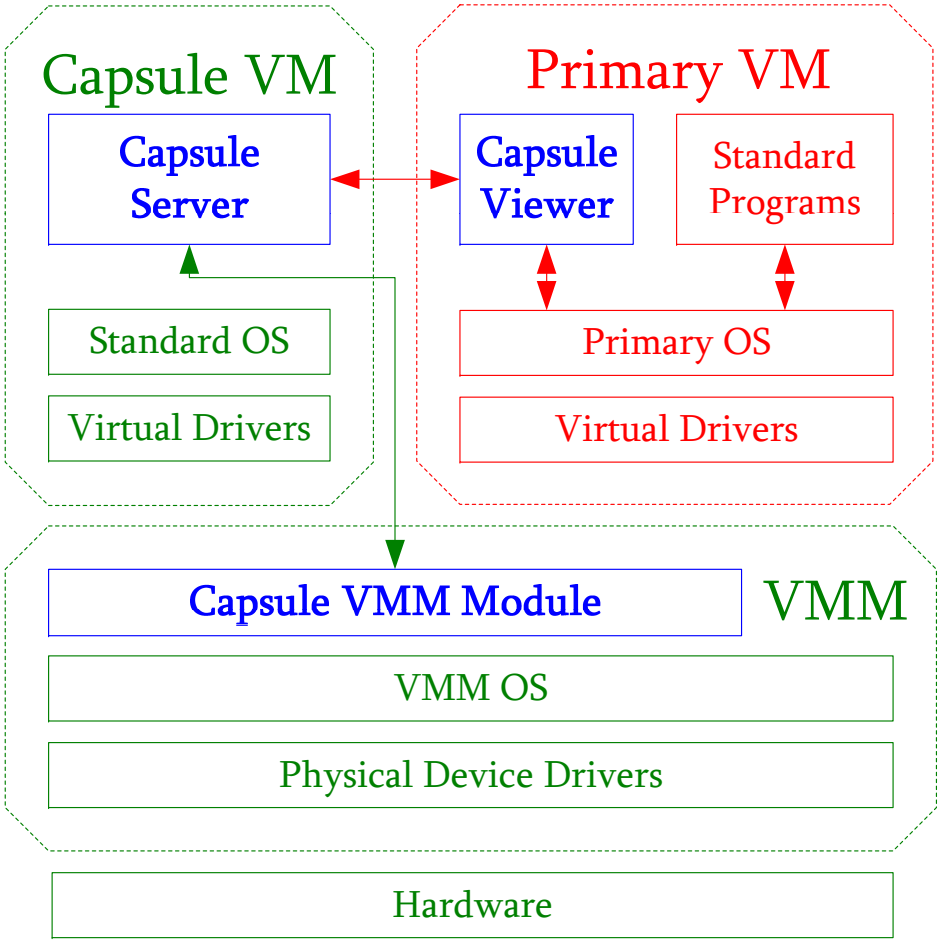


3. Close Container

Similar to TrueCrypt, but contents safe when open

Capsule Architecture

Green
=
Trusted
Computing
Base

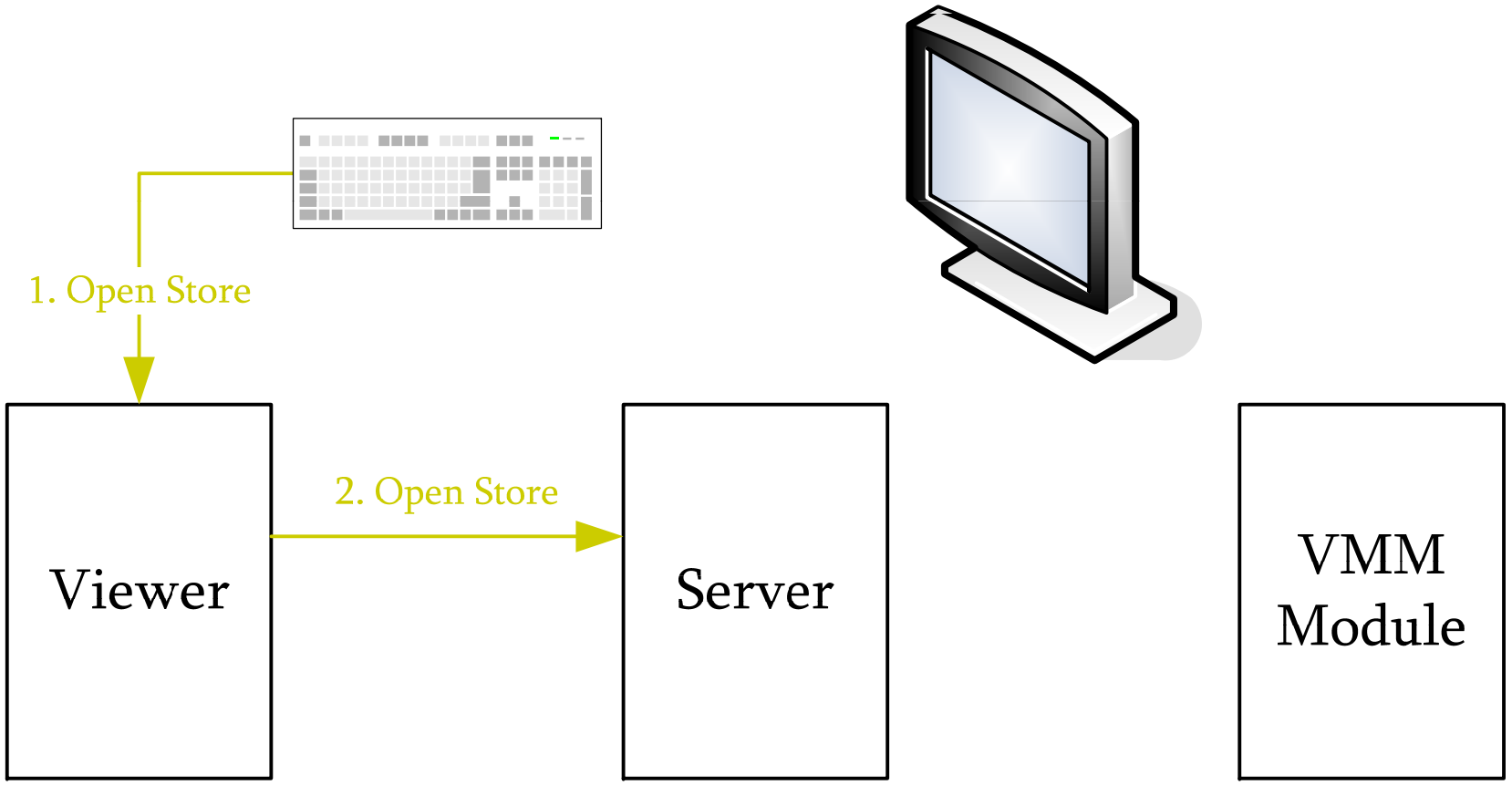


Red
=
Not Trusted

Threat Model

- We trust:
  - The user,
  - The capsule VM, and
  - The VMM
- Do not trust:
  - The primary OS
  - Applications
- Covert Channels
  - Channels within the primary VM are blocked
  - Channels in Capsule VM, VMM, and hardware may not be blocked

Opening a Storage Capsule



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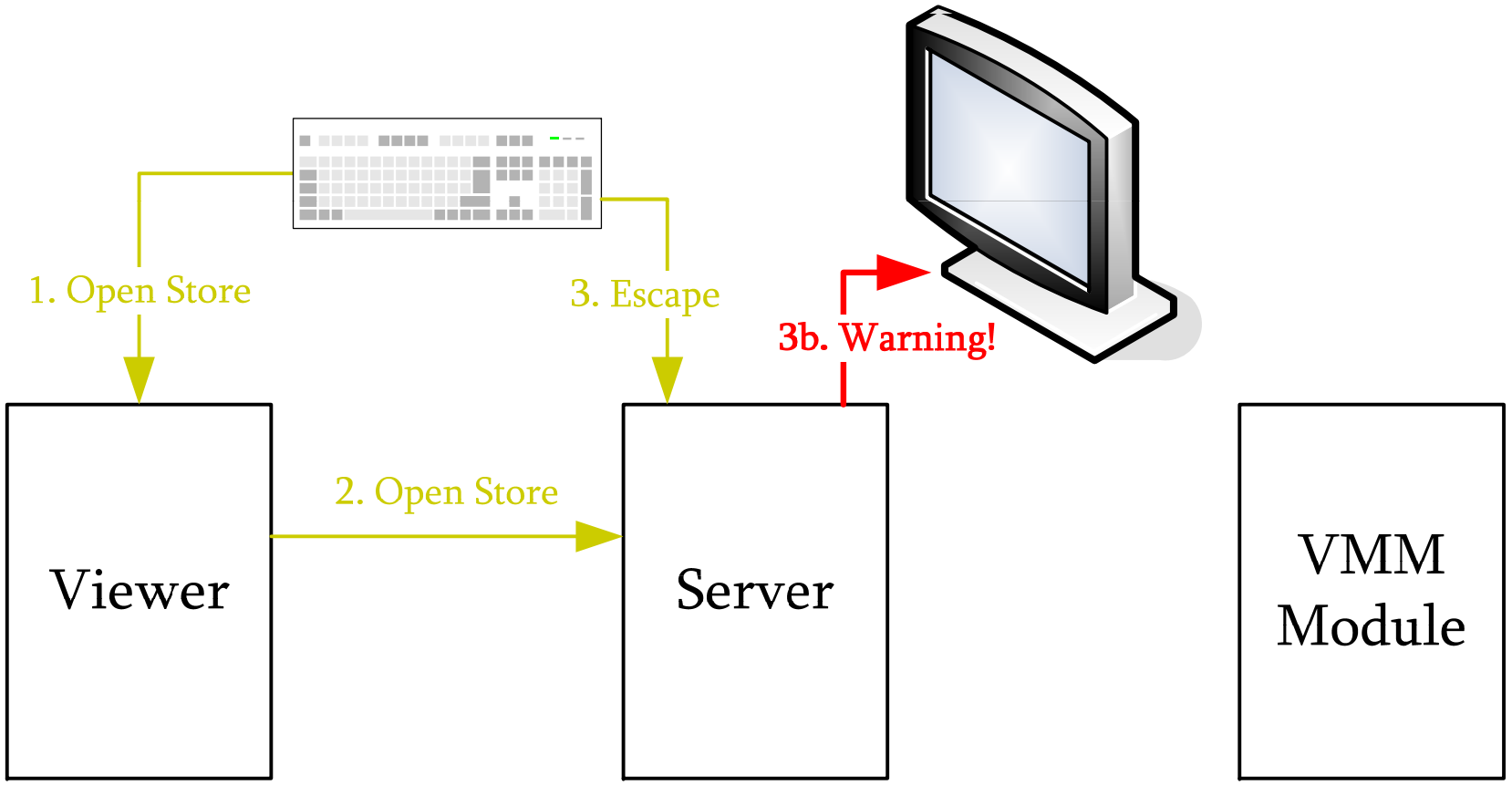

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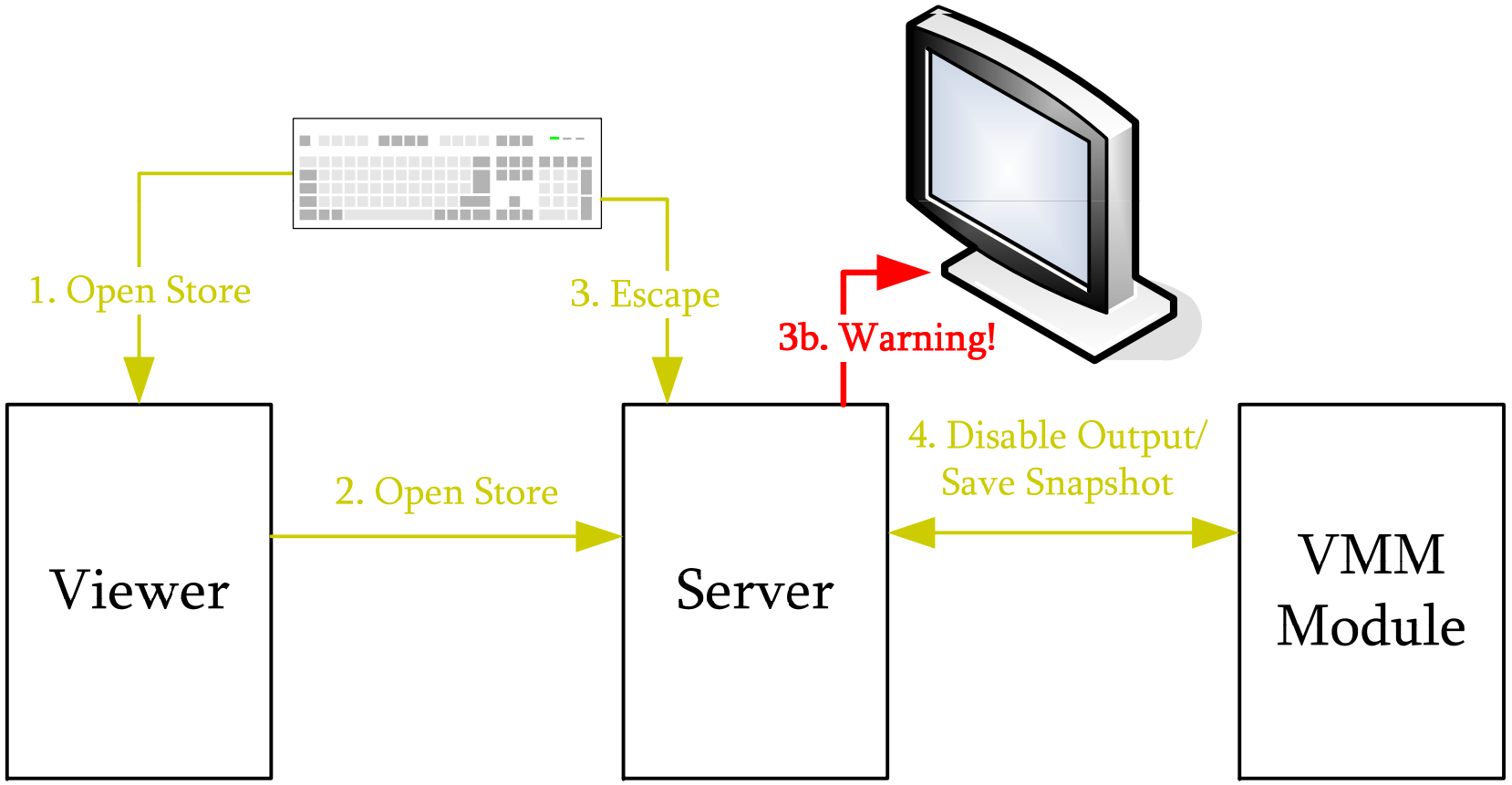
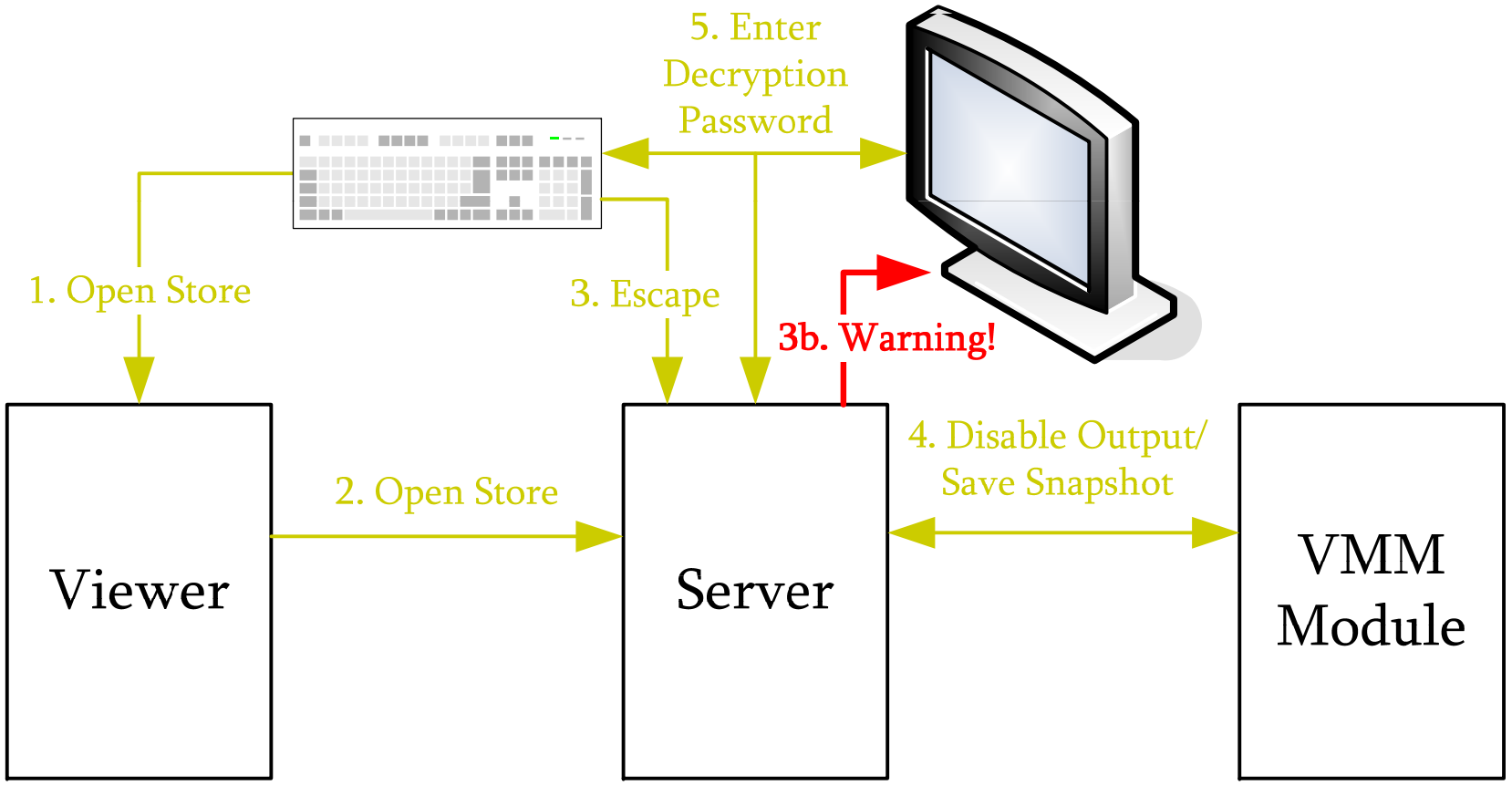
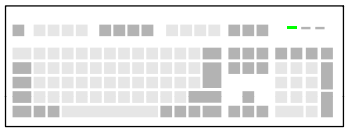
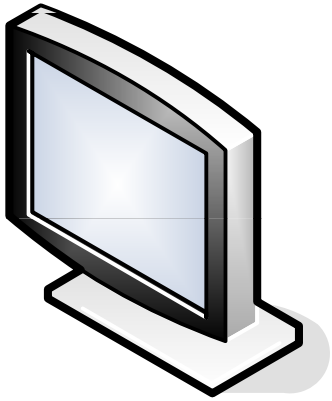


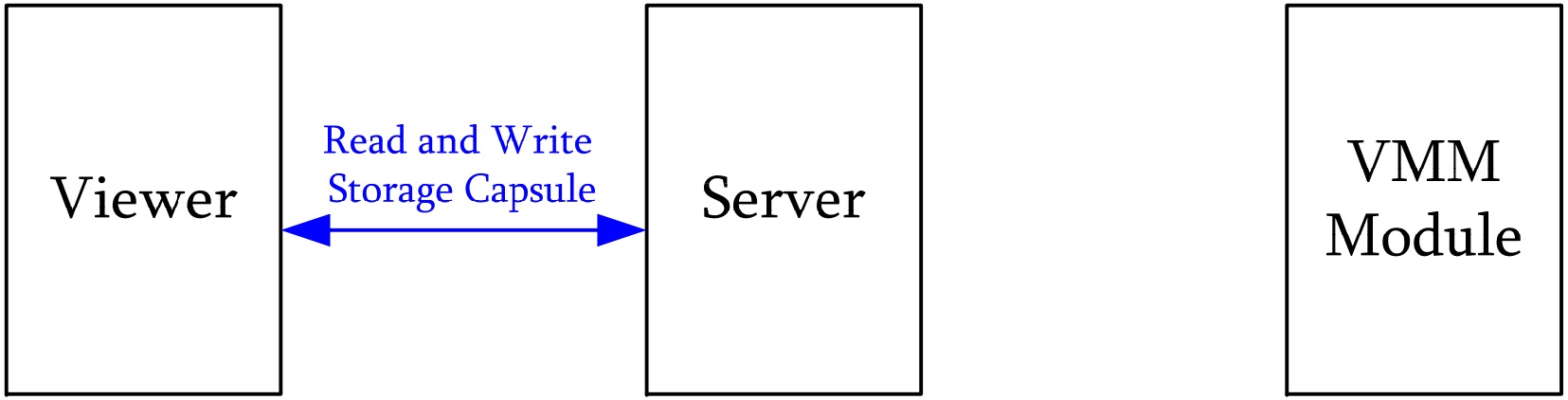
Opening a Storage Capsule



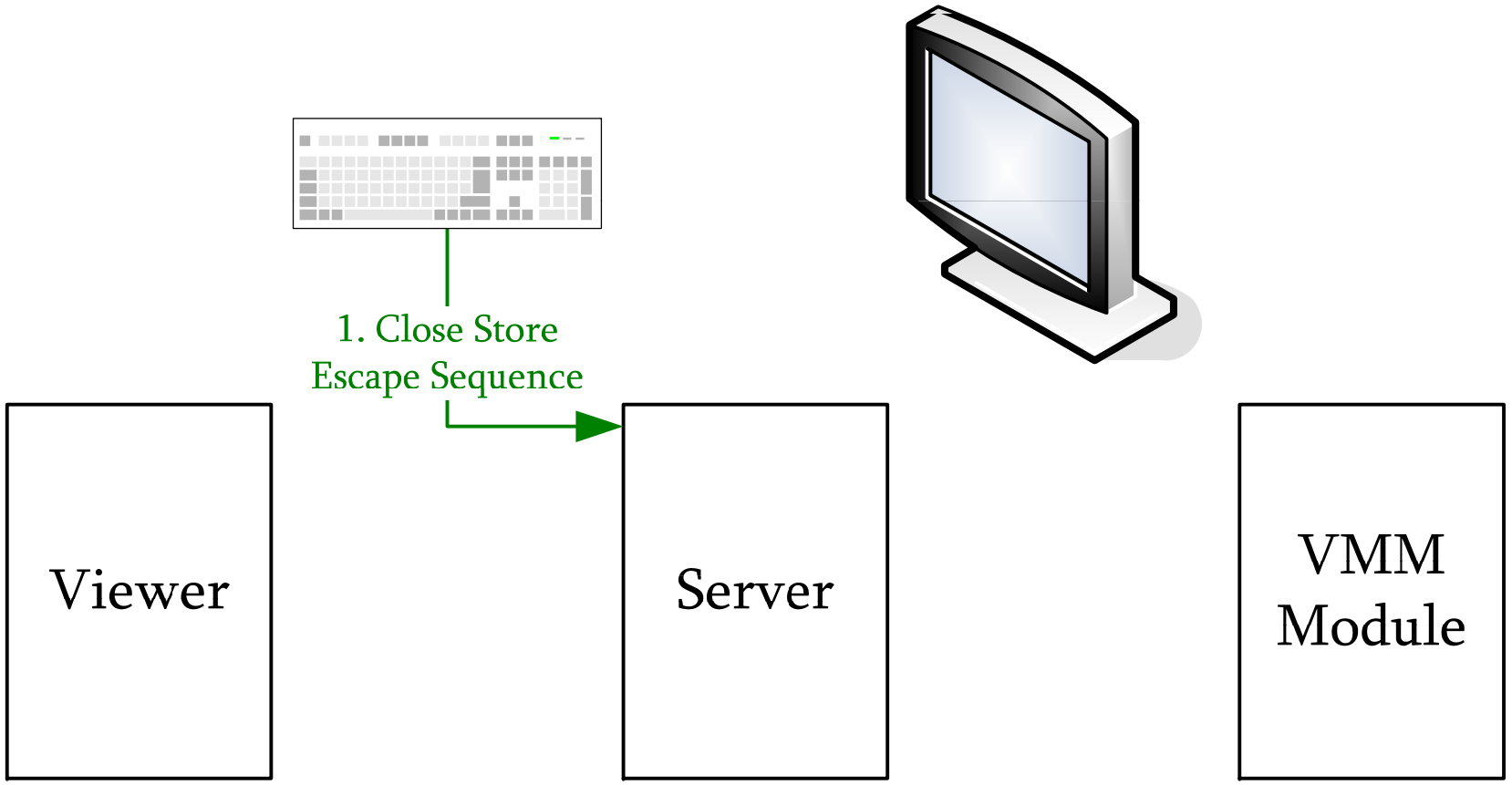
Accessing a Storage Capsule







Closing a Storage Capsule



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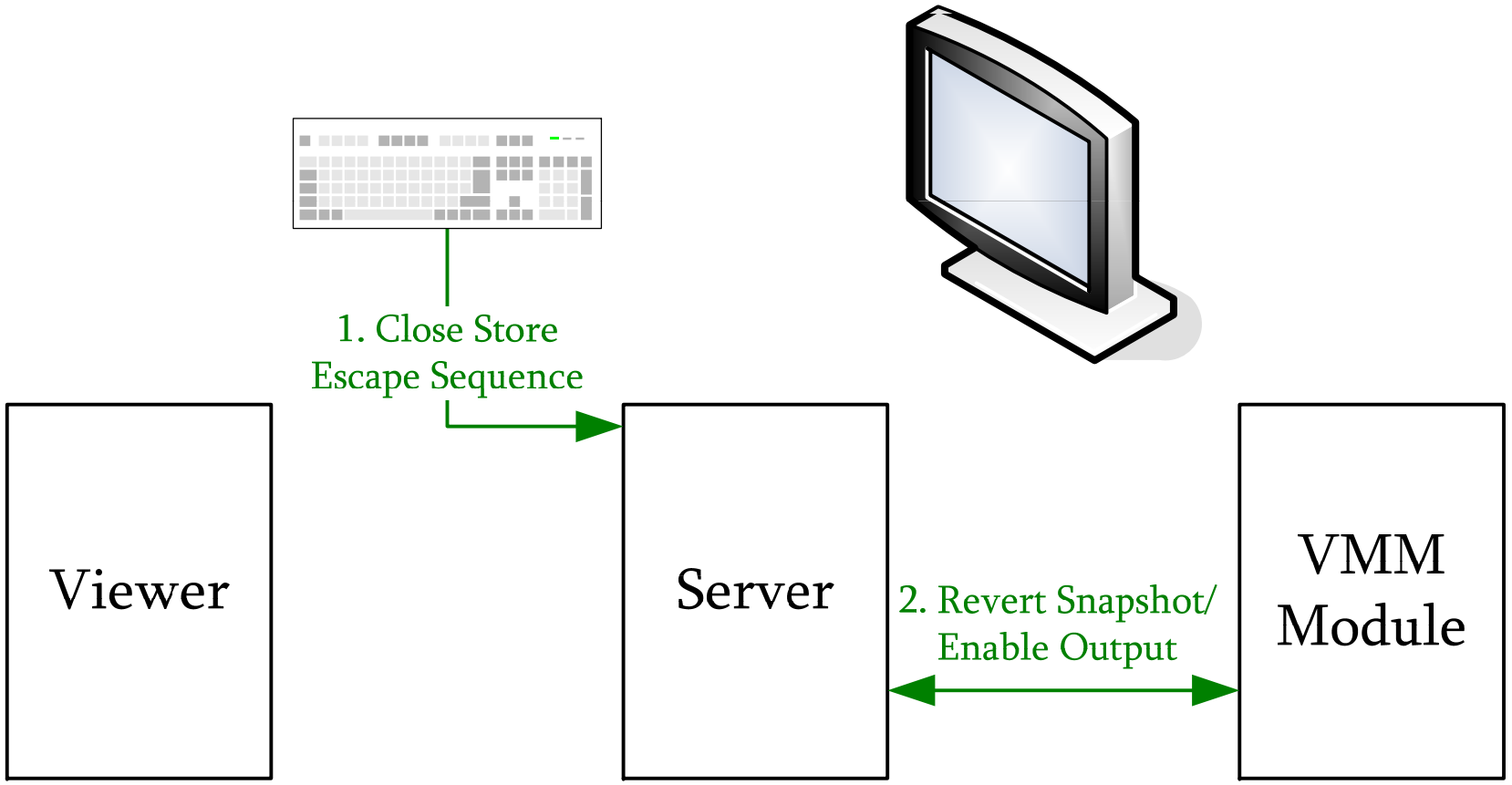
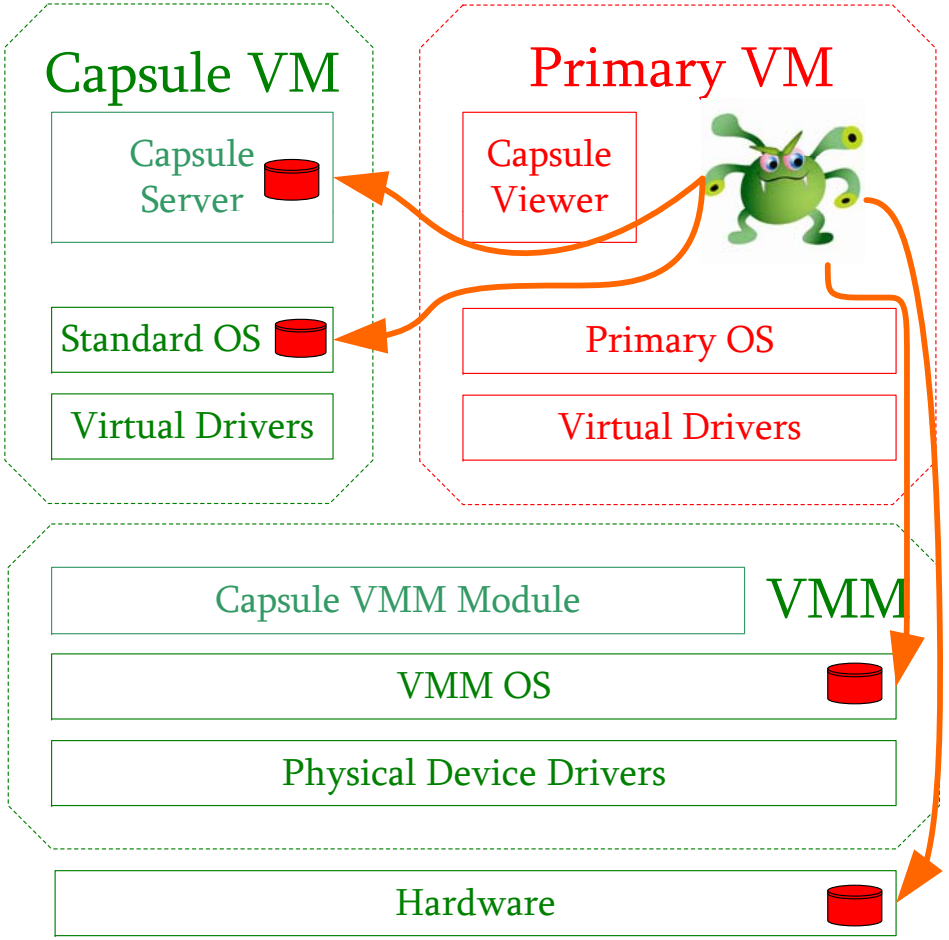


Covert Channels Illustrated



Attacks – Covert Channels

- Primary OS and Capsule could be manipulated, but we:
  - Fix the file store size
  - Re-encrypt the store before every export
  - The user controls transition timing with a secure key escape sequence
- External Devices – store data on floppy, CD-ROM, USB, SCSI, etc.
  - Device output is disabled in secure mode

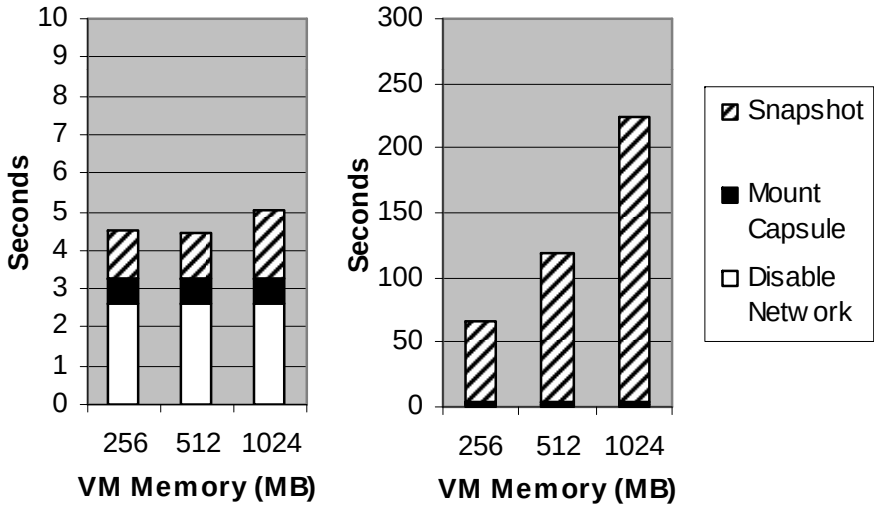
Attacks – Covert Channels (pt. 2)

- VMM – manipulate memory utilization and layout, store information in virtual network
  - VMM does not over-commit memory and uses fixed layout
  - Restart the virtual network during transition to normal mode
- Hardware – store data in CPU or disk cache
  - Restoration code adds noise to CPU, full reset would completely clear CPU
  - Would need to clear all disk caches or move all files to block disk covert channels

Attacks – Secure Mode Forgery

- Malware could fake secure mode UI
- To be safe, users are only required to:
  - Remember that they are supposed to enter a key escape sequence (like ctrl+alt+del) to enter secure mode
  - Heed warnings

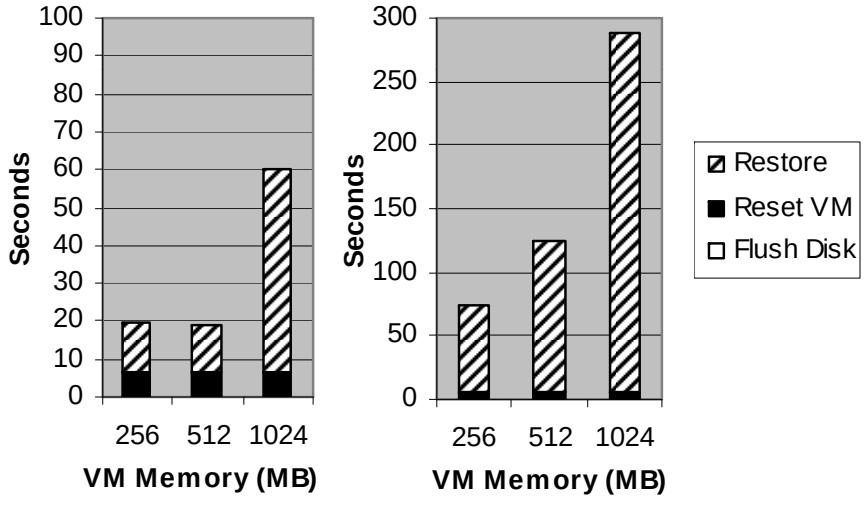
Performance – Transitions



w/ background snapshot

w/o background snapshot

To Secure Mode

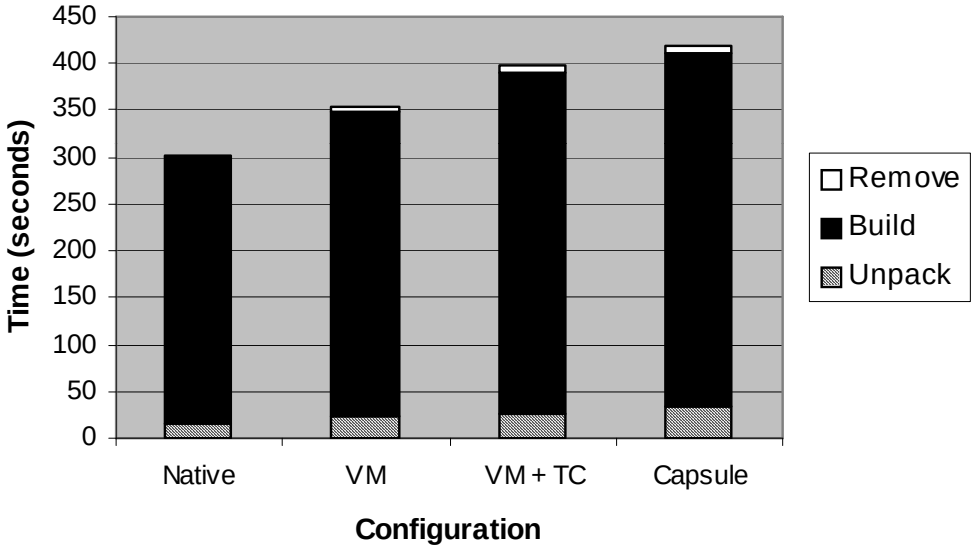


w/ background snapshot

w/o background snapshot

To Normal Mode

Disk Performance – Secure Mode



- For Apache build:
  - Storage Capsules 38% slower than native system
  - Only 5.1% slower than running TrueCrypt in VM

Limitations

- Changes made outside Capsules in secure mode are lost
  - Background computations
- Network connections are lost in secure mode
  - Downloads, services, etc.
- Short-lived sessions are impractical due to transition time

Conclusion

- Introduced Storage Capsules, a new mechanism for securing files on personal computers
  - Similar to existing file encryption software
  - Provide better protection and usability
  - Works in the face of a compromised OS
- Covert channel analysis
  - Explores covert channels on many layers

Questions