You Can Type, but You Can’t Hide

A Stealthy GPU-based Keylogger

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(FORTH-ICS)

Outline

- Background
- A GPU-Based keylogger
- Evaluation
- Defenses

Keyloggers

- Malware that records keystrokes

Types:

Hardware (devices plugged in keyboard)

Software (user mode or kernel mode)

User mode:

They use OS functionalities:

- Character device files Linux OS
- GetAsyncKeyState Windows OS

Kernel mode:

They implement “Hook” functions

- Can be detected by AVs/anti-malware software

Motivation

- How can we hide the malicious code from AVs/anti-malware software?
- Is it possible to use the GPU for building a stealthier malware?

General-Purpose Programming on GPUs (GPGPU)

- GPUs can be programmed for general purpose computation
  - Familiar API as C language extensions
- Existing GPGPU frameworks
  - OpenCL (Universal Programming Language)
  - NVIDIA CUDA (For NVIDIA Graphics Cards)
- General-Purpose Programming is directly supported by most commodity drivers/video cards
  - A GPU-based keylogger will run without problems on most systems

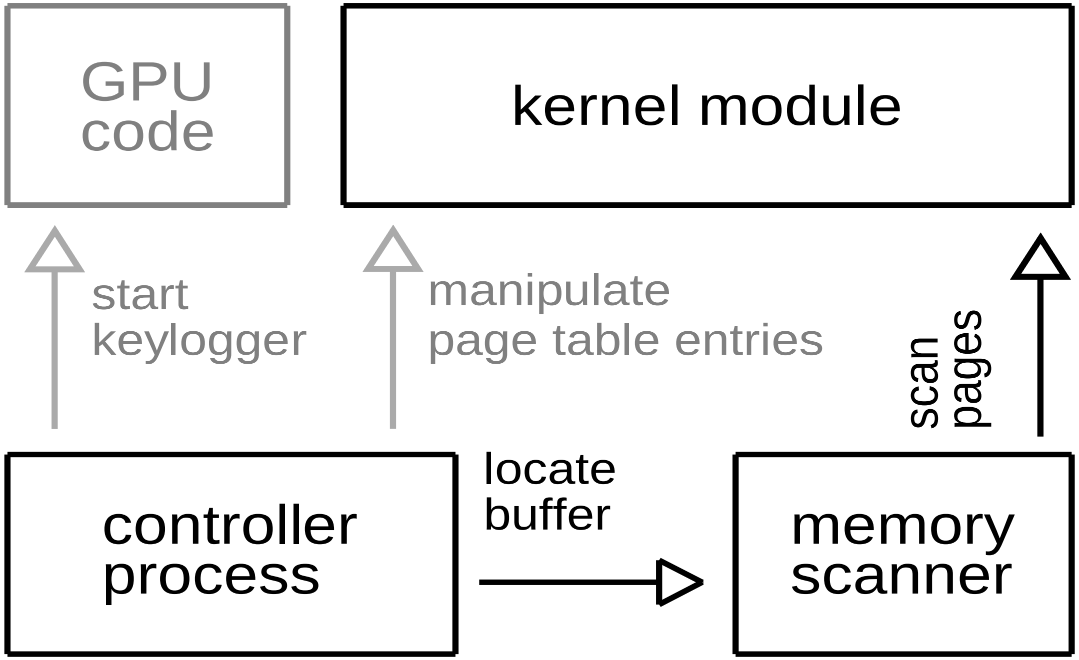
Overall approach

- Scan kernel’s memory to locate the keyboard buffer
- Remap the memory page of the buffer to user space
- Set the GPU to periodically read and scan them for sensitive information (e.g., credit card numbers)
- Unmap the memory in order to leave no traces

Implementation

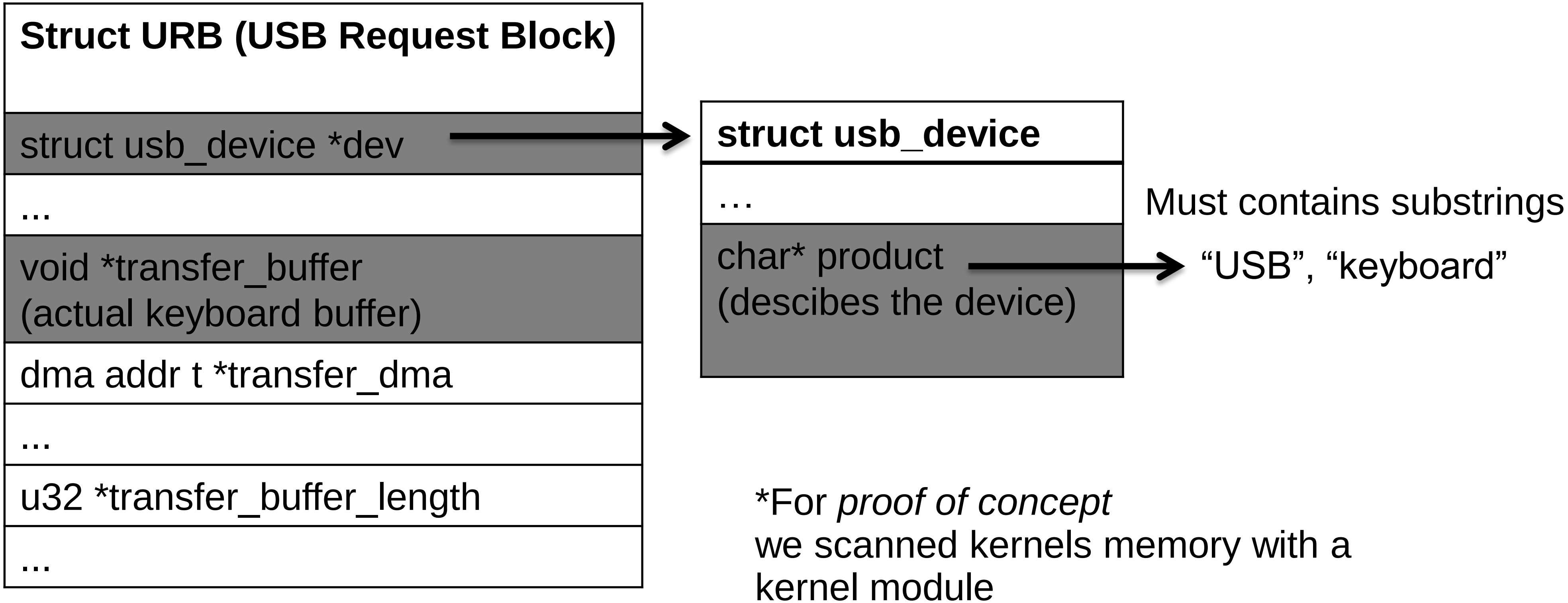
Step 1: **Locate the keyboard buffer**

- *Keyboard buffer dynamically changes address after system rebooting or after unplugging and plugging back in the device*



Implementation

Scan the kernel memory using heuristics



Struct URB (USB Request Block)

struct usb_device *dev

...

void *transfer_buffer
(actual keyboard buffer)

dma addr t *transfer_dma

...

u32 *transfer_buffer_length

...

struct usb_device

…

char* product
(descibes the device)

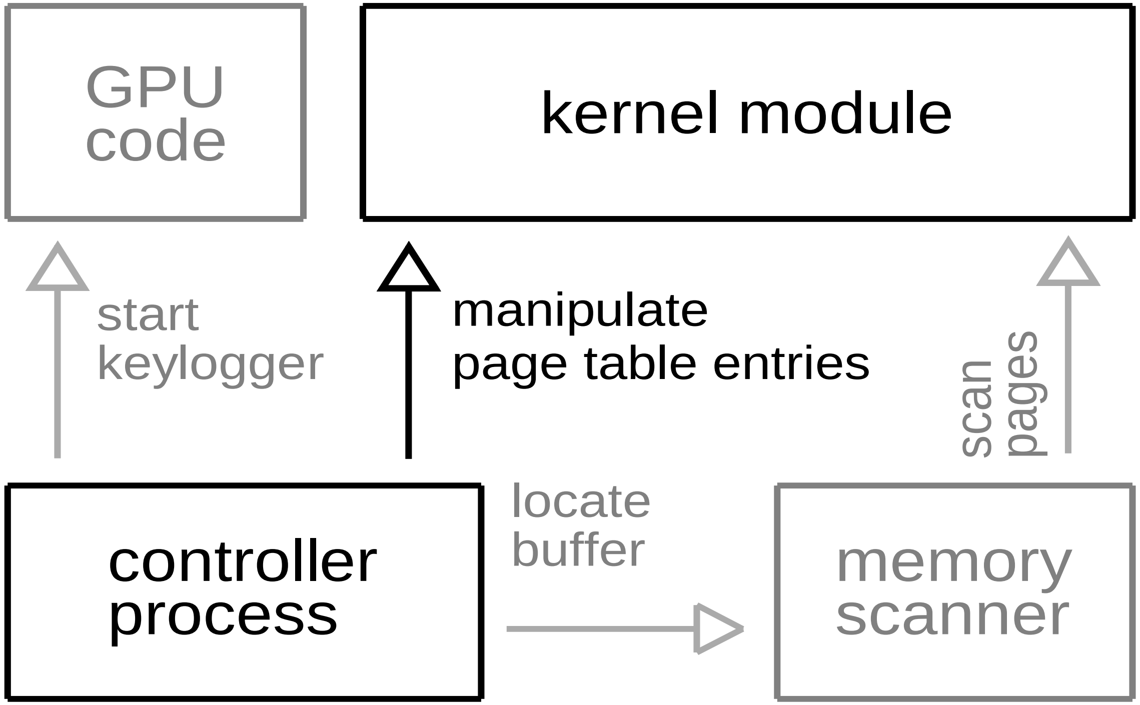
Must contains substrings

“USB”, “keyboard”

*For *proof of concept*
we scanned kernels memory with a
kernel module

Implementation

Step 2: **Configure the GPU to constantly monitor buffer contents for changes**

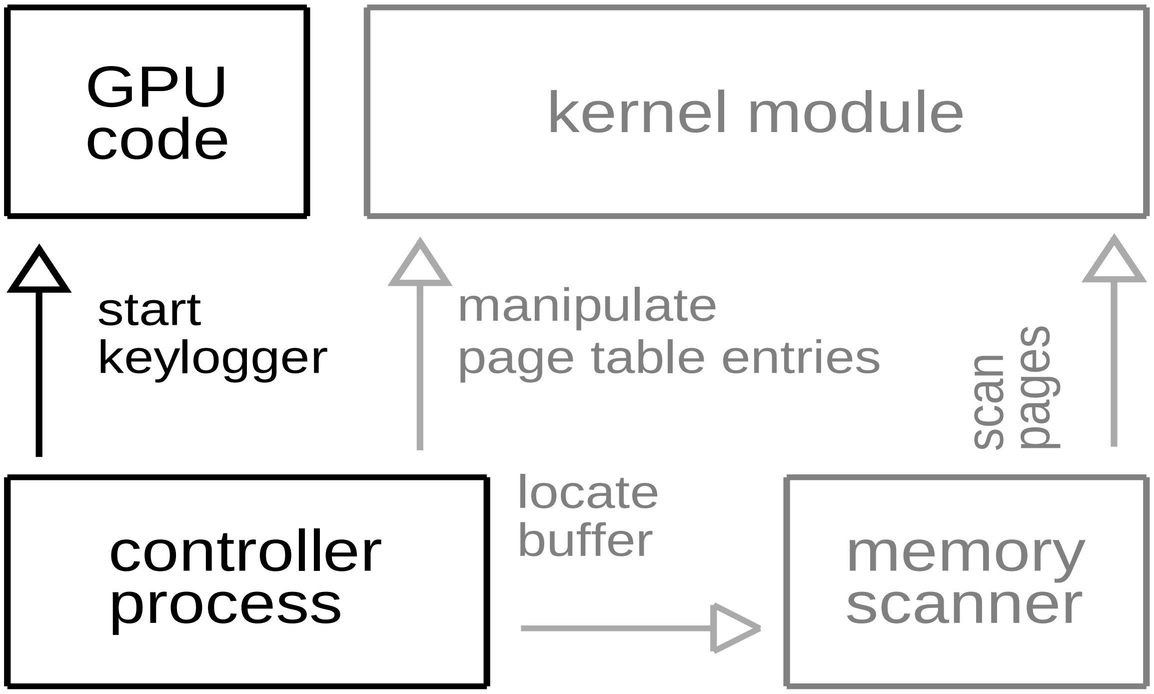


Implementation

- The GPU driver allows DMA access **ONLY** to the host process' address space
  - *Only to memory regions allocated through a special CUDA API call*
- Use a kernel module to remap the physical page of the buffer to the user-level process' memory space

Implementation

Step 3: **Start GPU process & Capture keystrokes**



Implementation

- Uninstall the module
- Use polling to catch keystrokes
    - *“wake up” GPU process periodically through the CPU controller process*
- Simple state machine translates keystrokes into ASCII characters
- Store keystrokes into Video RAM

Implementation

Step 4: **Scan captured keystrokes for sensitive information**

- GPU-based regular expression parser

Credit card	Regular expresion
VISA	^4[0-9]{12}(?:[0-9]{3})?$
MasterCard	^5[1-5][0-9]{14}$
American Express	^3[47][0-9]{13}$
Diners Club	^3(?:0[0-5]|[68][0-9])[0-9]{11} $
Discover	^6(?:011|5[0-9]{2})[0-9]{12}$

Evaluation

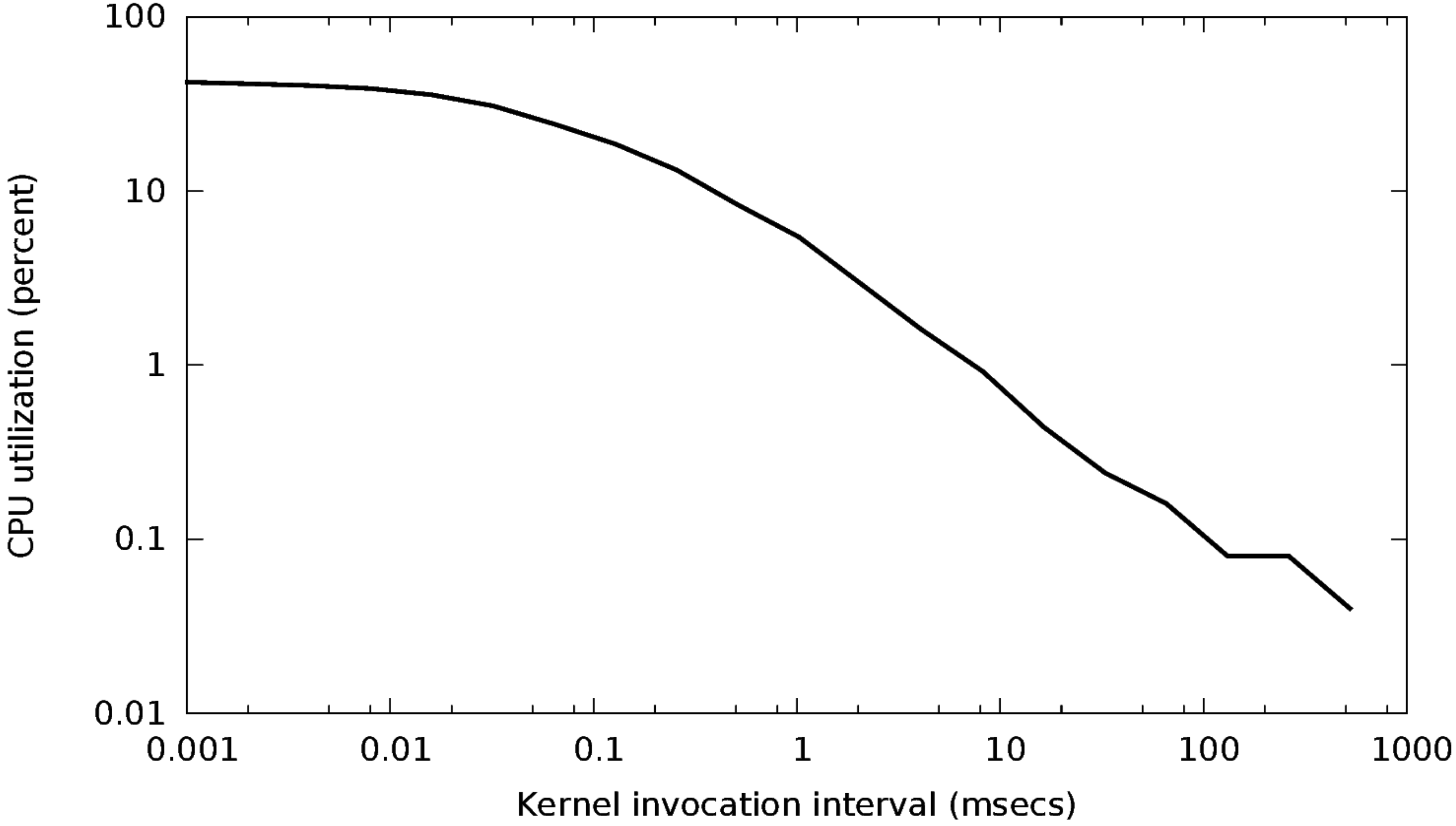
- Ubuntu Linux 12.10 with kernel v3.5.0
- Used CUDA 5.0 SDK
- Executable less than 4 KB

- Polling interval tradeoff:

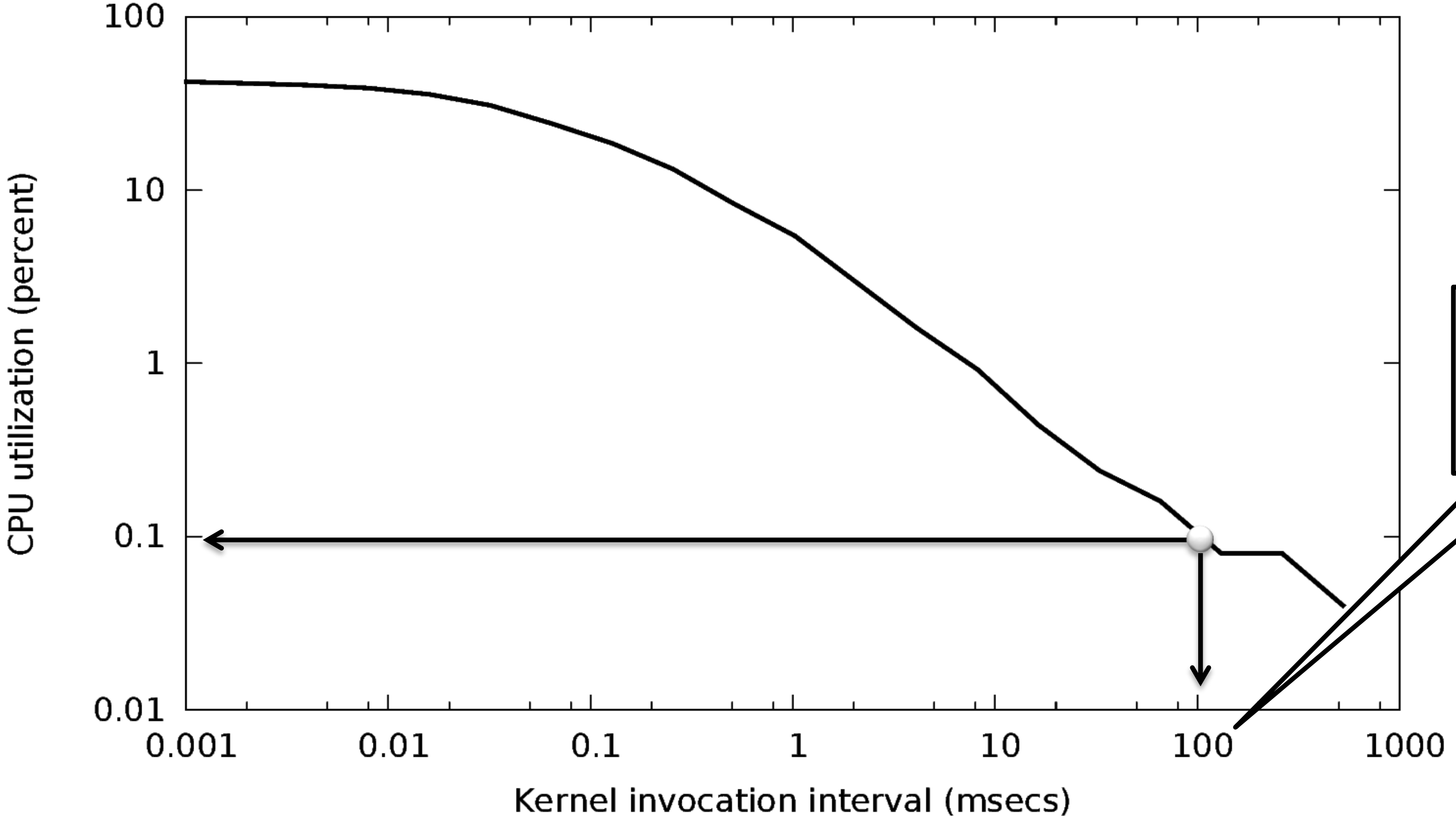
Monitoring granularity vs. CPU/GPU utilization

- ❑ Low Frequency: *might miss keystroke events*
- ❑ High frequency: *might cause detectable CPU/GPU utilization increase*

CPU Utilization

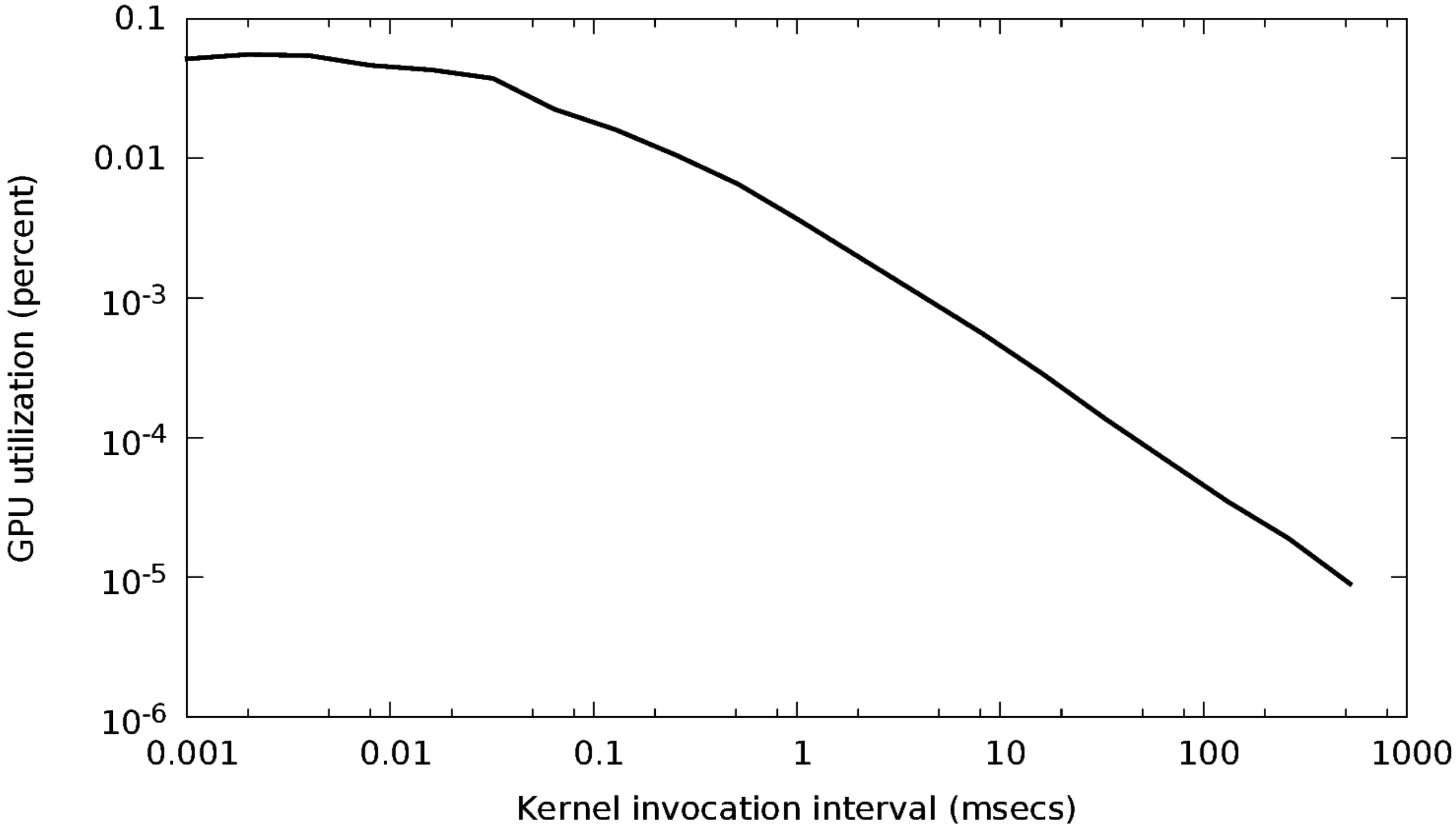


CPU Utilization

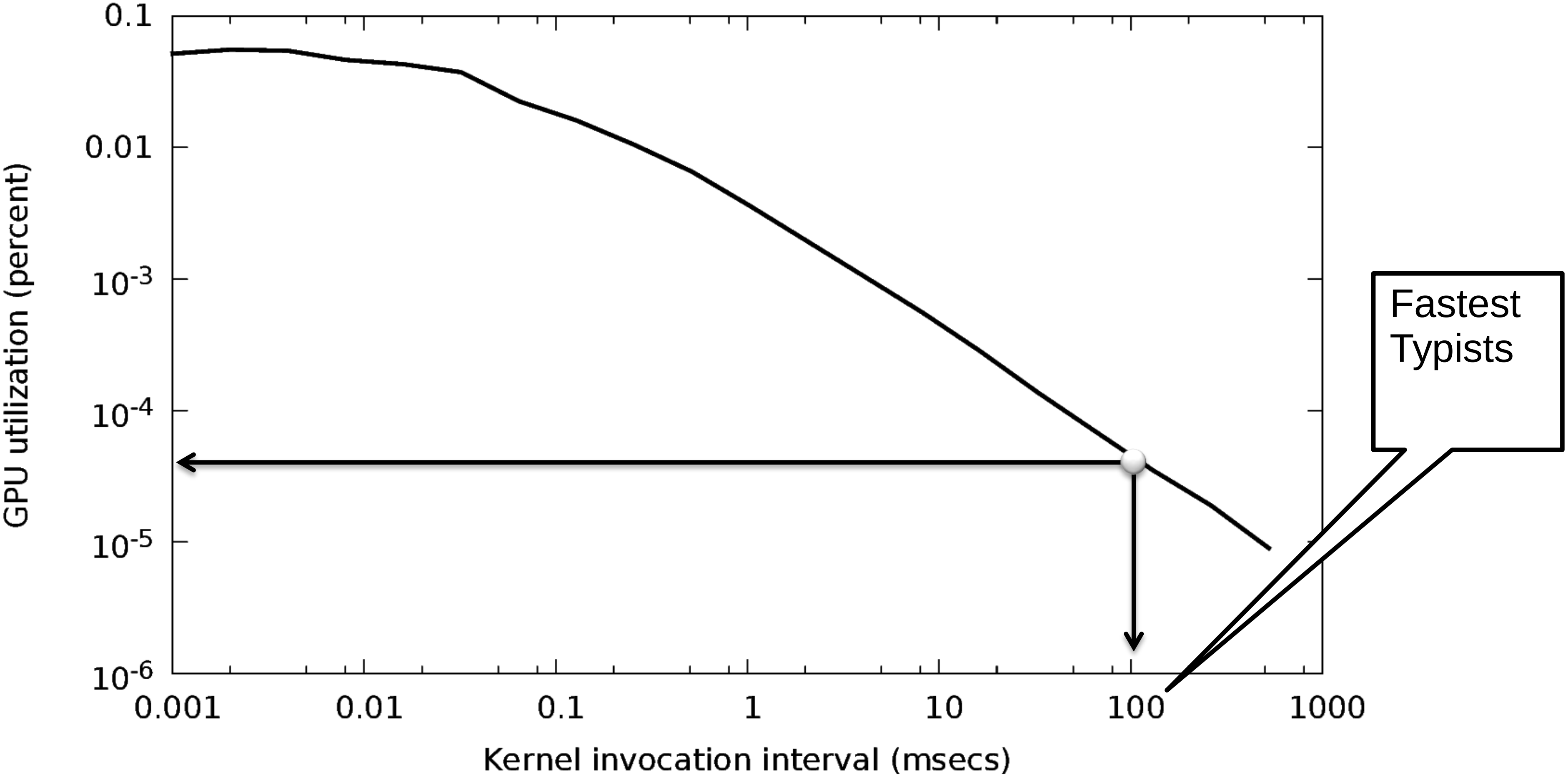


Fastest Typists

GPU Utilization



GPU Utilization



Fastest Typists

Possible Defenses

- Monitoring GPU access patterns
  - Multiple/repeated DMAs from the GPU to system RAM
- Monitoring GPU usage
  - Unexpected increased GPU usage

Current Prototype Limitations

- Requires a CPU process to control its execution
  - Future GPGPU SDKs might allow us to drop the CPU controller process
- Requires administrative privileges
  - For installing and using the module
  - However the control process runs in user-space
    - No kernel injection needed or data structure manipulation, in order to hide

Conclusion

- GPUs offer new ways for robust and stealthy malware
- Presented a fully functional and stealthy GPU-based keylogger
    - Low CPU and GPU usage
    - No Device Hooking
    - No traces left after exploitation
    - User Mode application. No kernel injection needed

Thank you

Locate the keyboard buffer

```
#define __va(x) ((void *)((unsigned long)(x)+PAGE_OFFSET))

for (i = 0; i < totalmem; i += 0x10) {
        struct urb *urbp = (struct urb *)__va(i);
        If ( ( (urbp->dev % 0x400) == 0) &&
                ((urbp->transfer_dma % 0x20) == 0) &&
                (urbp->transfer_buffer_length == 8) &&
                (urbp->transfer_buffer != NULL) &&
                strncmp(urbp->dev->product, "usb", 32) &&
                strncmp(urbp->dev->product, "keyboard", 32)) {


                        /* potential match *
        }
}
```

Related Work

- DMA Malware “DAGGER” by: *Patrick Stewin* and *Iurii Bystrovx*
  - Implemented in Intel's Manageability Engine (it is used for remote Bios operations)
- GPU assisted malware by: *Giorgos Vasiliadis, Michalis Polychronakis* and *Sotiris Ioannidis*
  - GPU-based self-unpacking malware