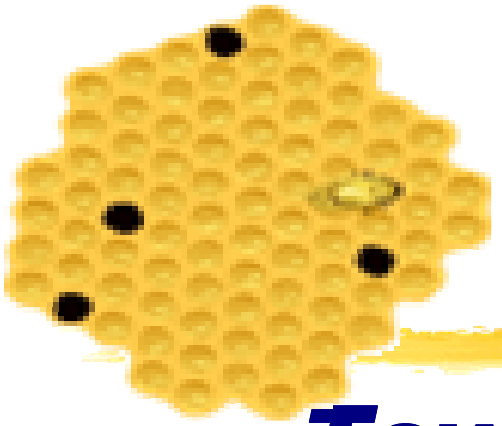

Towards an Invisible Honeypot Monitoring Tool

HITB06

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Who am I ?

- Nguyen Anh Quynh, a PhD student of Takefuji-lab, Keio university, Japan
- Interests: Network/Computer Security, Operating system, Robust system, Virtualization
- Non-geek hobby: traveling, reading and playing soccer



Motivation

- Sebek is a de-facto data capture tool of honeynet architecture
- But there are various ways to defeat Sebek because Sebek is not "invisible" enough
- Xebek is our solution on Xen Virtual Machines to address Sebek's problems
  - More "invisible"
  - More flexible
  - Better performance

Overview

- Honeynet architecture and Sebek
- Sebek's problems
- Xebek comes to rescue
  - Introduction to Xen Virtual Machine
  - Xebek architecture & implementation
  - Demonstration
- Q & A

Part I

- Honeynet architecture and Sebek
  - Honeypot introduction
  - Honeynet architecture
  - Sebek technology

Honeypot technology

- What is a honeypot?
  - The information system resource whose value lies in unauthorized or illicit use of that resource
  - Has no production value, anything going in/out the honeypot is likely a probe/attack/compromise
  - Primary value to most organizations is information

Honeypot impact

- **Advantage**
  - High valuable data
  - Reduce false positives
  - Catch new attacks (0-day bug?) & false negatives

- **Disadvantage**
  - Limited view
  - Risk of take over

Honeypot types

Categorized based on level of interaction

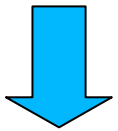
Low-interaction

- Emulate services, applications, OSes
  - Low risk and easy to deploy/maintain
  - But capture limited information

Honeyd

High-interaction

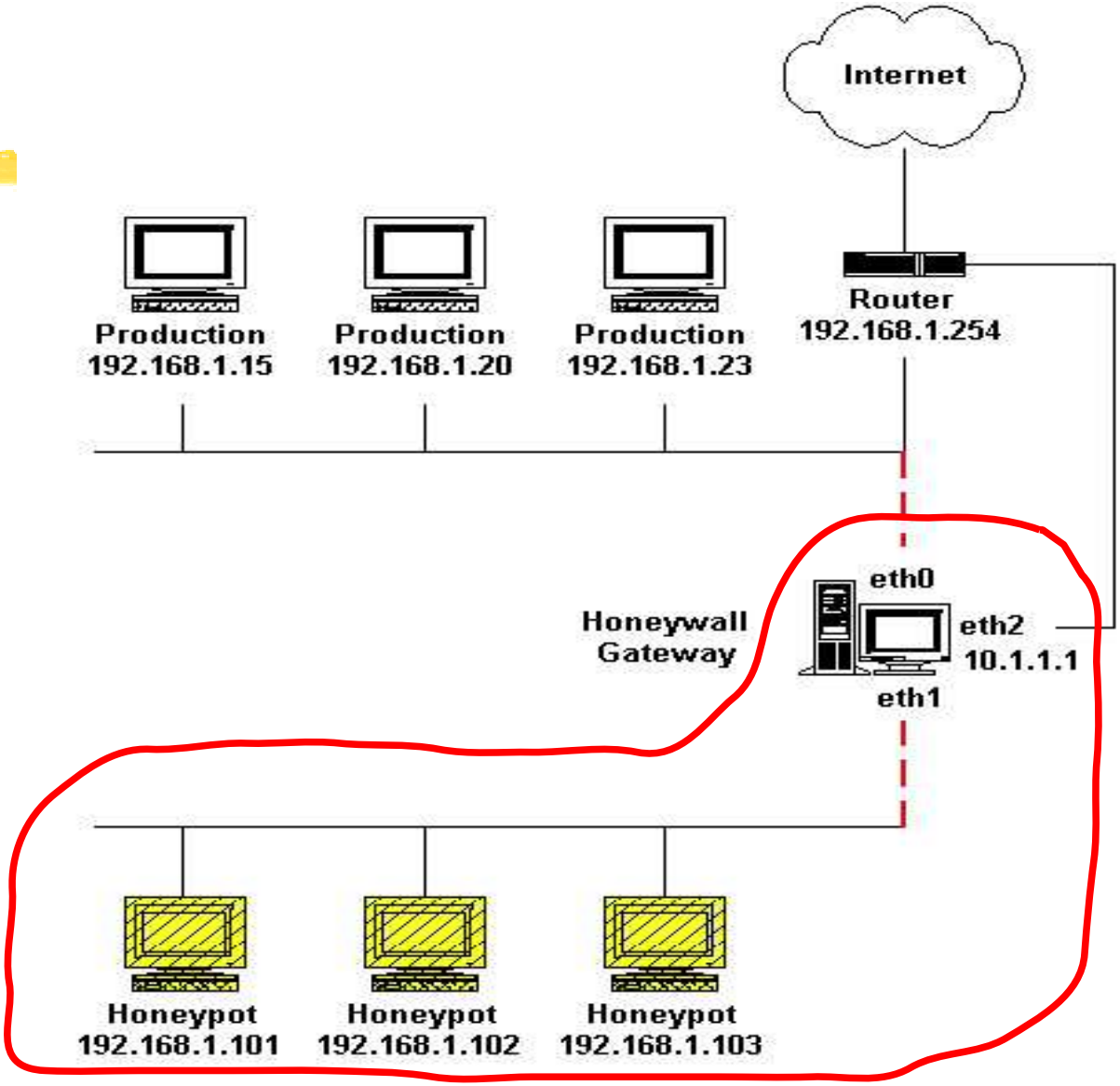
- Real services, application, OSes
  - Capture extensive information
  - But high risk and hard to maintain



Honeynet

How honeynet works

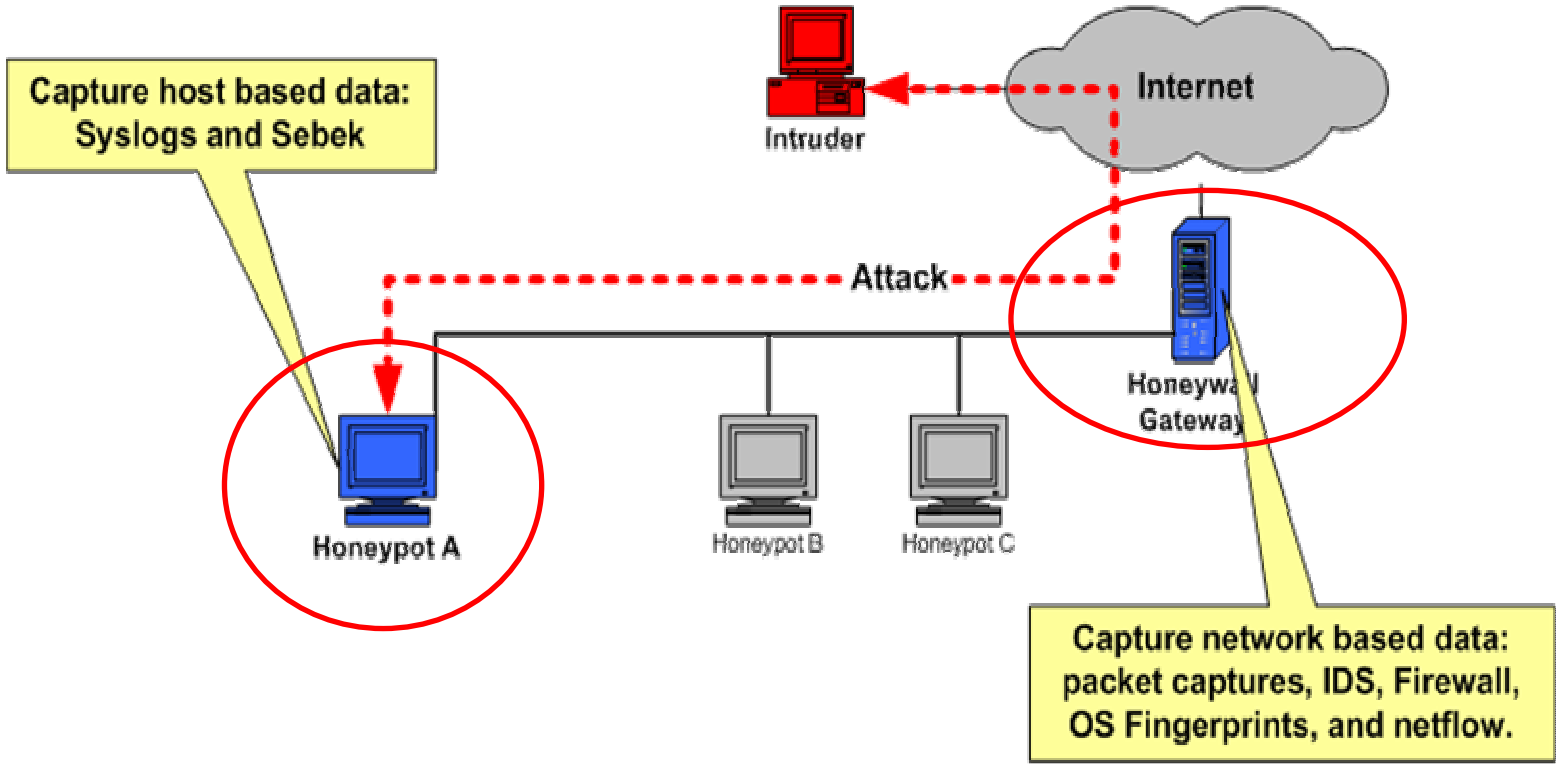
- A highly controlled network where every packet entering or leaving is monitored, captured and analyzed



Honeynet components

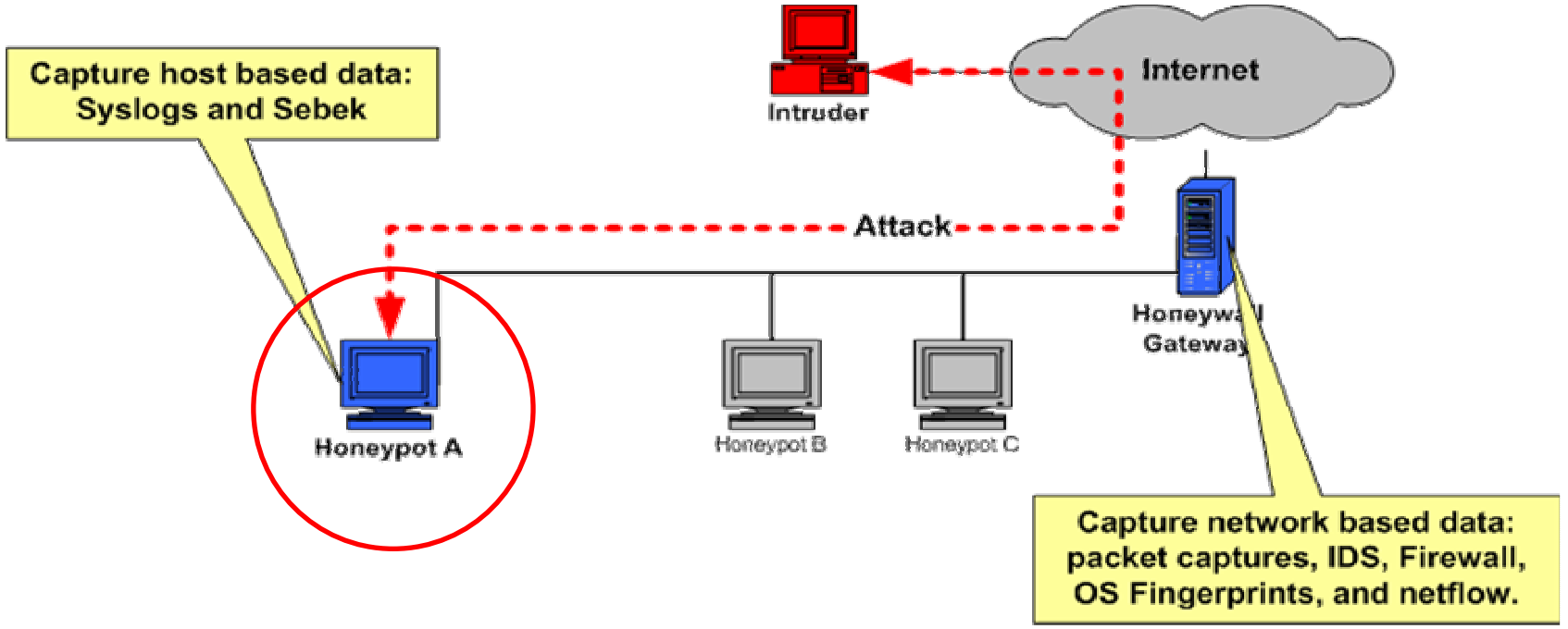
2 key components

- Data capture
- Data logging & analysis



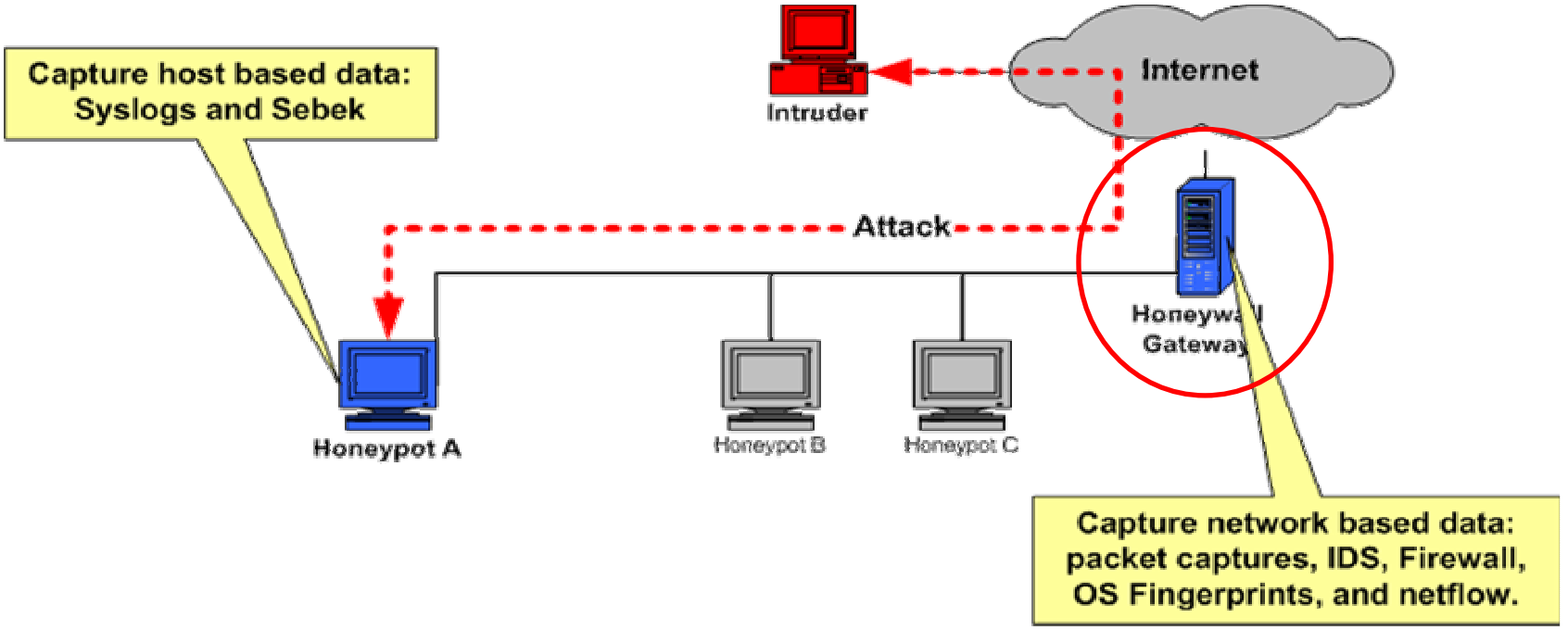
Data capture

- Capture activities at various levels
  - Application
  - Network
  - OS level



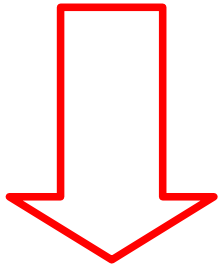
Data analysis

- Manage and analysis captured data from honeypots
  - Investigate malware
  - Forensic purpose



Honeynet generations

- Gen I
- Gen II, Gen III (currently)
  - radical change in architecture focuses on the data capture tool



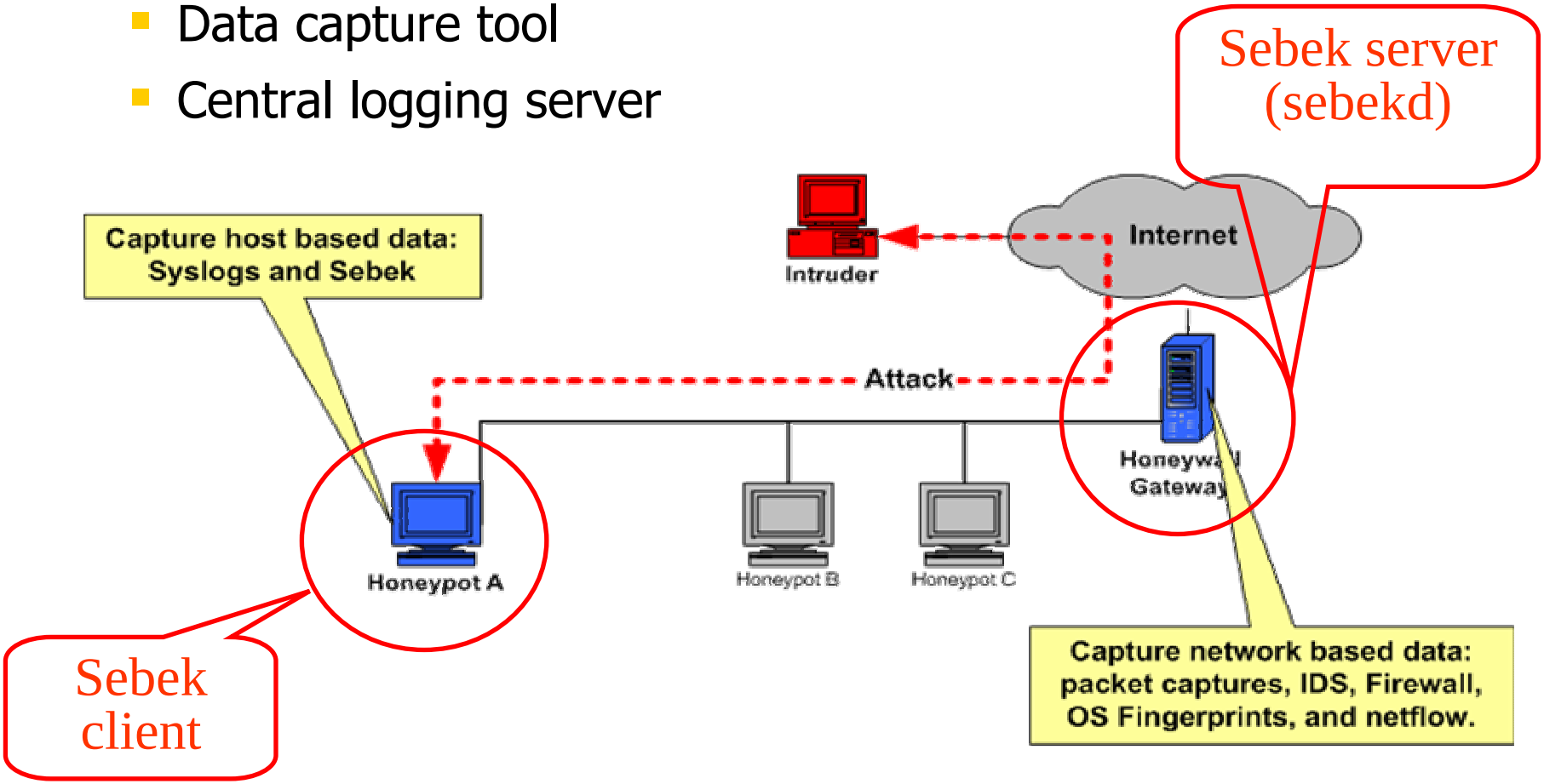
Sebek as a data capture tool

Sebek : a data capture tool

- Born in Honeynet Gen II
- Play a key role in Honeynet architecture
- Gen III (currently)

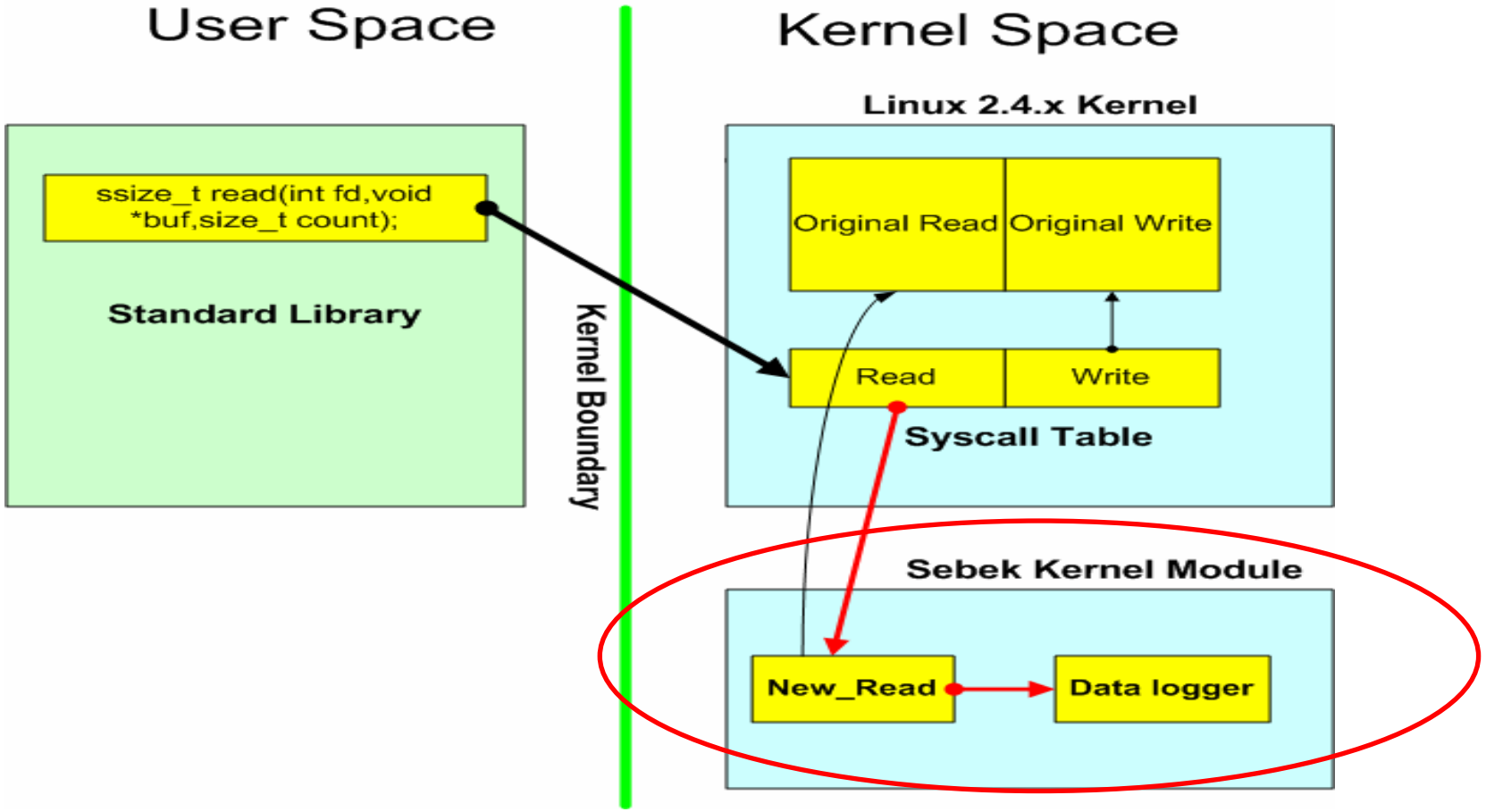
Sebek architecture

- Sebek components
  - Data capture tool
  - Central logging server



Sebek client technique

- Data capture tool: patches system-calls (open/fork/read/write/socket)
- Send out gathered data via network-stack (UDP protocol)



Sebek features

- hidden kernel module
- dumps activity to the network via UDP protocol to a central logging machine
- fool attacker by modifying network stack, so Sebek traffic is invisible (well, almost!)

Part 2

- Current problems of Sebek
  - Easy to identify
  - How easy it is?
    - Possible even with unprileged user
  - How ?
  - **7 methods** to defeat Sebek

Sebek client requirement

- Most vital requirement for a data capture tool: Function as covert as possible => Invisible problem
  - Otherwise, game over
    - No more chance to watch out the attacker
    - No more chance to catch 0-day bug (daydream?)
    - Attacker can destroy the honeypot
    - Who fools who then?

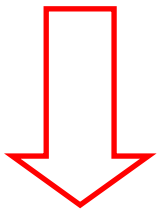
But can Sebek deliver?

- Hmm, not really. Various ways to defeat Sebek
  - 1. Can be discover by even unprivileged user
  - 2. Network statistics disclose Sebek
  - 3. Brute-force scanning method
  - 4. System-call address checking
  - 5. Remove Sebek is feasible
  - 6. Sniff at the right place
  - 7. Bring down the central logging server

Method (1)

- Sebek can be discover by even unprivileged user
  - dd-attack
    - Generate lots of data

      dd if=/dev/zero of=/dev/null bs=1
    - Check to see if network congestion ?

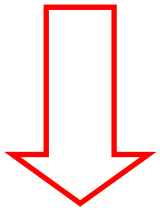


Why?

Network stack is employed to send data out

Method (2)

- Network statistics disclose Sebek
  - Compare dev->getstats()->tx_bytes with value found in /proc/net/dev

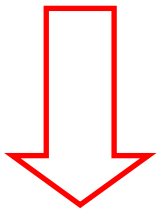


Why?

Network stack is employed to send data out

Method (3)

- Brute-force scanning method to detect hidden kernel module
  - Look for hidden kernel module
  - **linux-airt** tool by madsys



Why?

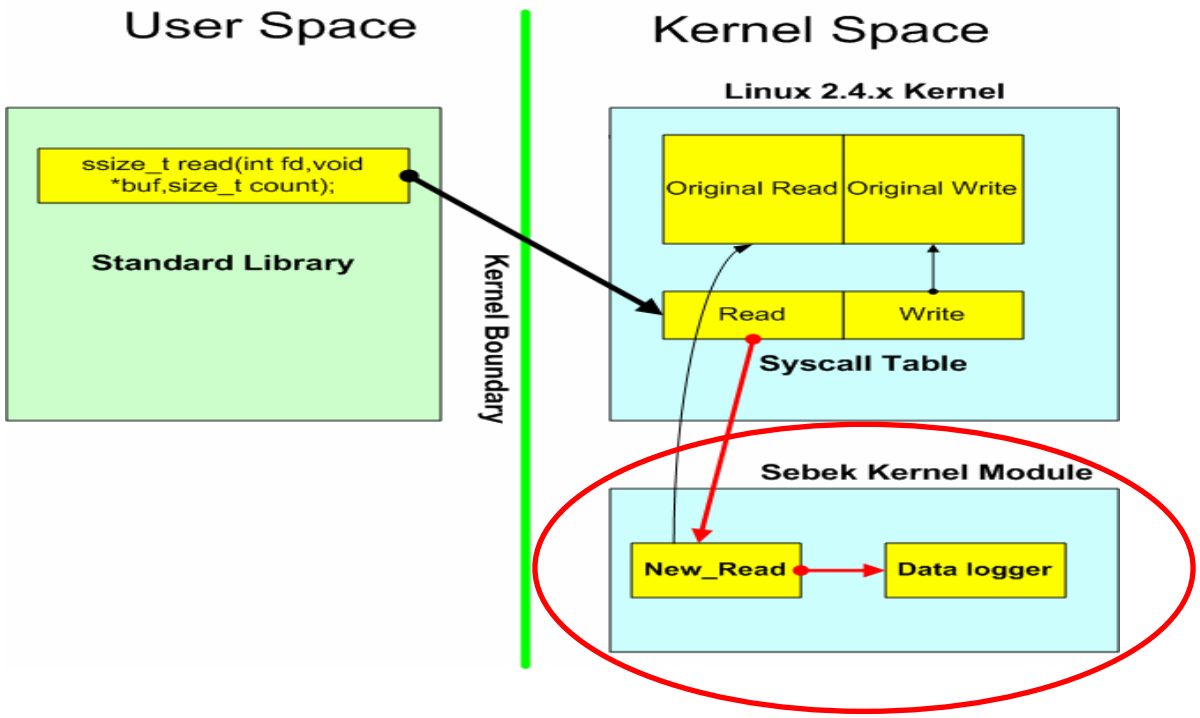
Sebek is implemented as a (hidden)kernel module

Method (4)

- System-call addresses checking
  - System-call addresses at abnormal places?

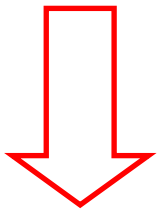
Why?

Sebek replaces original system-calls



Method (5)

- Remove Sebek is feasible
  - (unsebek.c by J.Corey)
  - Look for the **sys_call_table** by scanning in memory
  - Recover original system-call with exported symbols

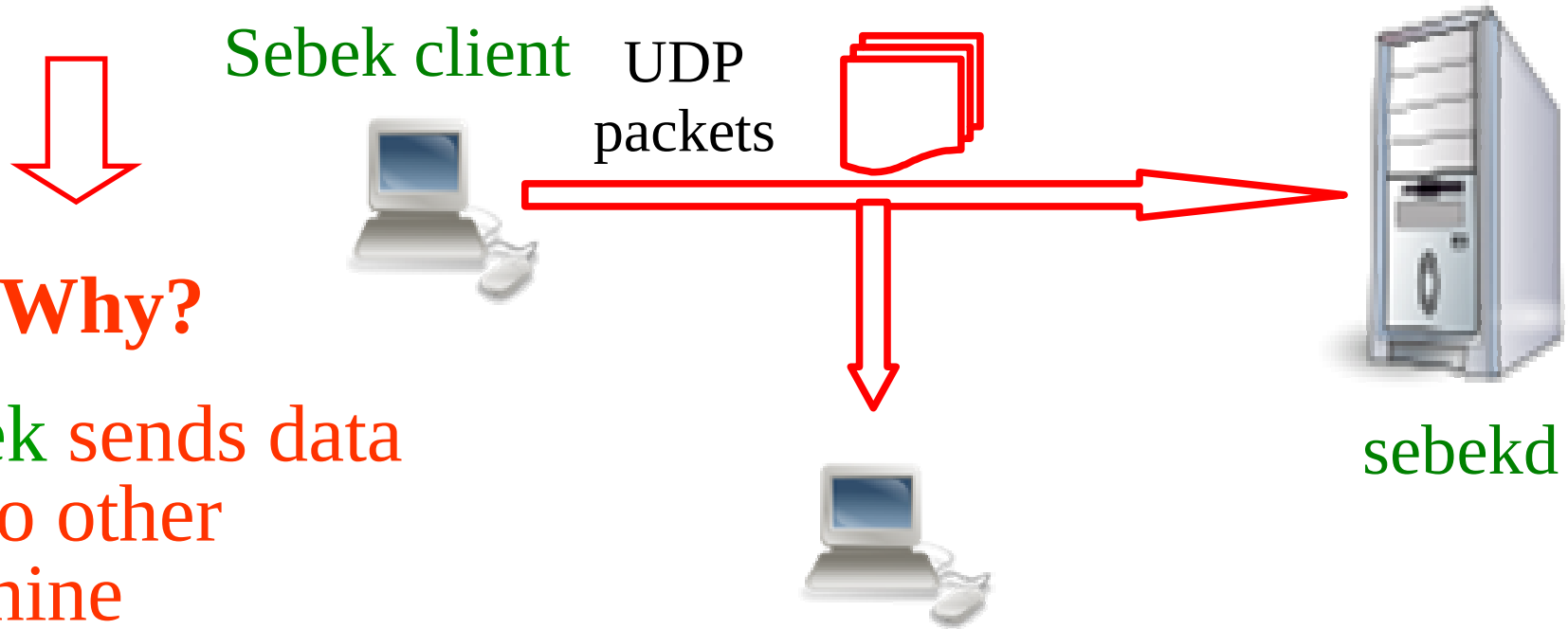


Why?

Sebek replaces orginal system-calls

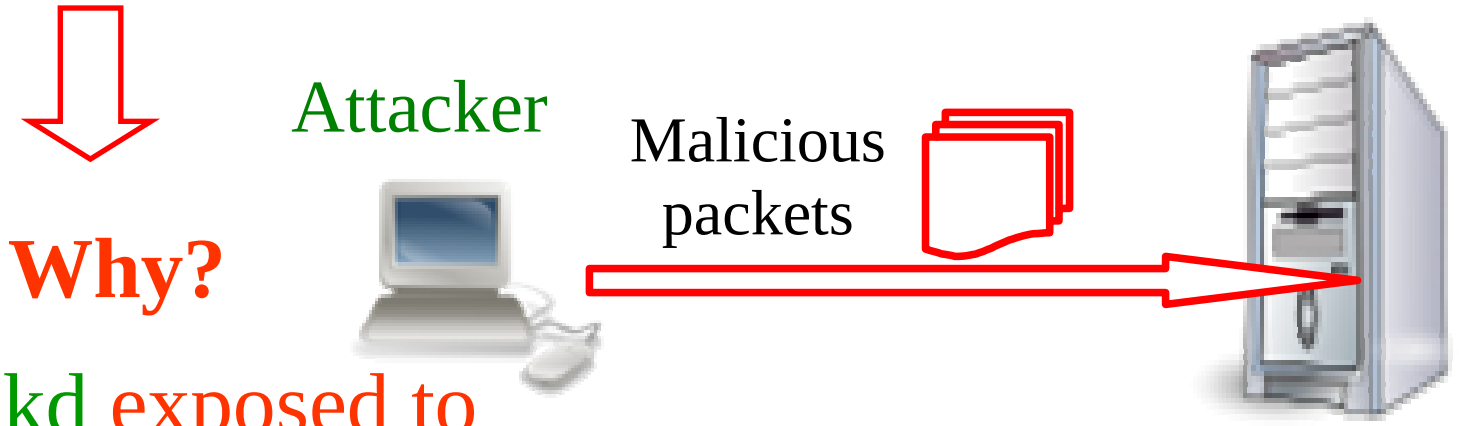
Method (6)

- Detect honeypot with Sebek
  - Sniff at the right place from outside



Method (7)

- Bring down the central logging server
  - Data logging server (sebekd) has vulnerable libpcap?



Why?

sebekd exposed to network

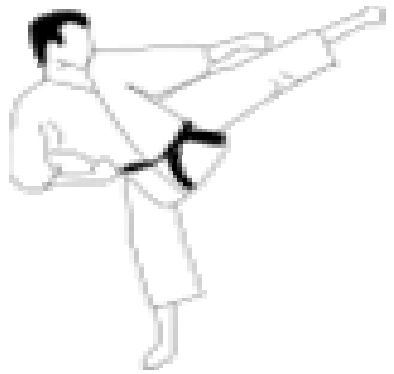
Sebekd
with **buggy libpcap**

Reasons make Sebek sux ☺

- (1) Uses network stack to send data out
- (2) Logging data sent out can be sniffed online
- (3) Function as kernel module + replace original system-calls
- (4) Central logging server (sebekd) exposed to the network
- (5) Data transfer might not be reliable (UDP)

Do you still think that current honeynet can fool skillful hackers?

- I seriously doubt that!
- Should we give up?
- No, let's keep fighting and raise the bar a little bit ;-)



Part 3

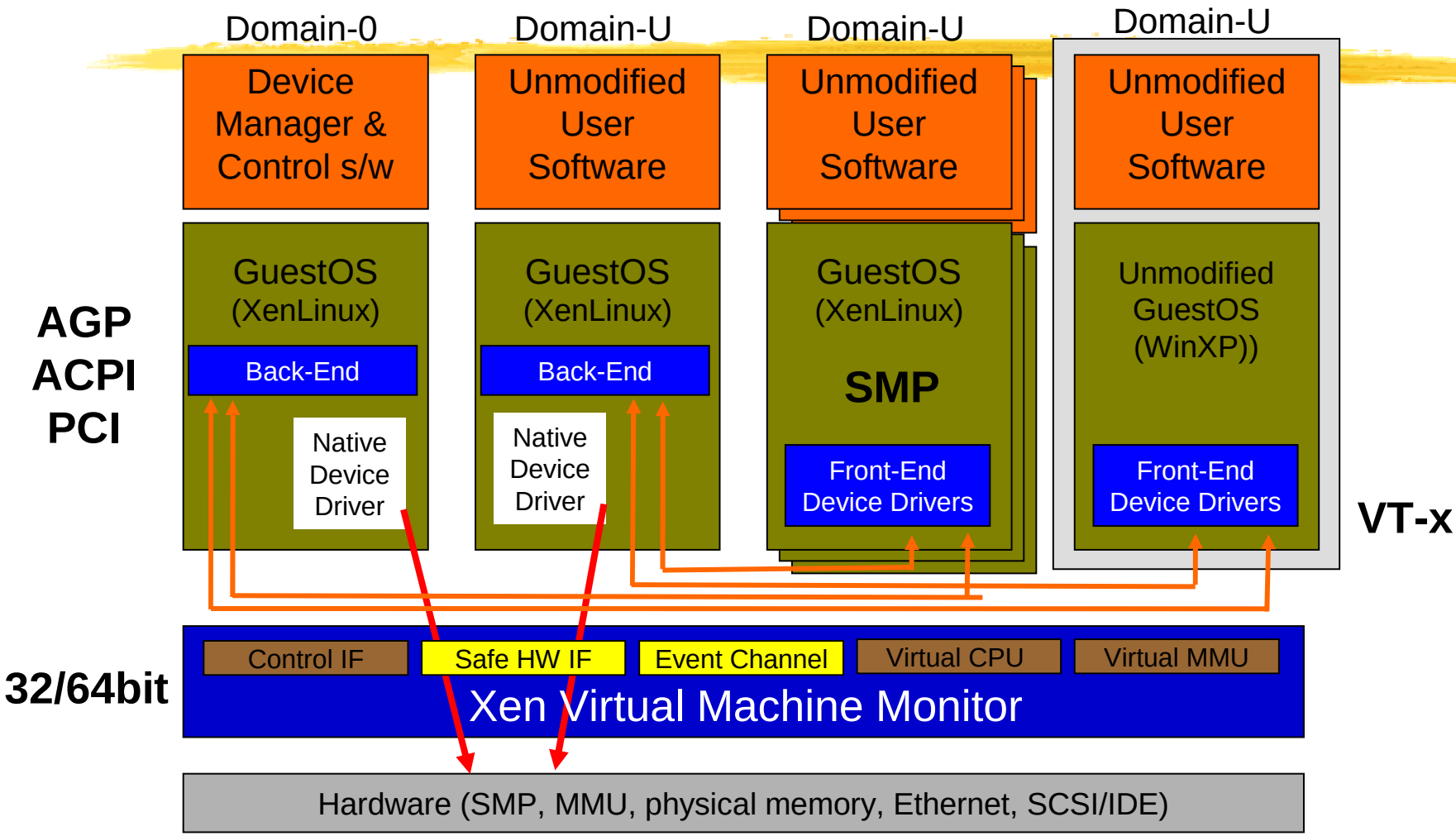
Xebek comes to rescue

- Virtual honeypot on virtual machine
- Xen Virtual Machine technology
- Xebek solution

Fix Sebek's problems

- Bring up virtual machine technology: Xen
- Exploit the advantage introduced by Xen to address discussed problems

Xen 3.0 Architecture



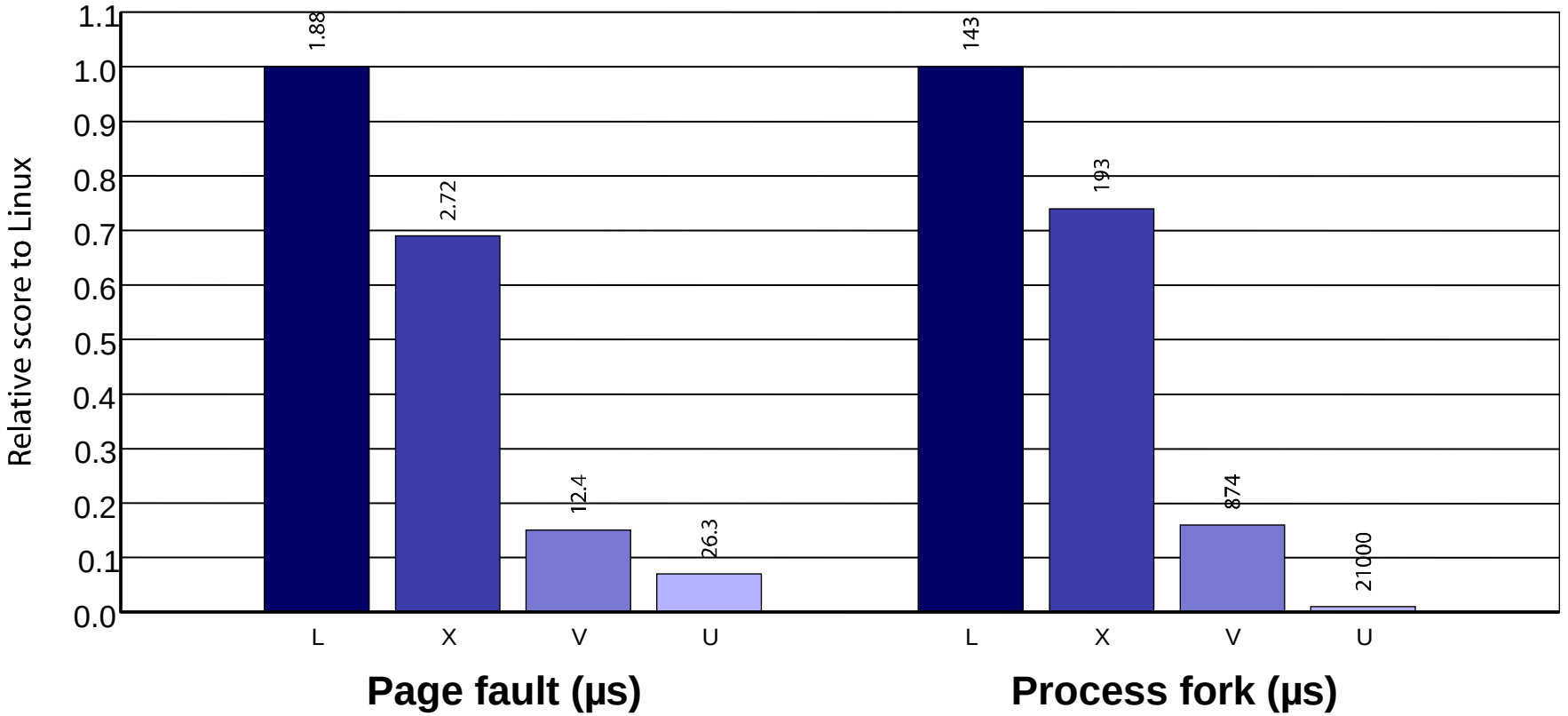
Xen's main components

- Xen hypervisor runs on top of hardware
- Domains with modified kernel for Xen architecture, run on top of Xen
- Special device drivers in Dom0 & DomU (backend-frontend architecture)
- Xen control tools in Dom0 (**xend**, **xm**)
- Others: **xenbus**, **xenstore**, **event-channel**, **balloon driver**, …

x86 CPU virtualization

- Xen runs in ring 0 (most privileged)
- Ring 1/2 for guest OS, 3 for user-space
  - GPF if guest attempts to use privileged instr
- Xen lives in top 64MB of linear addr space
  - Segmentation used to protect Xen as switching page tables too slow on standard x86
- Hypercalls jump to Xen in ring 0

MMU Micro-Benchmarks

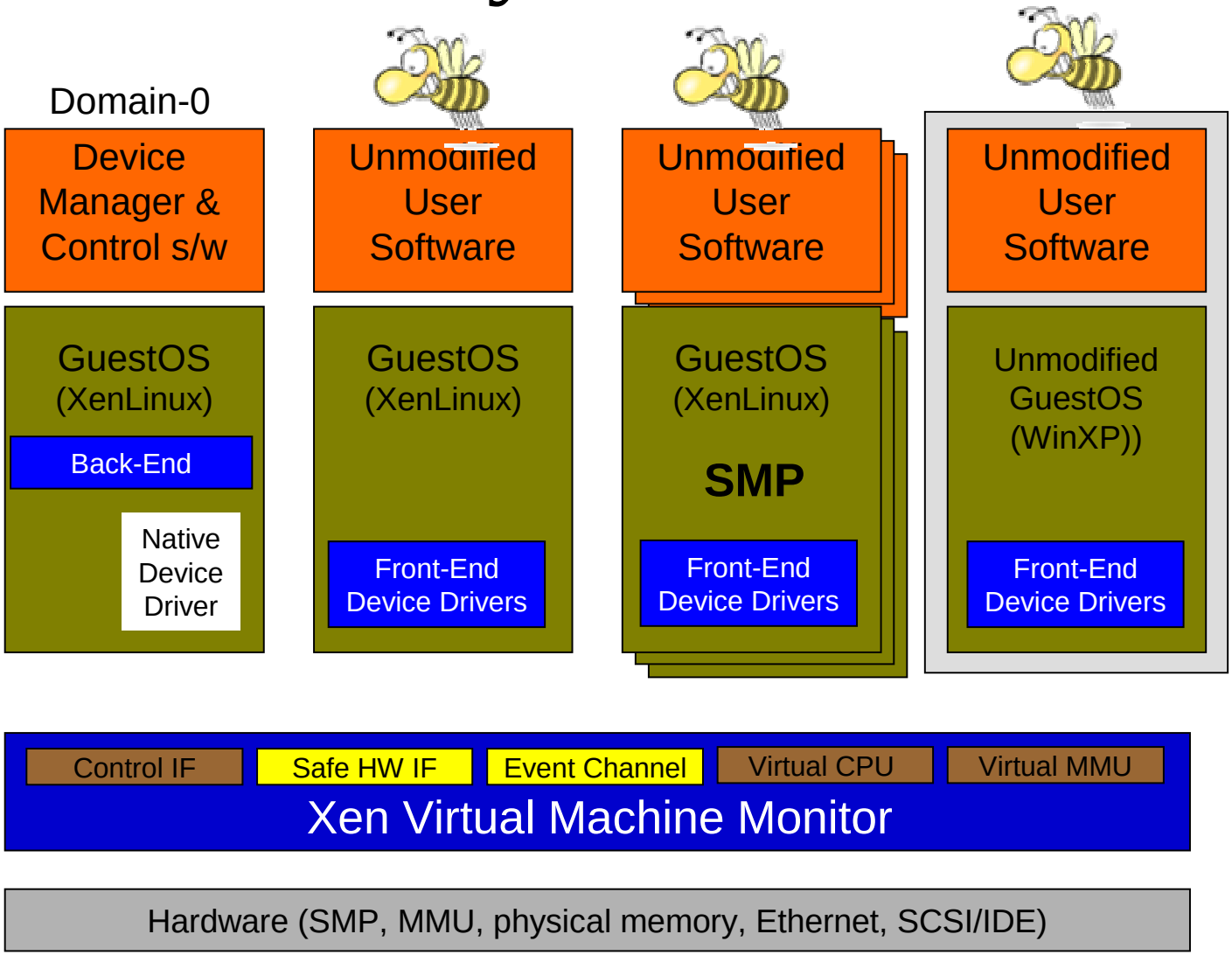


lmbench results on Linux (L), Xen (X), VMWare Workstation (V), and UML (U)

Xen's future: Bright

- Xen 3.0 was realeased at the end of 2005
- Object: to be gradually merged into Linux kernel in 2006
- Already adopted by ISPs, datacenters, banks,...
- Will be widely used in the near future

Xen-based honeynet



Xebek solution for Xen-based honeynet

- Xebek: Goals and approaches
- Xebek Architecture
- Xebek Implementation's issues
- Xebek Evaluation
- Hardening Xebek
- Detecting Xebek

Xebek goals and approaches

- (1) Capture data as Sebek does, but with some improvements
- (2) Eliminate problems of leaving too many traces when forwarding data out
- (3) Harden the central logging server

Goal (1)

- Capture data as Sebek does, but with some improvements
  - Sebek3 captures data by intercepting system-calls (read/write/open/fork/socket)
  - ==> so Xebek does.
  - But Xebek patches the system-calls, so Xebek does not run as a kernel module

(1) Uses network stack to send data out

(2) Data can be sniffed

(3) Function as KLM & replace original system-calls

(4) Central logging server exposed to the network

(5) Data transfer might not be reliable (UDP)

Goal (2)

- Eliminate problems of leaving too many traces when forwarding data out
  - Xebek does not use network stack to deliver data as Sebek does
  - Using shared memory between DomU and Dom0 instead to exchange data

(1) Uses network stack to send data out

(2) Logging data can be sniffed online

(3) Function as KLM & replace original system-calls

(4) Central logging server exposed to the network

(5) Data transfer might not be reliable (UDP)

Goal (3)

- Harden the central logging server
  - Put the central logging server in Dom0 to pick up data forwarded from DomU
  - No more exposed to the network

(1) Uses network stack to send data out

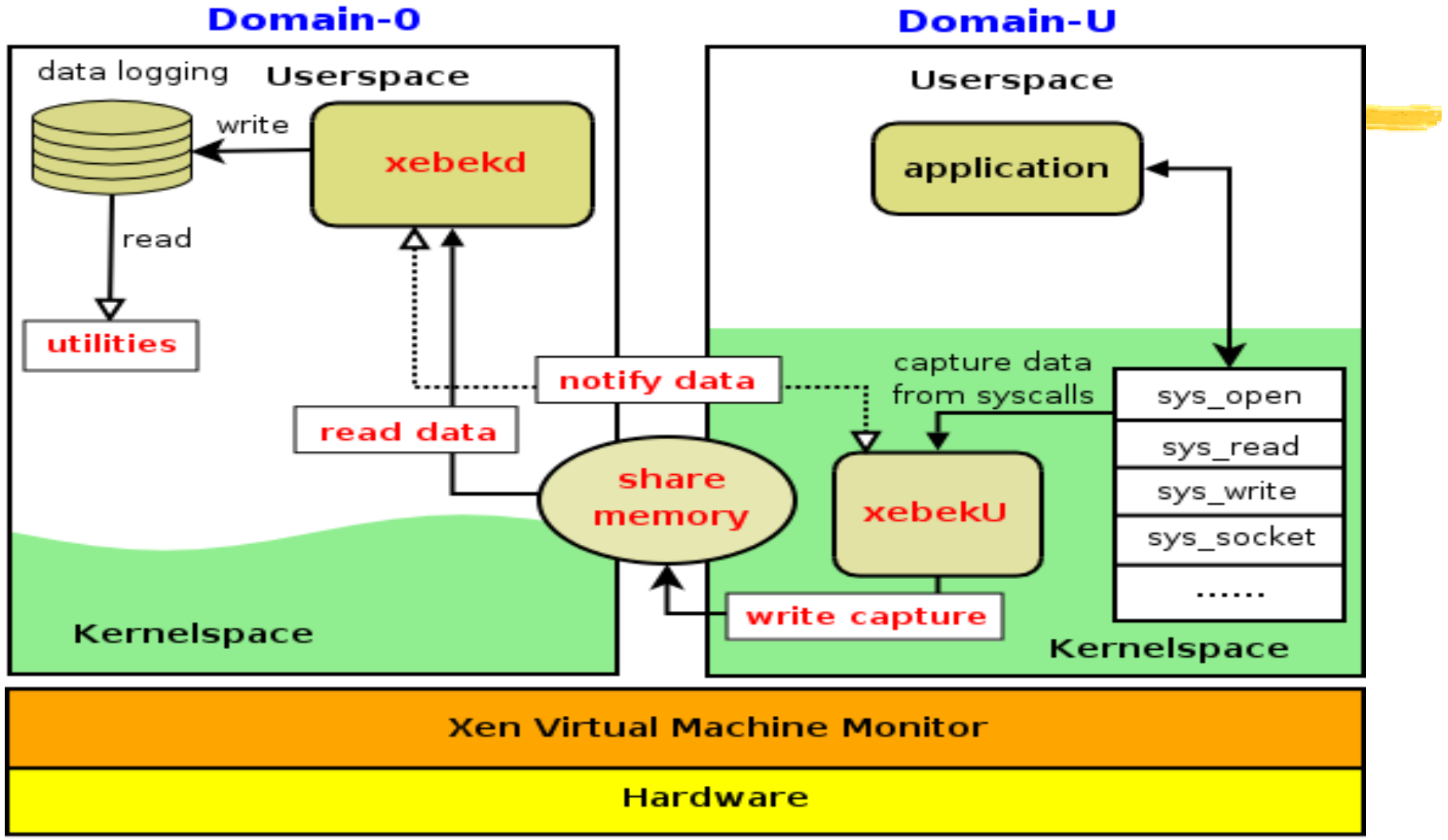
(2) Data can be sniffed

(3) Function as KLM & replace original system-calls

(4) Central logging server exposed to the network

(5) Data transfer might not be reliable (UDP)

Xebek architecture



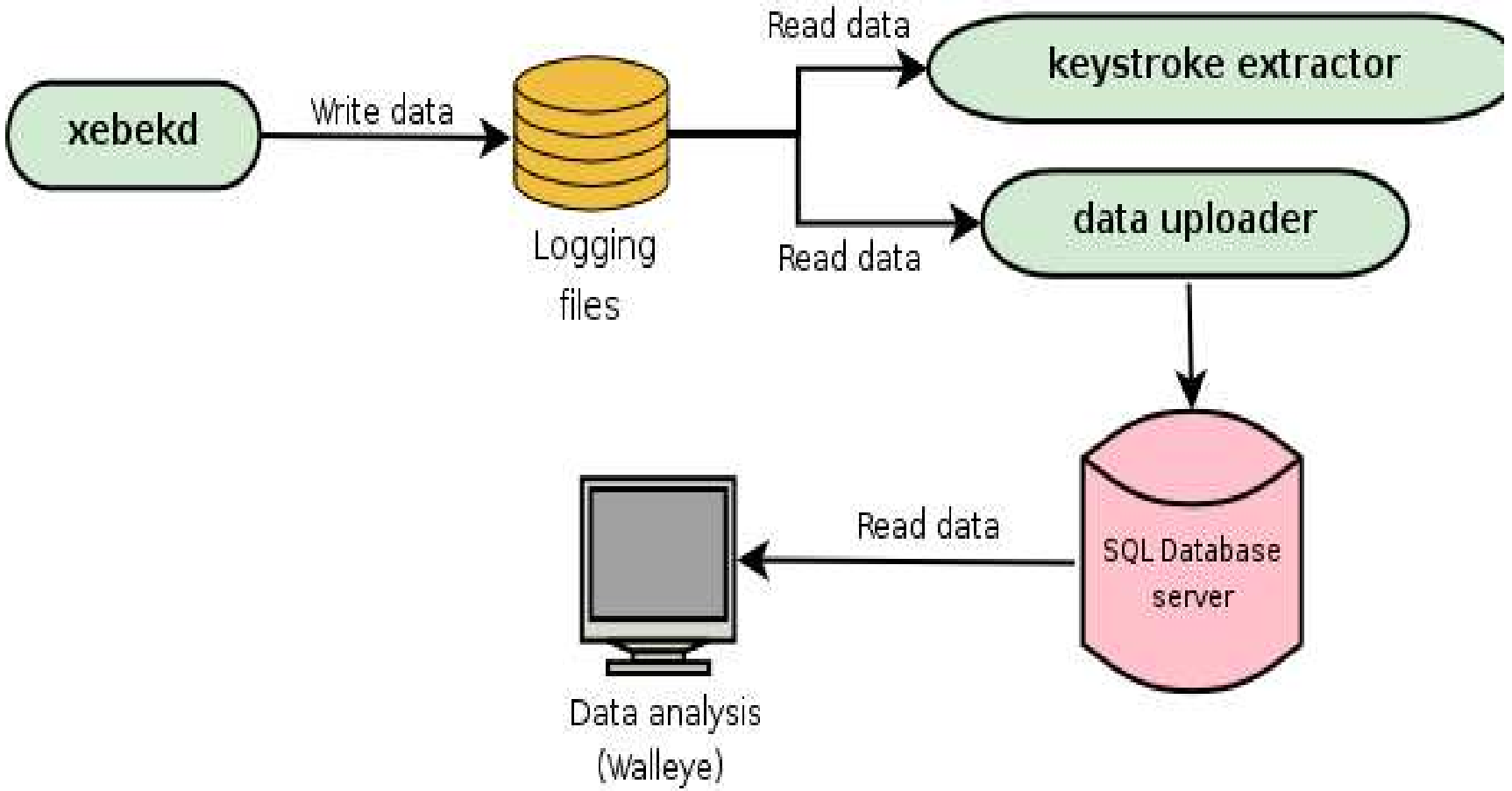
xebekU

- Xebek component in DomU's kernel
  - patch the system-calls (open/read/write/fork/socket)
  - establish shared memory with Dom0
  - put the gathered data from system-calls to shared-memory, then notify **xebekd**

xebekd

- logging recorder in Dom0
  - waits for notification from xebekU
  - pick up data in shared-memory, then save to corresponding logging file
  - notify xebekU on completion

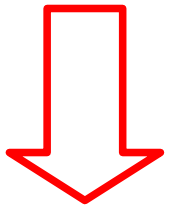
Xebek utilities



Implementation issues

Shared memory structure

- Need to be accessed at the same time by 2 parties
  - xebekU writes to shared memory
  - xebekd reads from shared memory



ring buffer format

Ring buffer format

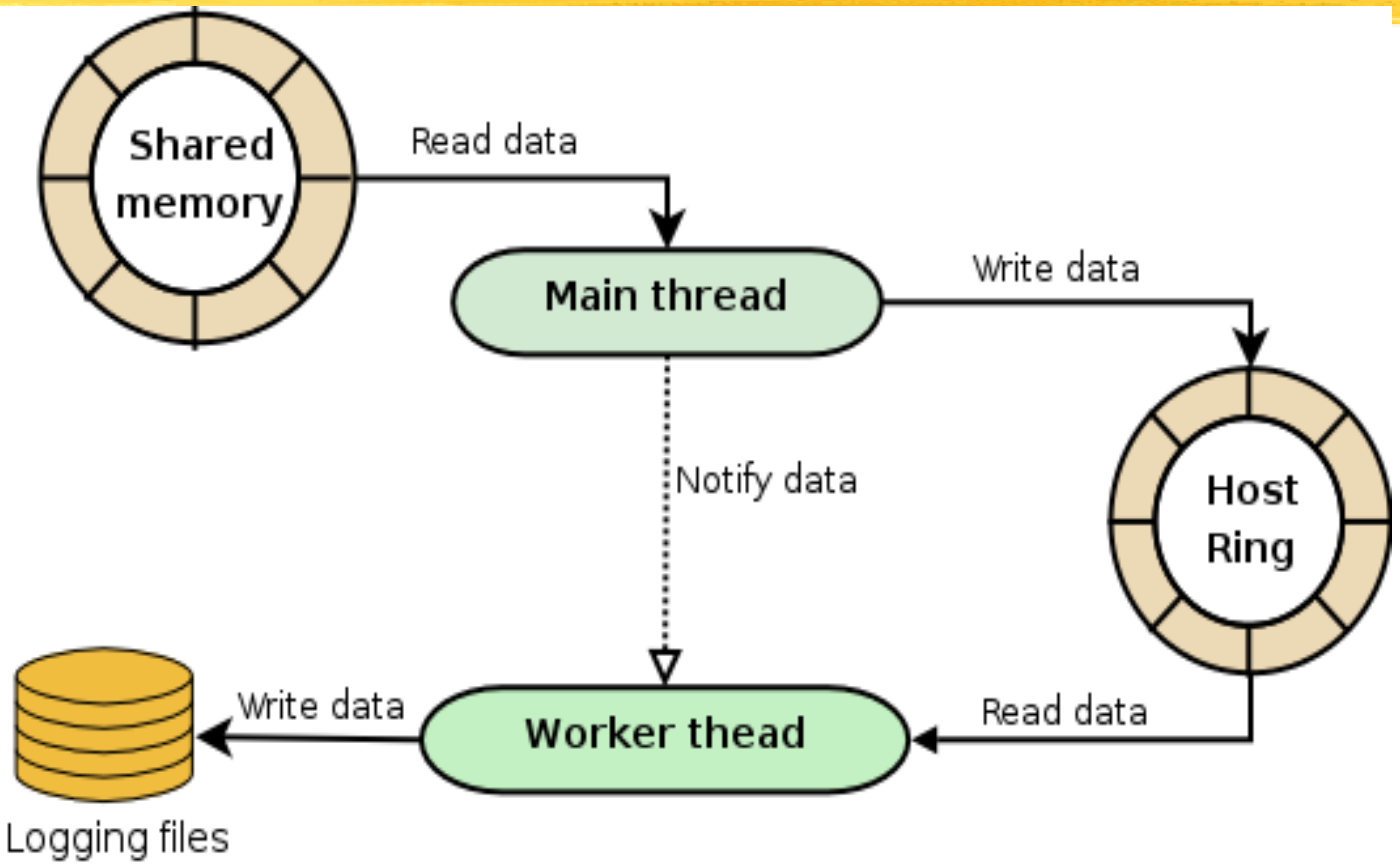
Buffer with 2 heads

- Write head: fill up buffer
- Read head: realease buffer space

```
struct ringbuf {
{
   u32 write; /* write head */
   u32 read; /* read head */
   u32 size; /* buffer size */
   char buf[0];
} __attribute__((packed));
```

xebekd: multiple threading

- main thread
- worker thread
- host_ring: ring buffer structure



Coding

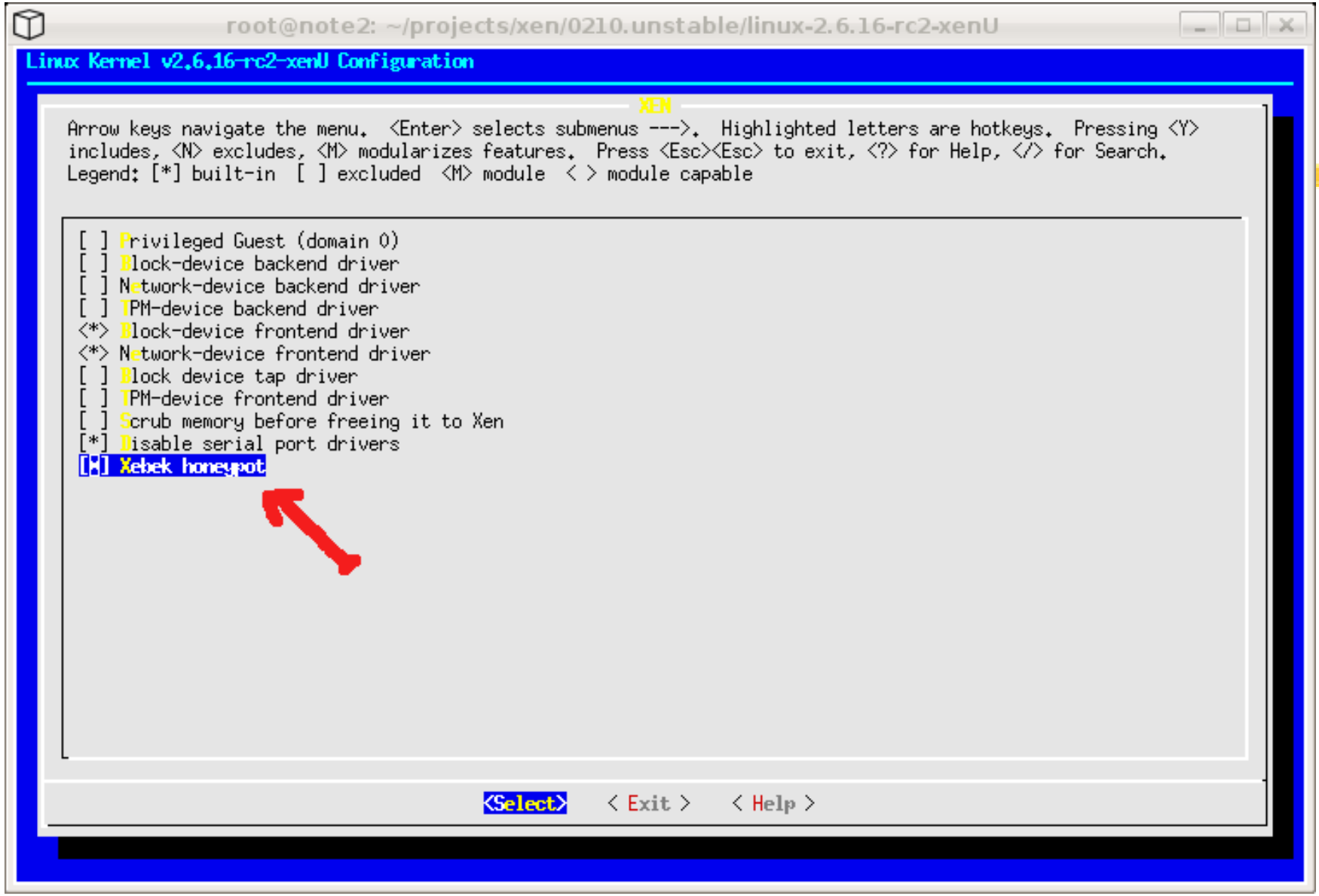
- Version 0.2 – Linux based DomU only ATM
  - Kernel patch
  - Kernel module is also available (NOT encourage!)
- xebekd + xebeklive+ xkeys: 1676 lines
- xebekU: 1848 lines (linux-2.6.16-rc2)
  - Small increase in kernel binary size
    - 946550 bytes -> 948494 bytes
  - Small patch to kernel

File name	Modified lines
kernel/fork.c	54
fs/open.c	21
fs/read_write.c	148
net/socket.c	44

Patching kernel/fork.c::do_fork())

```
#ifdef CONFIG_XEN_XEBEK
    struct xebek_packet p;
    if (my_private.active) {
        p.event = EVT_FORK;
        fill_time(&p.time);
        p.size = sizeof(current->comm);
        p.version = XEBEK_VERSION;
        p.magic = XEBEK_MAGIC;
        p.uid = current->uid;
        p.ppid = current->parent->pid;
        p.pid = current->pid;
        copy_to_buffer(&p, current->comm, p.size, 0);
    }
#endif
```

Compile Configuration

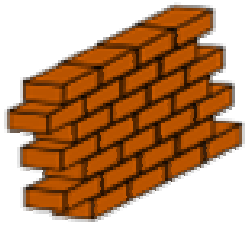


Xebek evaluation

Method	Native	Sebek	Xebek
OPEN	8.194	1509.073 (~184 times)	9.720 (18.62%)
READ	1.221	972.649 (~976 times)	1.968 (61.13%)
WRITE	1.106	1.113 (-)	1.822 (64.69%)
FORK	900.380	900.433 (~0%)	900.421 (~0%)
TCP	842.256	1276.562 (51.56%)	1004.912 (19.31%)
UDP	1050.991	1100.262 (4.68%)	1085.241 (3.25%)

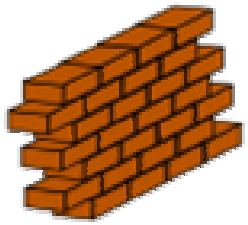
LMBench benchmark results

Hardening Xebek



- Harden DomU:
  - Protect kernel binary? No need ☺
  - Protect kernel symbol? No need ☺
  - Shutdown all the paths to the kernel
    - No kernel module loading
    - /dev/{kmem, mem, port} removed
- Harden Dom0
  - Harden system (SELinux, LIDS, AppArmor)
  - Run Dom0 with no network access

Detecting Xebek



- Intruder gains kernel access ?
  - We are hopeless against brute-force scanning kernel memory
  - Block all path to kernel.
- Intruder has no kernel access?
  - Timing attack based on syscall latency?
  - Impossible to solve completely !!! ☹
- Removing kernel access might be suspicious !!!

Demonstration

Future work

- Analysis tool: Adapt Walleye for Xebek
- Maintenance Xebek patch for different kernel versions (costly?)
- Make Xebek more flexible
  - Adapt Xebek to the Sebek scheme
  - Optimize to reduce latency
  - Port Xebek to other platforms like *BSD/Solaris/...
  - ???

Conclusions

Xebek is a robust data capture tool for Xen-based virtual honeypot

- More "invisible"
- More reliable/flexible
- Open source: To be released under GPL licencse soon (when I have more free time ☹)

Towards an Invisible Honeypot Monitoring Tool

HITB06

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Thank you!

Questions/Comments?