Bunker: A Privacy-Oriented Platform for Network Tracing

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Network Tracing Raises Privacy Concerns

- Network tracing is an indispensable tool
  - Traffic engineering, fault diagnosis and recovery
  - Research studies
- Customers' privacy is vital concern to ISPs
  - ISPs view possessing raw traces as a liability

Threat Model for Raw Traces

- ISPs view raw data traces as a liability:
  - Accidental disclosure
  - Operational and remote attacks
  - Subpoenas

- **Implications**:
  1. Nobody can have access to raw data
  2. Trace anonymization can help mitigate privacy concerns

Two Approaches for Anon.

1. Offline anonymization
   - Trace anonymized after raw data is collected
   - Problem: high privacy risks

2. Online anonymization
   - Trace anonymized simultaneously with collection
   - Problem: high engineering costs

Both approaches have serious shortcomings

Simple Tasks can be Very Slow

- Regular expression for phishing:

  " ((password) | (<form) | (<input) | (PIN) | (username) | (<script) | (user id) | (sign in) | (log in) | (login) | (signin) | (log on) | (sign on) | (signon) | (passcode) | (logon) | (account) | (activate) | (verify) | (payment) | (personal) | (address) | (card) | (credit) | (error) | (terminated) | (suspend))[^A-Za-z]"

- libpcre: 5.5 s for 30 M = 44 Mbps max

Our Solution: Bunker

- Combines the best of both worlds
  - Avoids privacy issues of offline anon.
  - Avoids SW engineering challenges of online

- Idea:
  - We can use buffer-on-disk (like in offline anon.) if we can lock-down the trace data + software; only information exposed is anonymized trace

Outline

- Motivation
- Design of Bunker
- Security attacks
- System evaluation
- Conclusions

Main Idea: Lock-down Raw Data in Bunker

- "Closed-box" protects sensitive data
  - Contains all raw trace data & processing code
  - Restricted access to closed-box (e.g., no console)

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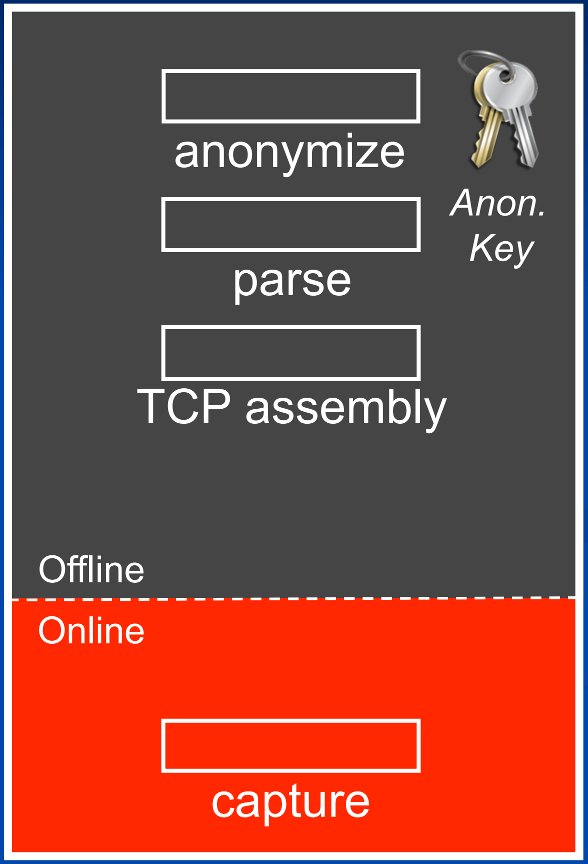
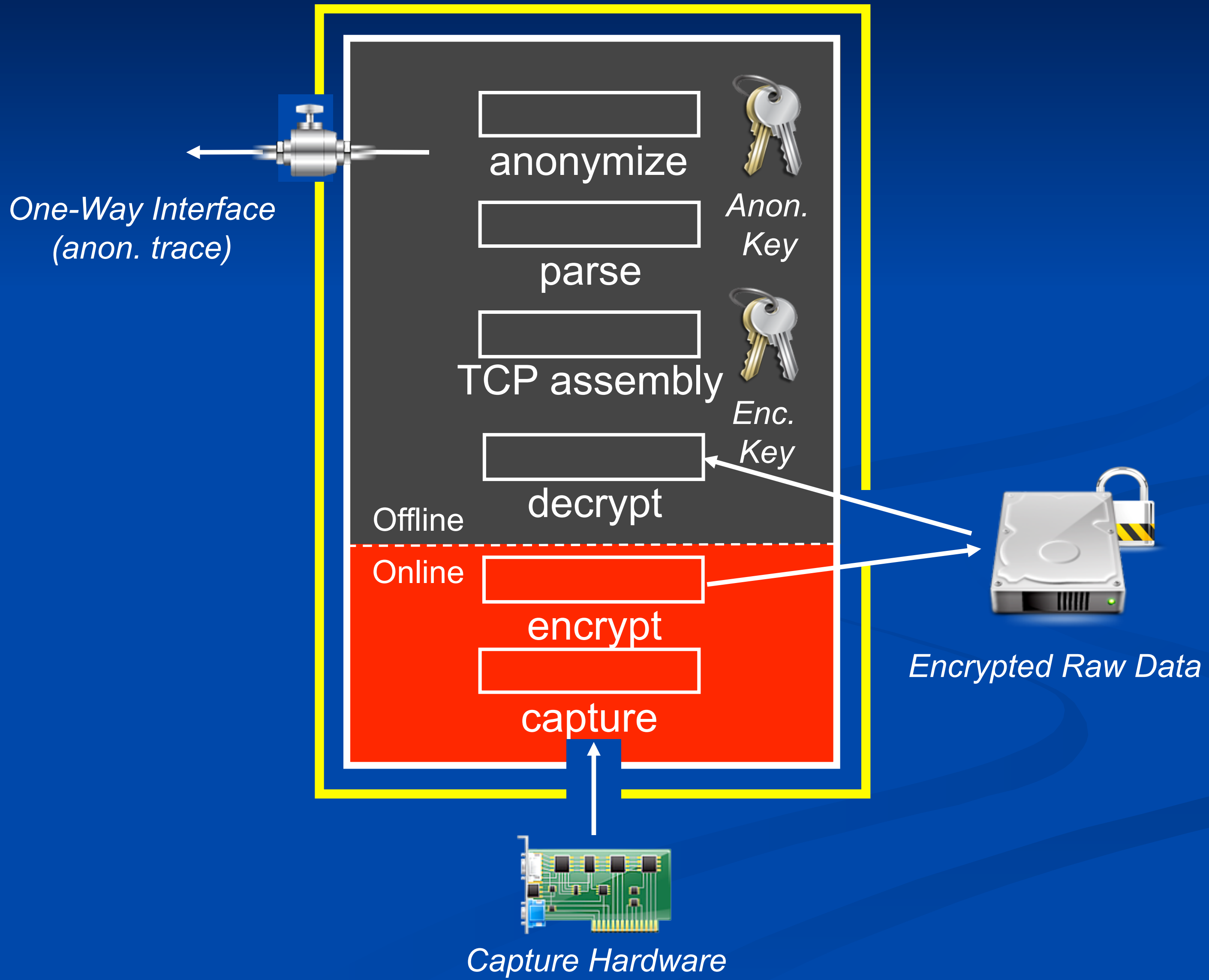
- "Safe-on-reboot": erases data from closed-box
  - ECC RAM is cleared by BIOS upon reboot
  - Encryption protects on disk data
    - Randomly generated key held in RAM inside closed-box
  - Data on disk cannot be decrypted after reboot

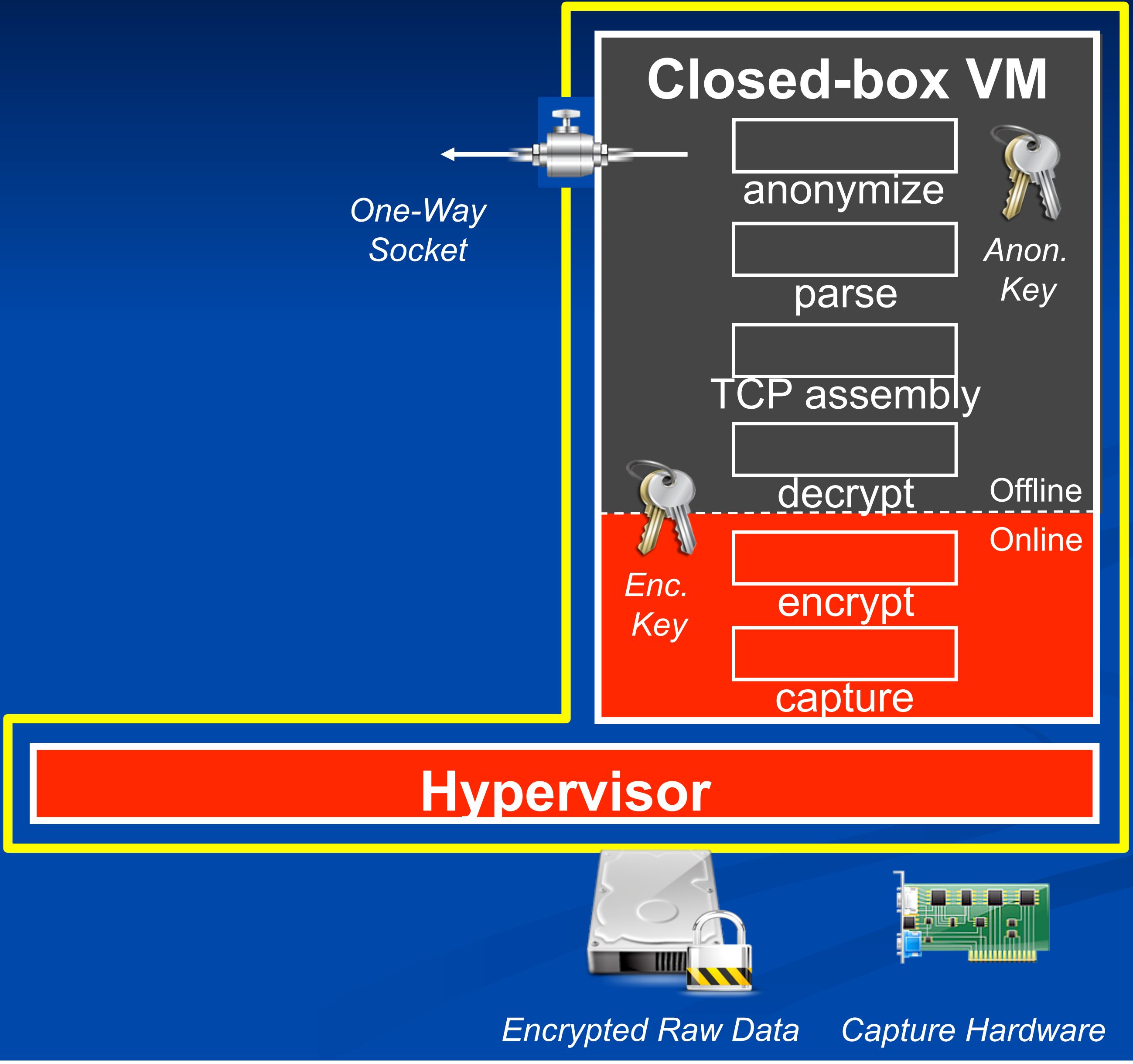
Generic Tracing System



Bunker's Logical Design



VM-based Implementation



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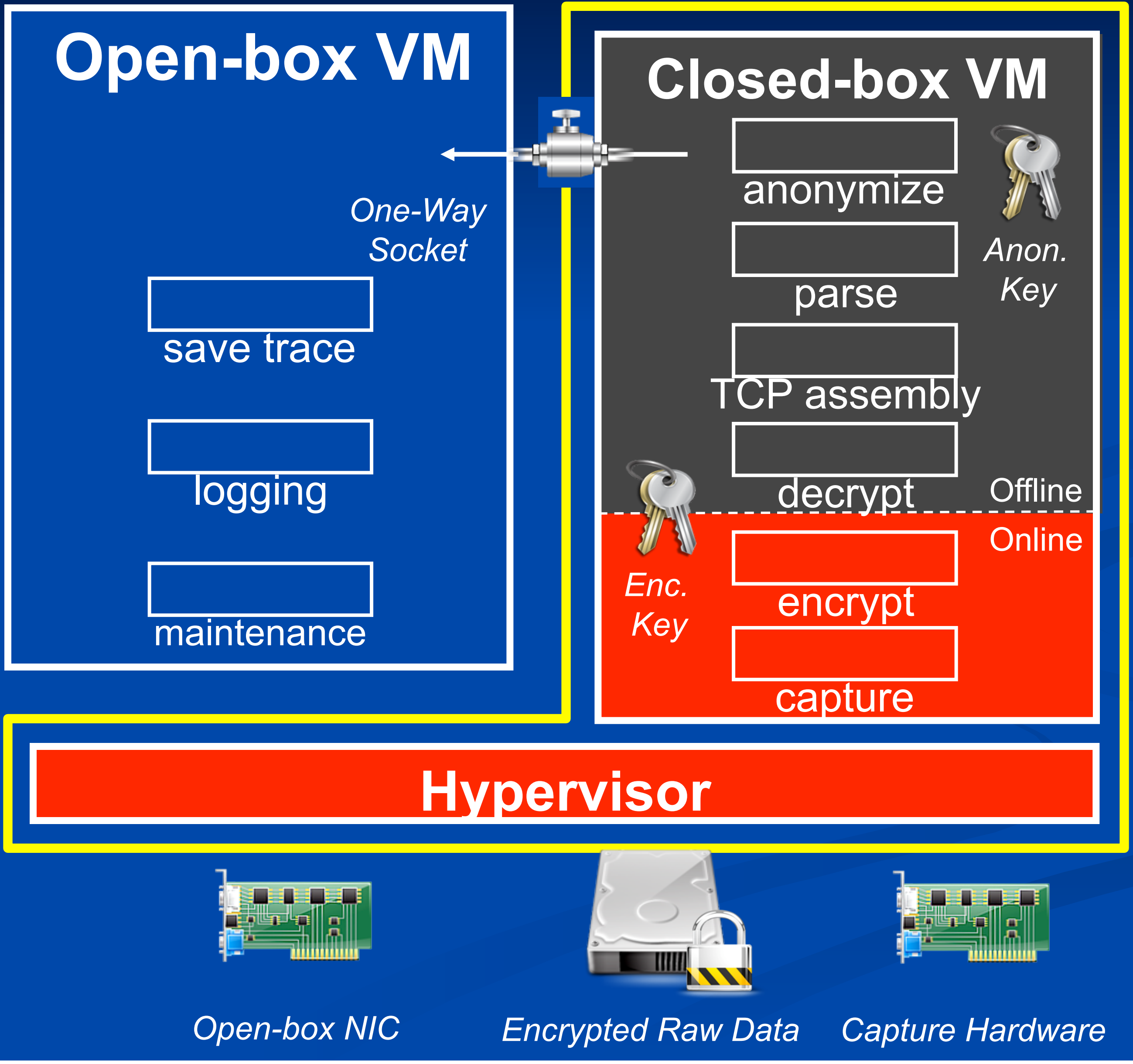

How We Implemented Closed-box?

- Eliminate all I/O + drivers from kernel except the ones needed
    - custom-made menuconfig

- Use firewalls to restrict network communication
  - e.g., standard iptables configuration

How to Use Bunker?

- Upon bootup Bunker offers two configurations
  1. Debugging: all drivers enabled
  2. Tracing: most I/O + drivers disabled

- Upon choosing tracing configuration
  - Display and keyboard freeze (no drivers)
  - Kernel's init runs a script to start trace
  - Operator can log in open-box VM via its NIC

Benefits

- Strong privacy properties
  - Raw trace and other sensitive data cannot be leaked
- Trace processing done offline
  - Can use your favorite language! (e.g., Python)
  - Parsing can be done with off-the-shelf components

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Why is Bunker secure?

- Bunker has large TCB but narrow interfaces
  - Bunker remains secure as long as vulnerability cannot be exploited through the narrow interfaces

- Three classes of attacks:
  - Attacking the closed-box's interfaces
  - Hardware attacks
  - Trace injection attacks

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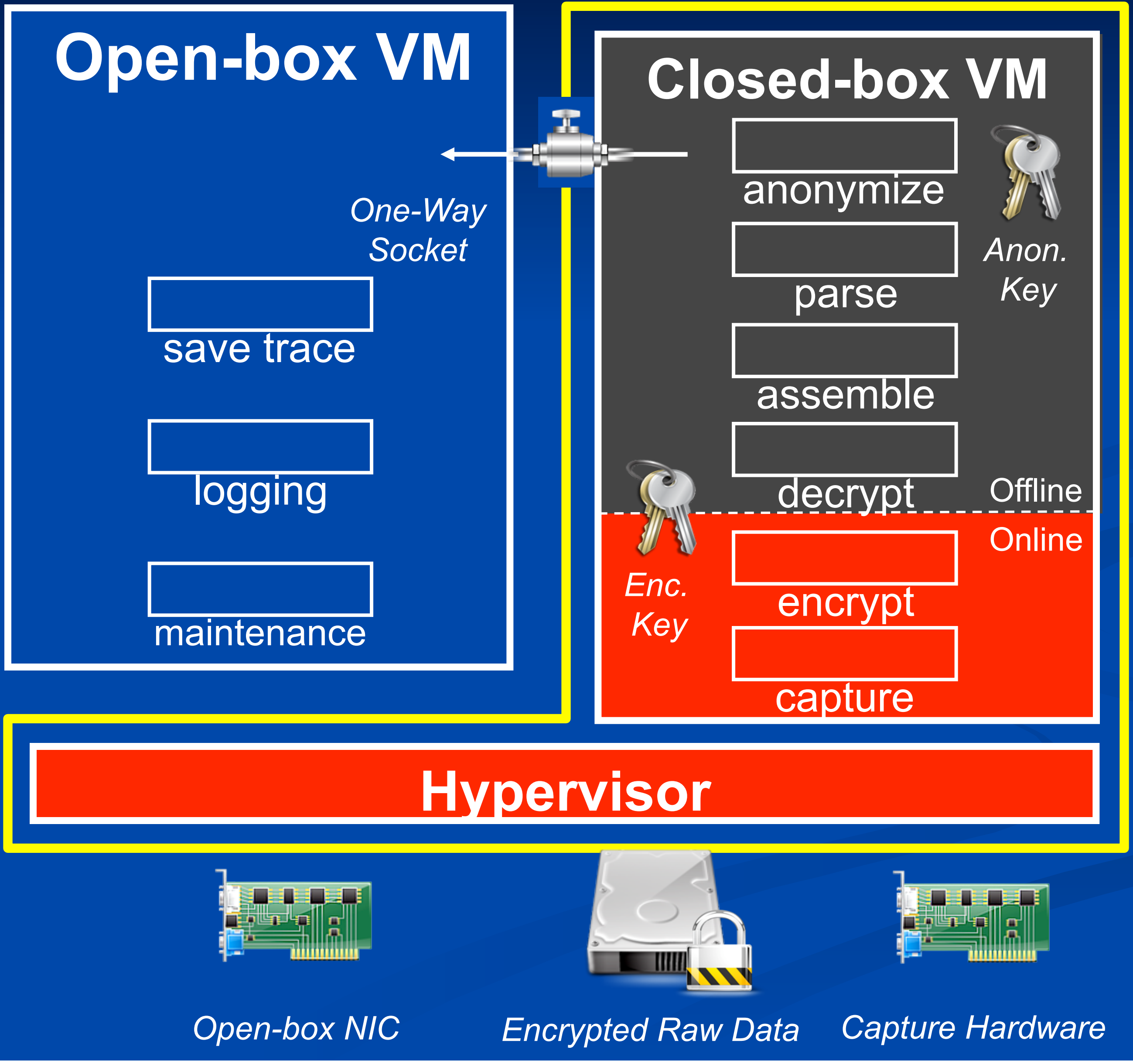

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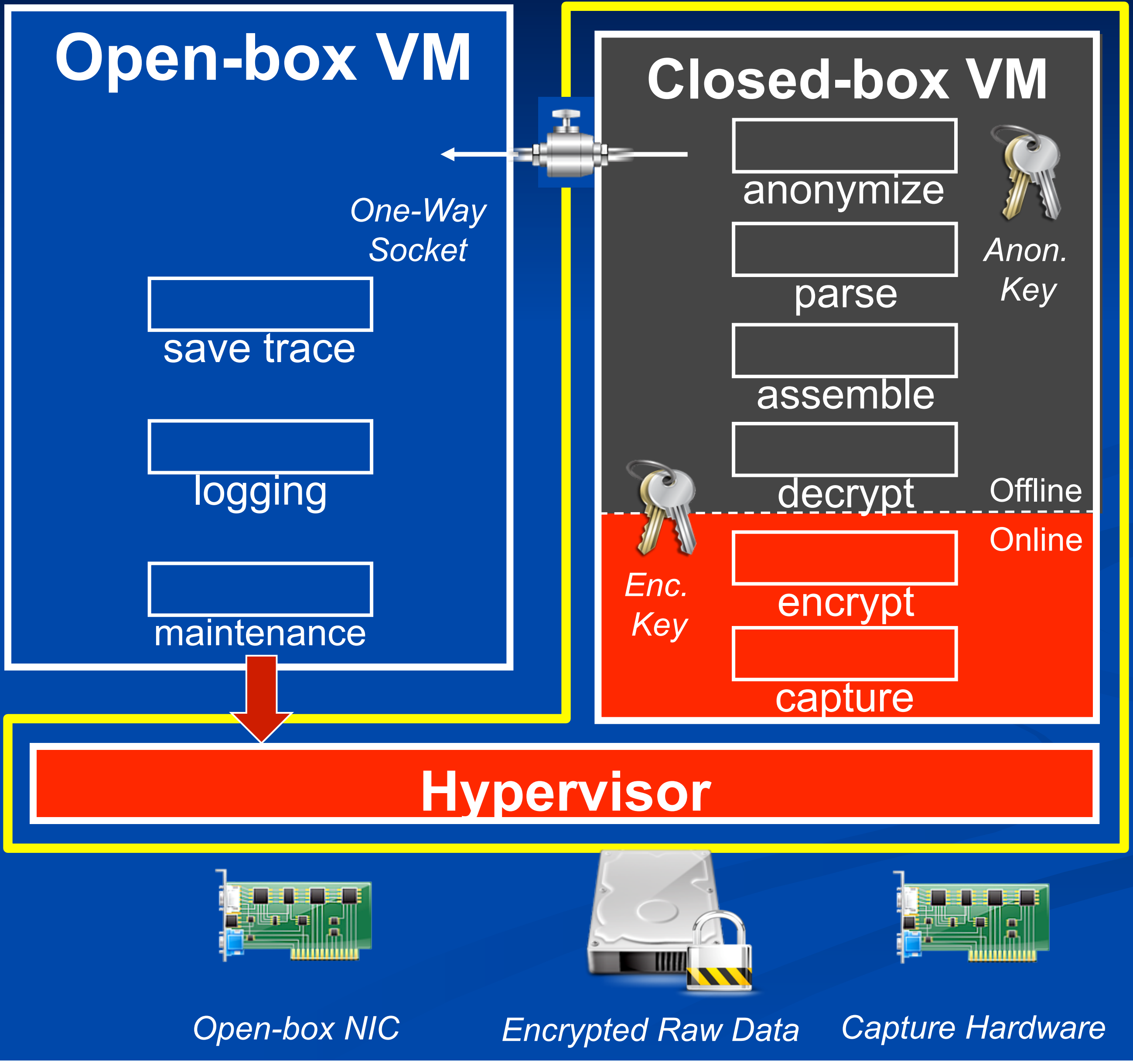

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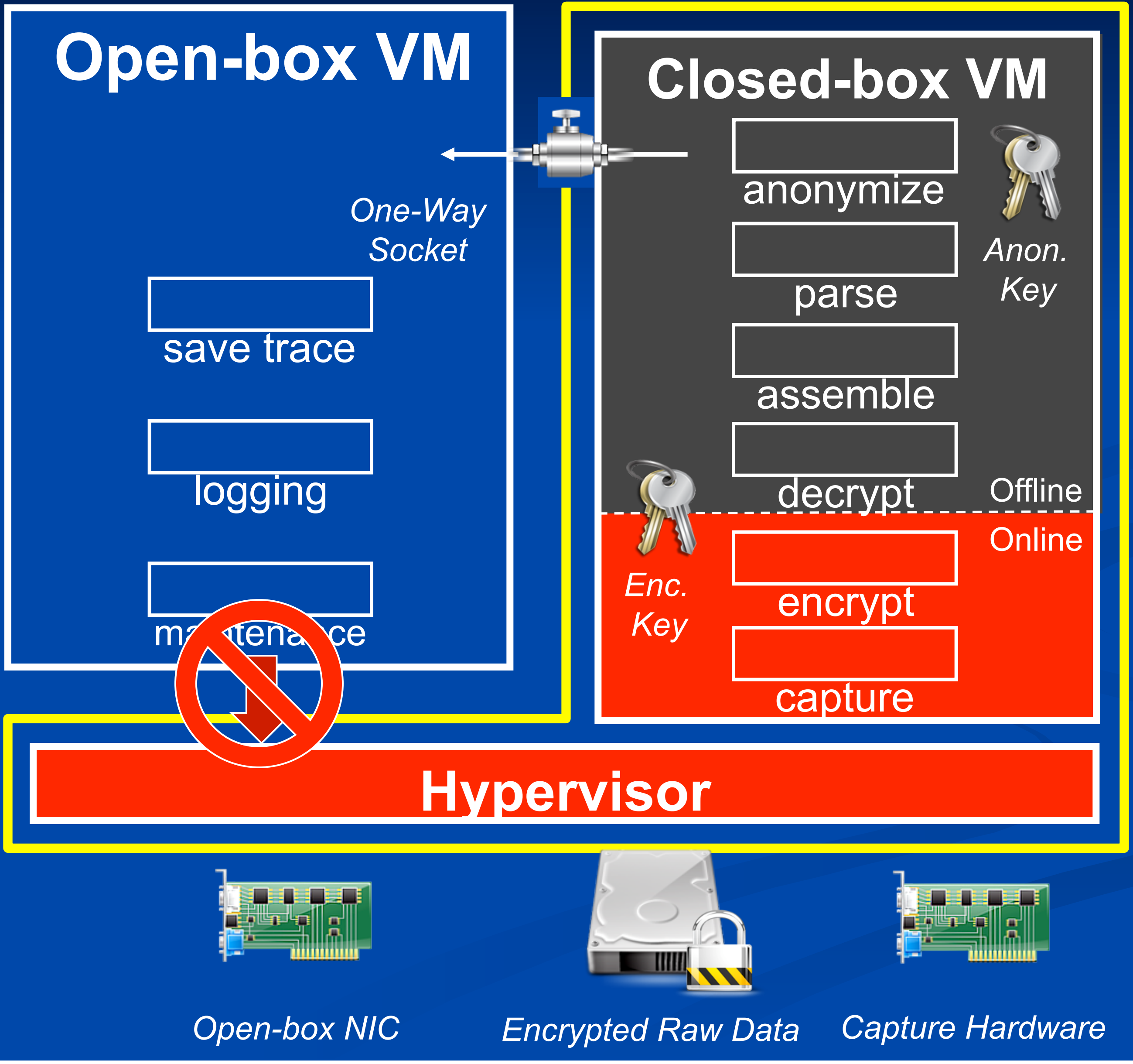

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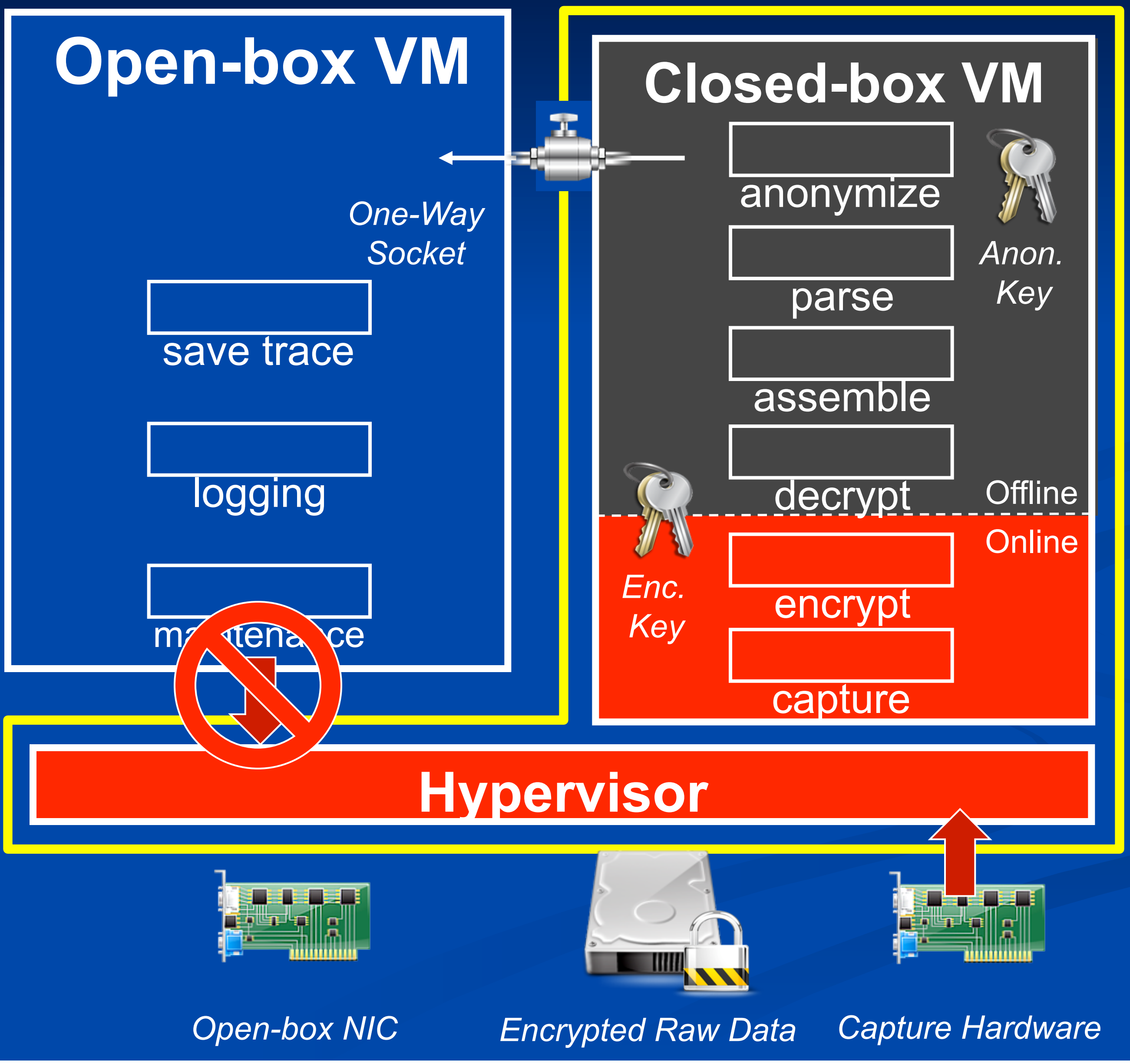

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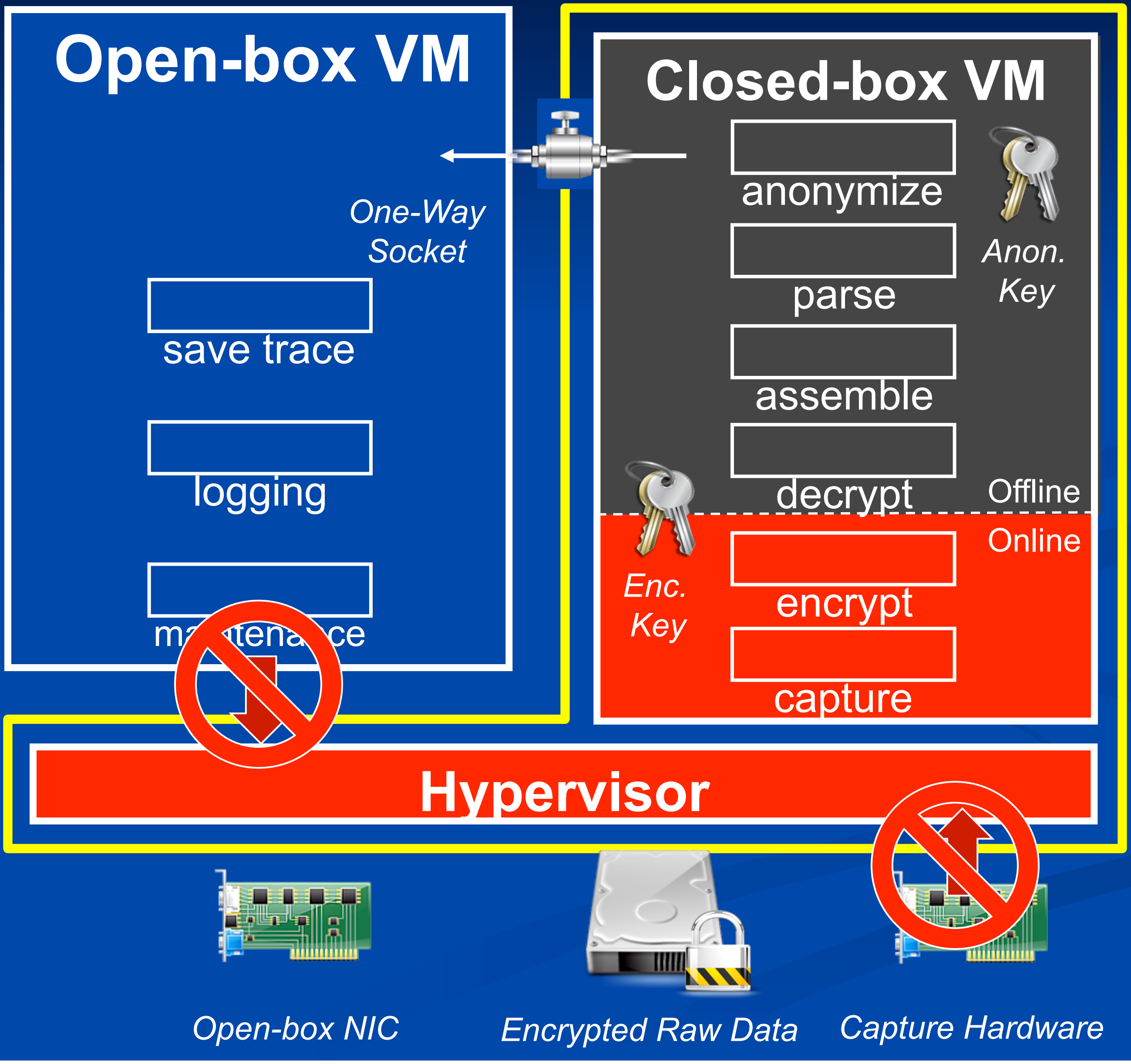

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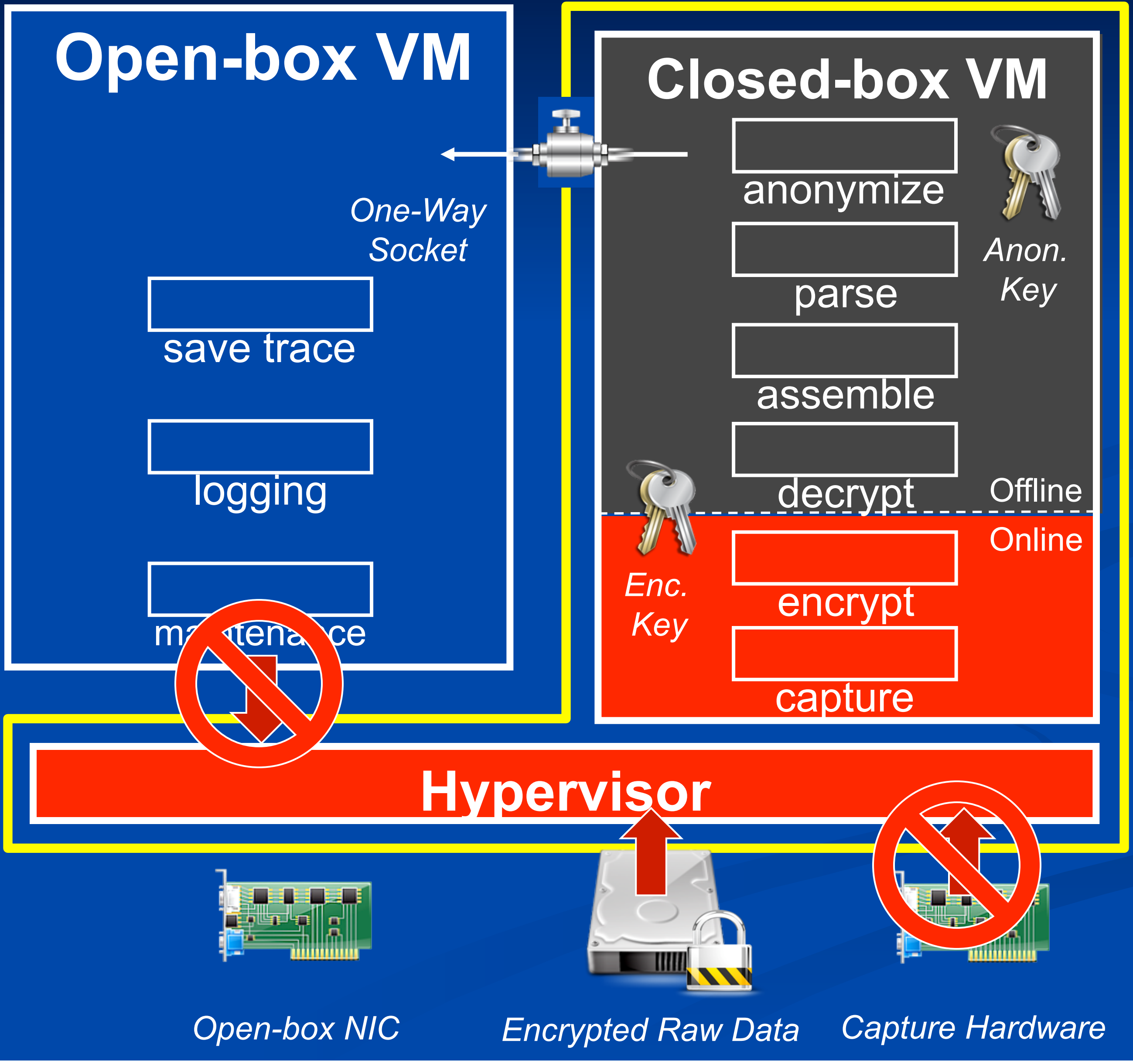

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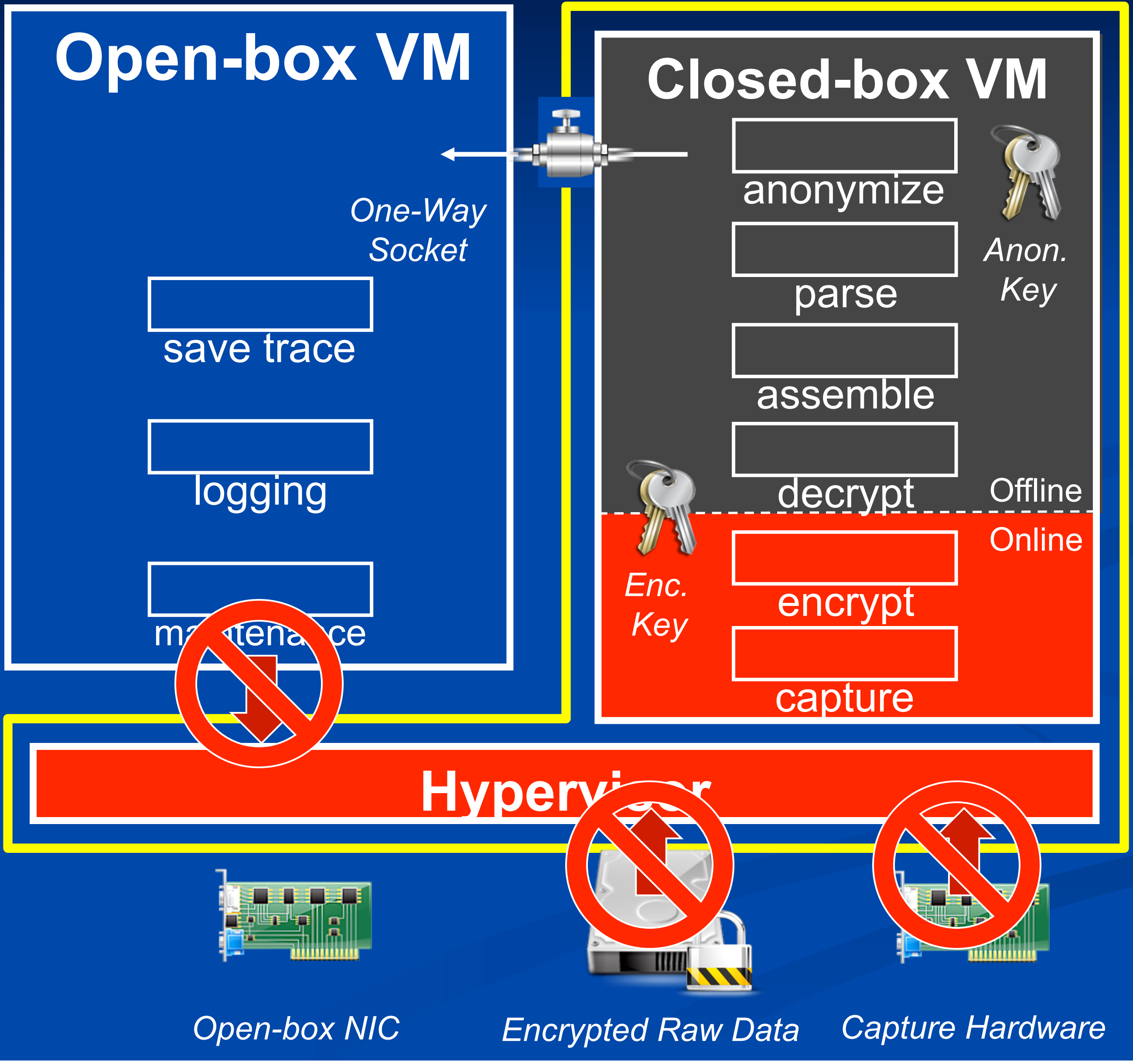

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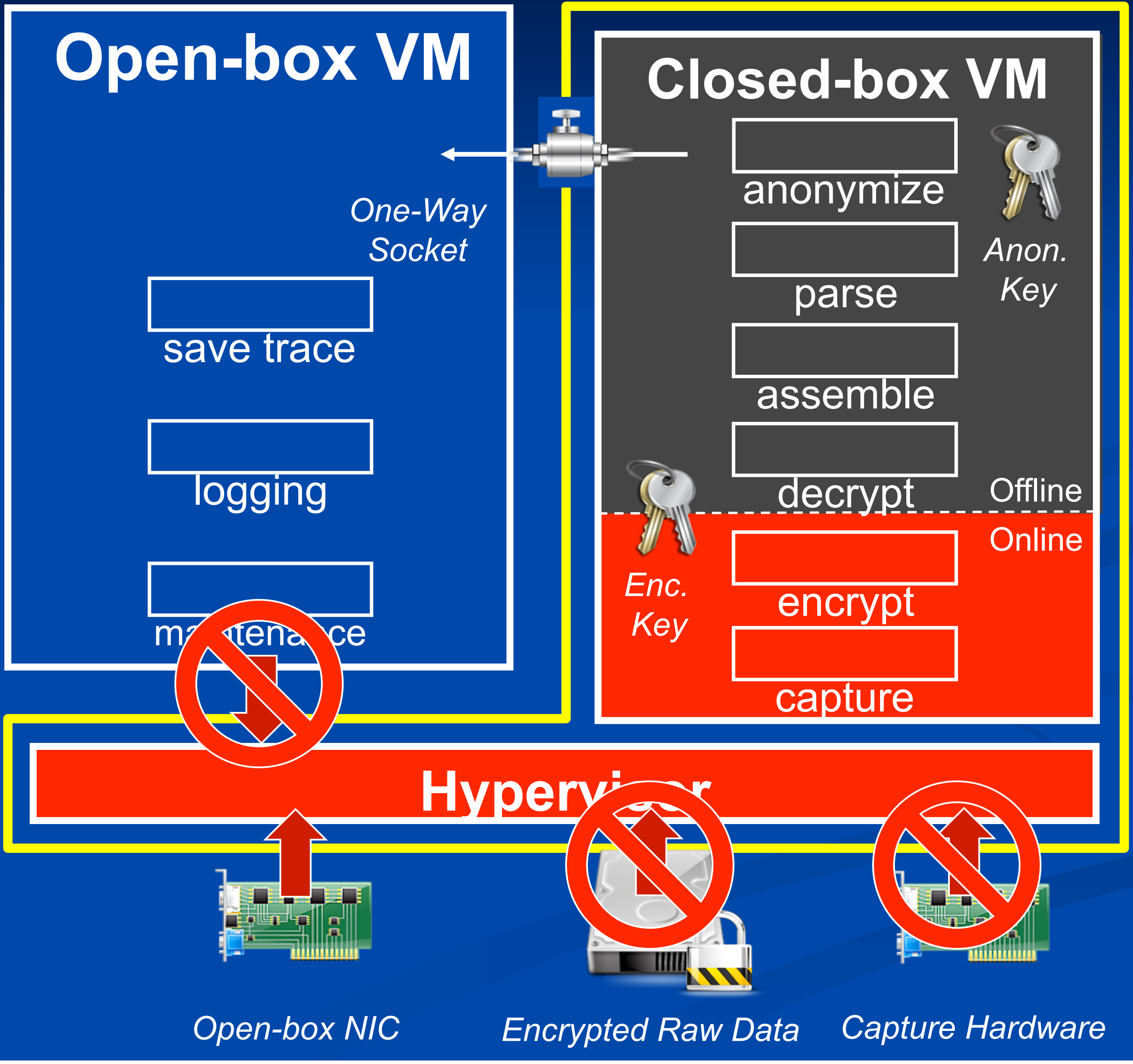

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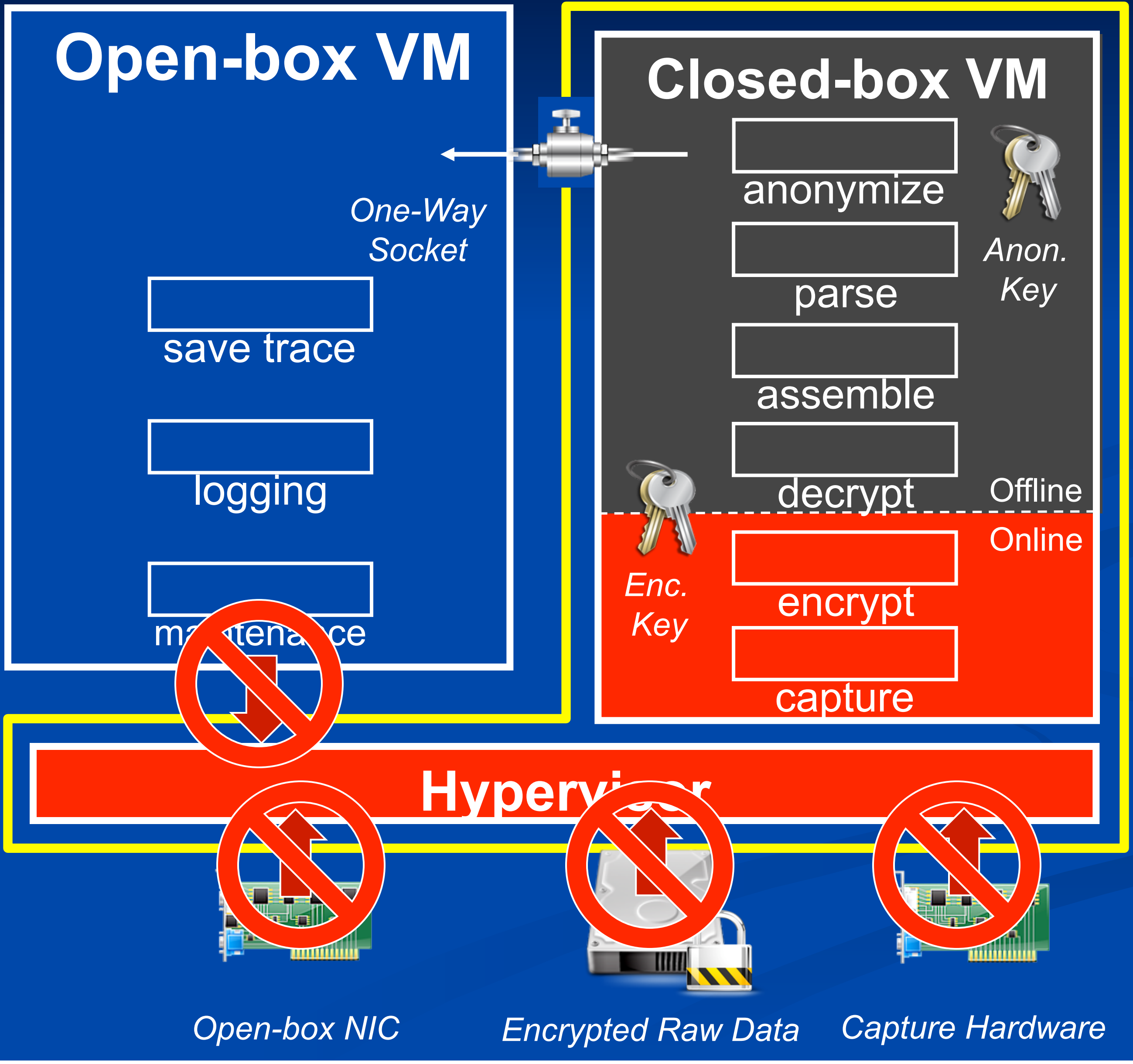

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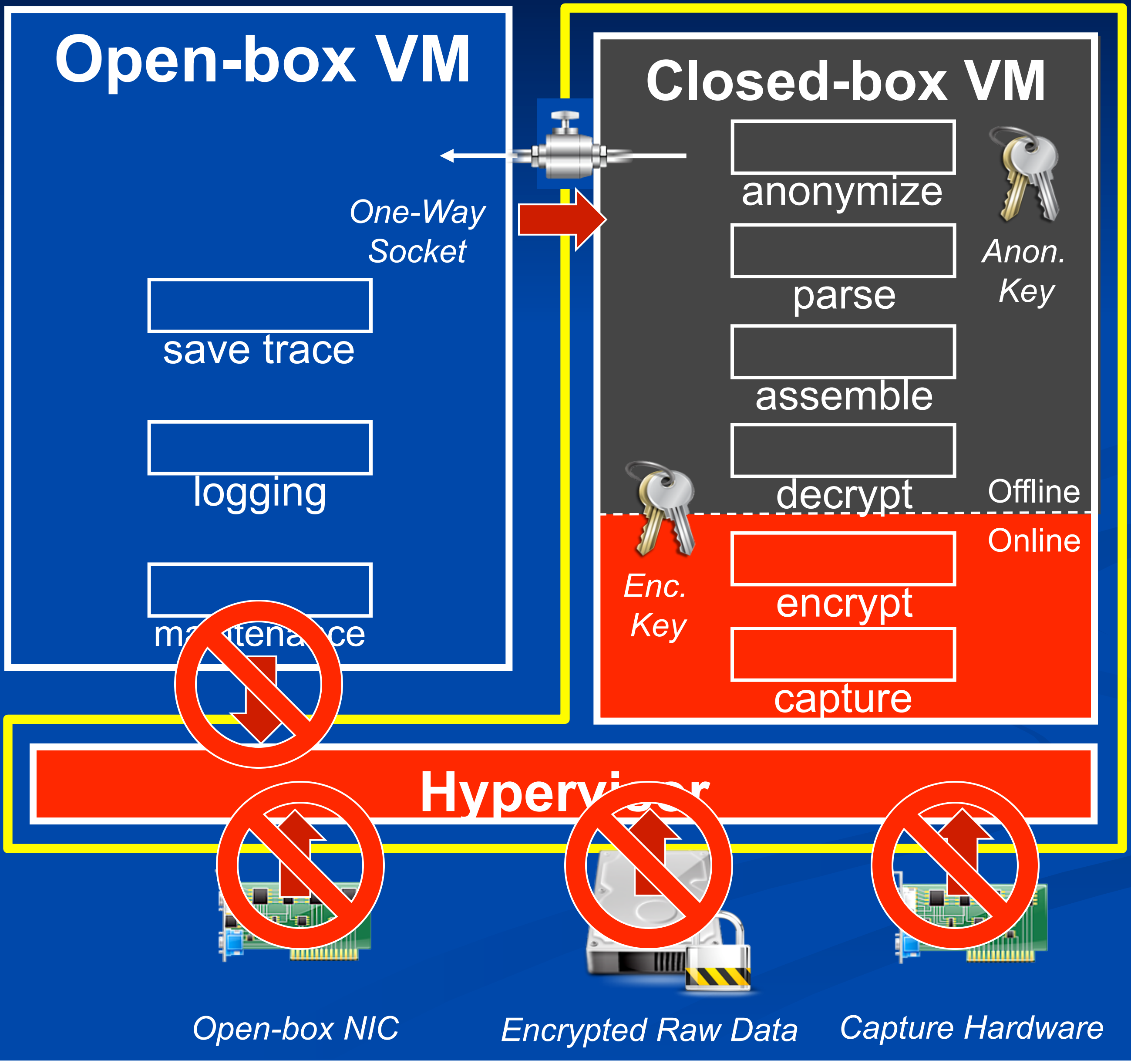

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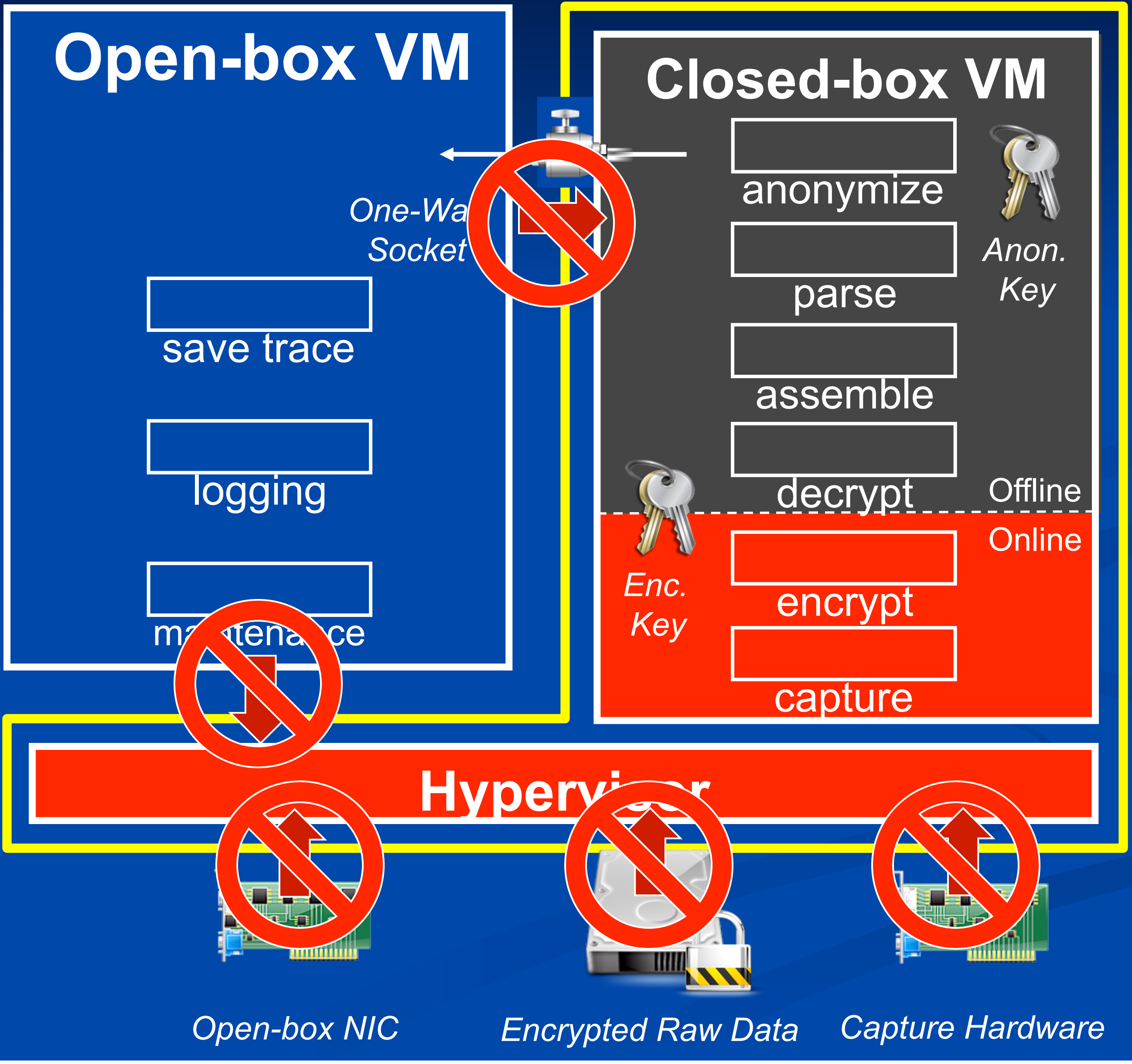

Three Classes of Attacks

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Attacker Tampers with Hardware

- Safe-on-reboot eliminates most H/W attacks
- Attack left: extracting keys from RAM while system is running
  - Cold-boot attacks
  - Attaching bus monitor
  - Specialized device to dump RAM without OS support

- Need hardware support
  - Secure co-processors could thwart such attacks
  - TPMs are not useful!

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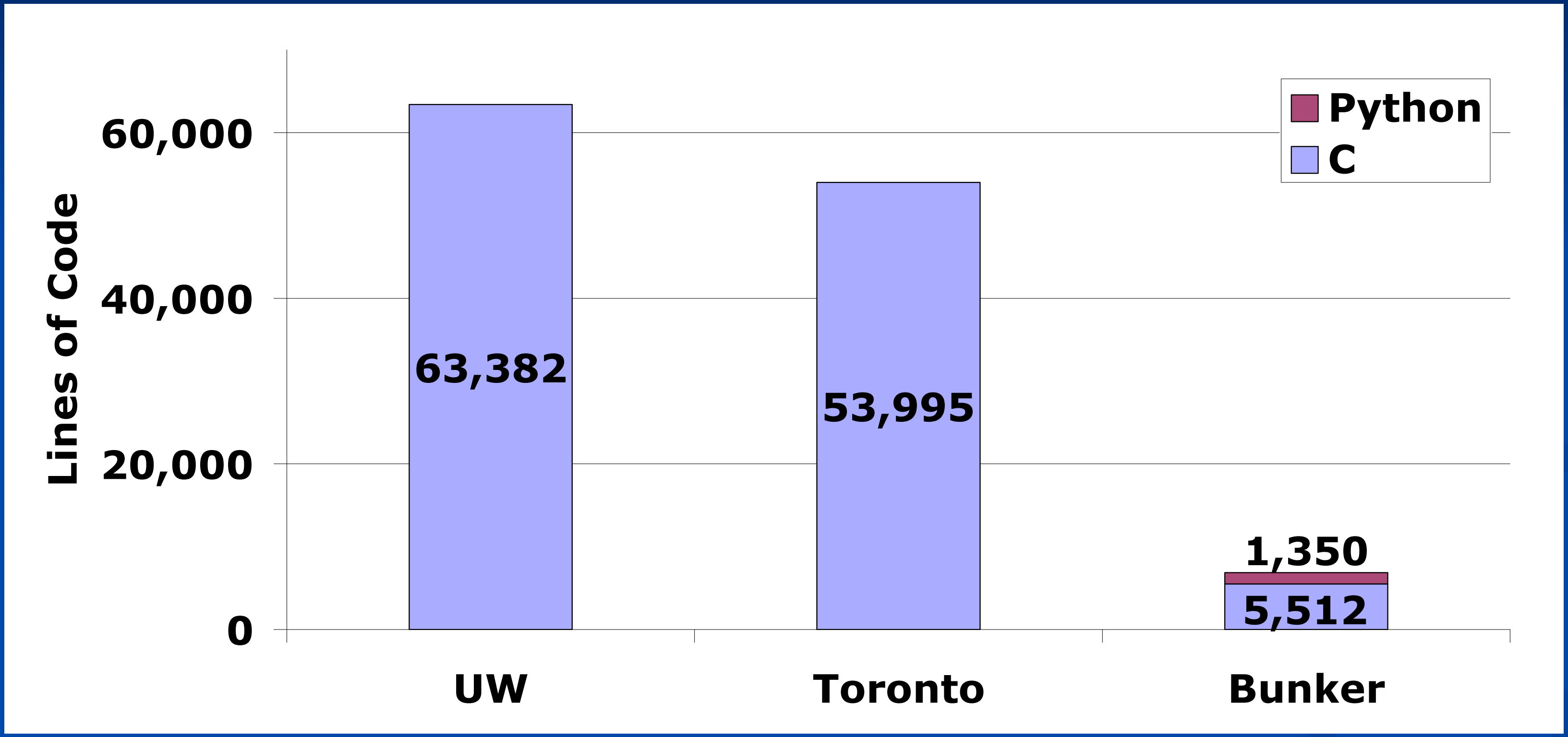
Software Engineering Benefits



Develop. time: 2 months (Bunker) vs. years (UW/Toronto)

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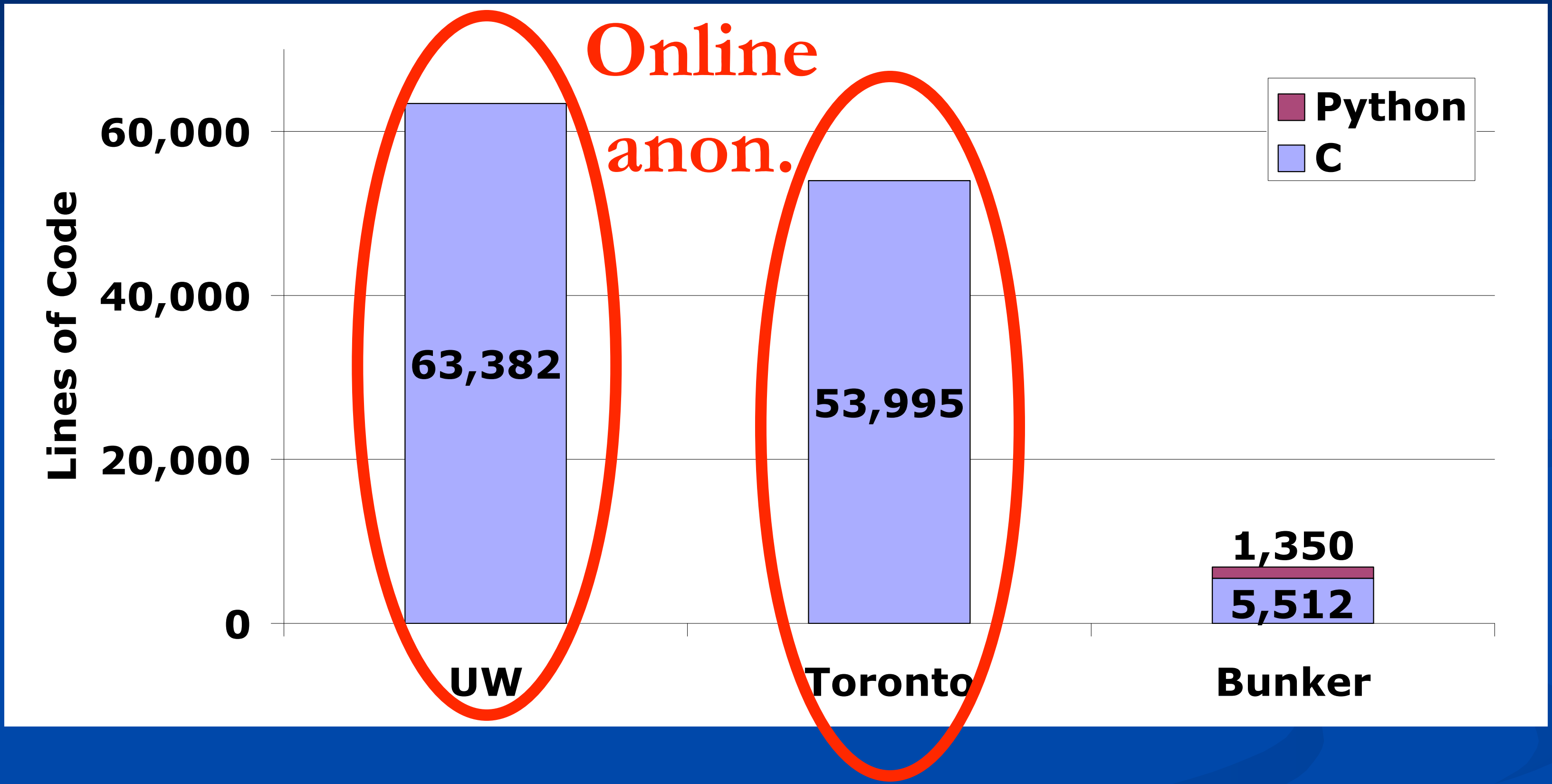

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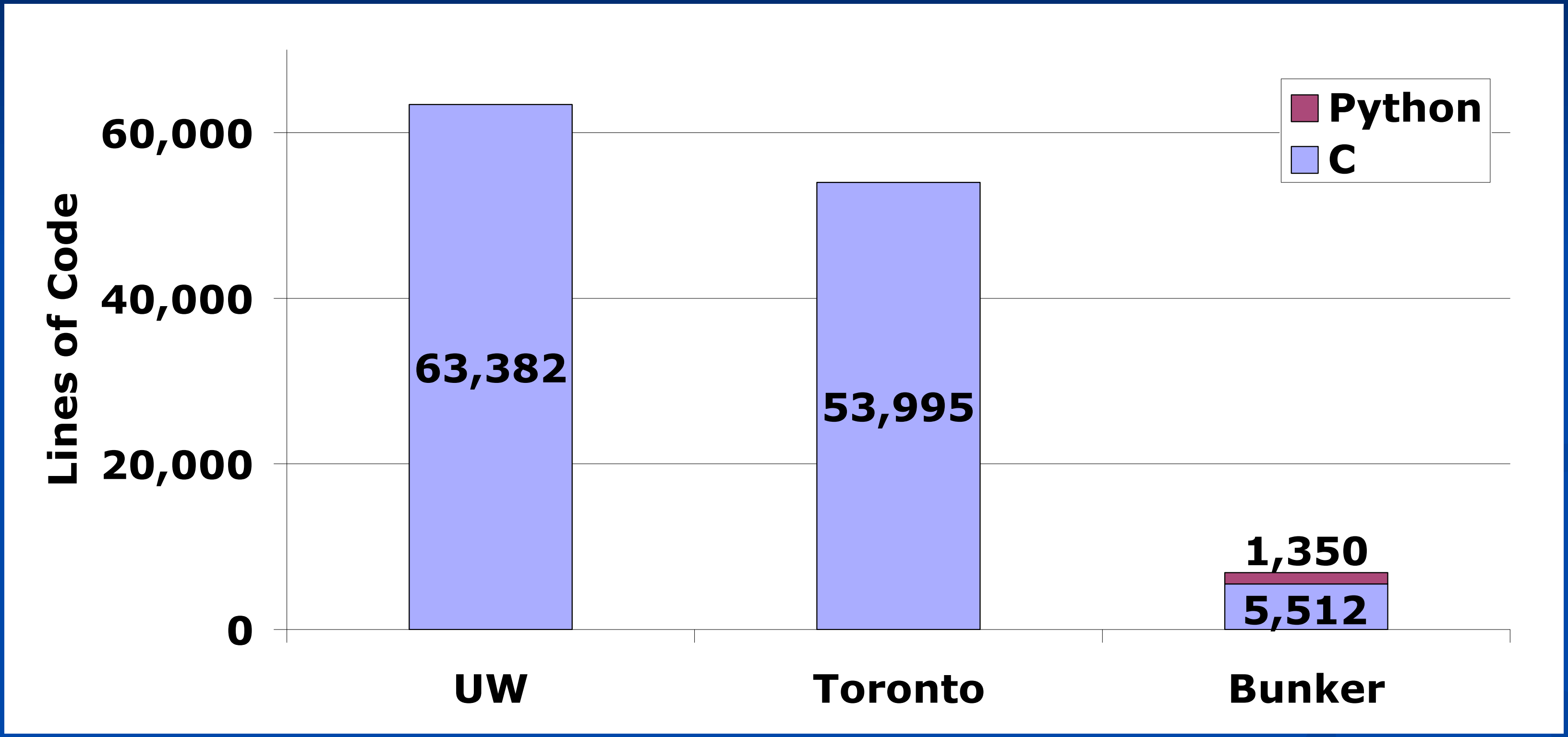

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Conclusions

- Today's network tracing requires privacy properties
  - Operators + researchers look "deep" into the packets
- Offline anon. does not offer privacy properties
- Online anon. requires serious engineering
- Bunker provides
  - the privacy of online anonymization
  - the simplicity of offline anonymization

Questions?

Code available at:

http://www.cs.toronto.edu/~stefan/bunker