Windows Memory Forensics and Direct Kernel Object Manipulation

Jesse Kornblum

Outline

- Introduction
- The Kernel
- Direct Kernel Object Manipulation
- Standard DKOM
- Devious DKOM
- Better Magic
- Relations Between Kernel Objects
- Questions

KYRUS TECHNOLOGY

Introduction

- Computer Forensics Research Guru
  - md5deep, hashdeep, fuzzy hashing (ssdeep), foremost, etc
  - AFOSI, DoJ, ManTech
- Kyrus Technology

KYRUS TECHNOLOGY

Introduction

- Direct Kernel Object Manipulation (DKOM)
- Powerful technique for p0wning a computer
  - or crashing it
- Memory forensics should be able help us
  - but can be subverted too
- But we shall prevail

KYRUS TECHNOLOGY

The Kernel

- The kernel must maintain lots of data
  - Processes
  - Threads
  - File handles
  - Network connections
  - Interrupts
  - Really everything on the system
- All stored in kernel data structures

KYRUS TECHNOLOGY

How it's Supposed to Work

- Structures are modified by API functions
- Several different levels of API functions
  - CreateProcess
  - NtCreateProcess
  - ZwCreateProcess
  - And many more!
- These functions provide
  - Sanity checking
  - Memory allocation
  - Data initialization

KYRUS TECHNOLOGY

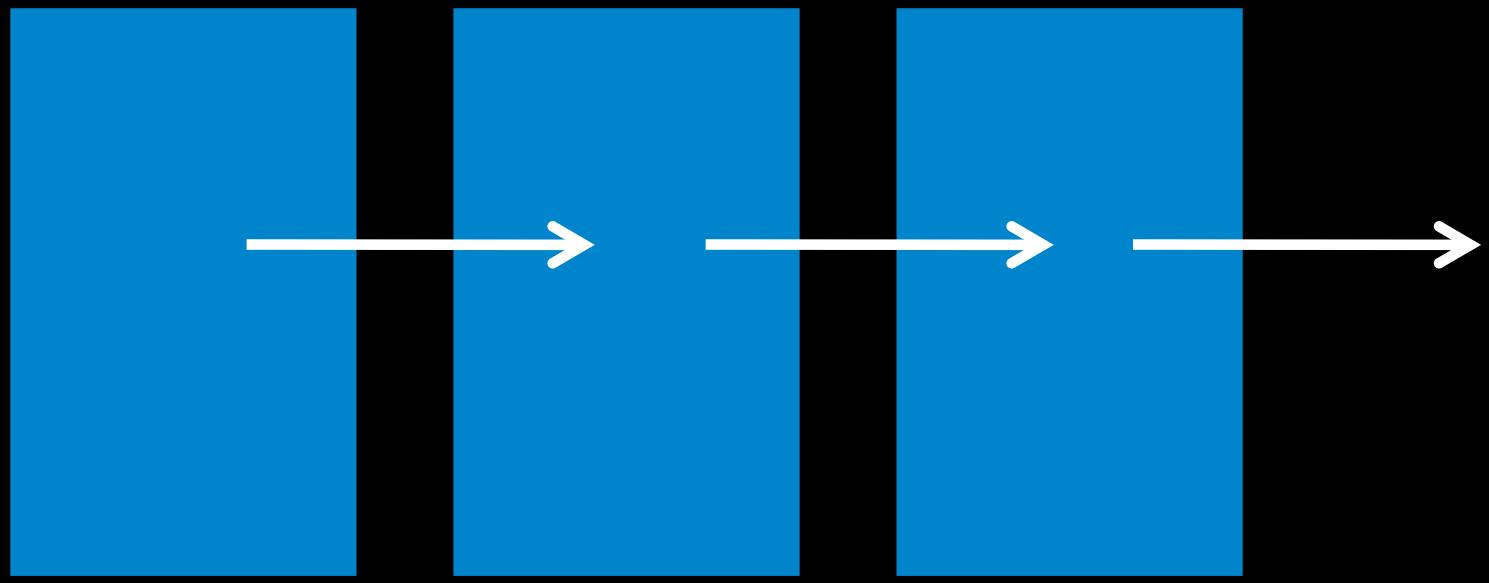
Direct Kernel Object Manipulation

- Modify data structures without using API functions
- Must be done by code running in ring zero
  - Also called kernel mode
  - But not userland programs
- Can be done by drivers
  - This is why drivers can cause crashes
- Code injected into the kernel process

KYRUS TECHNOLOGY

The Kernel

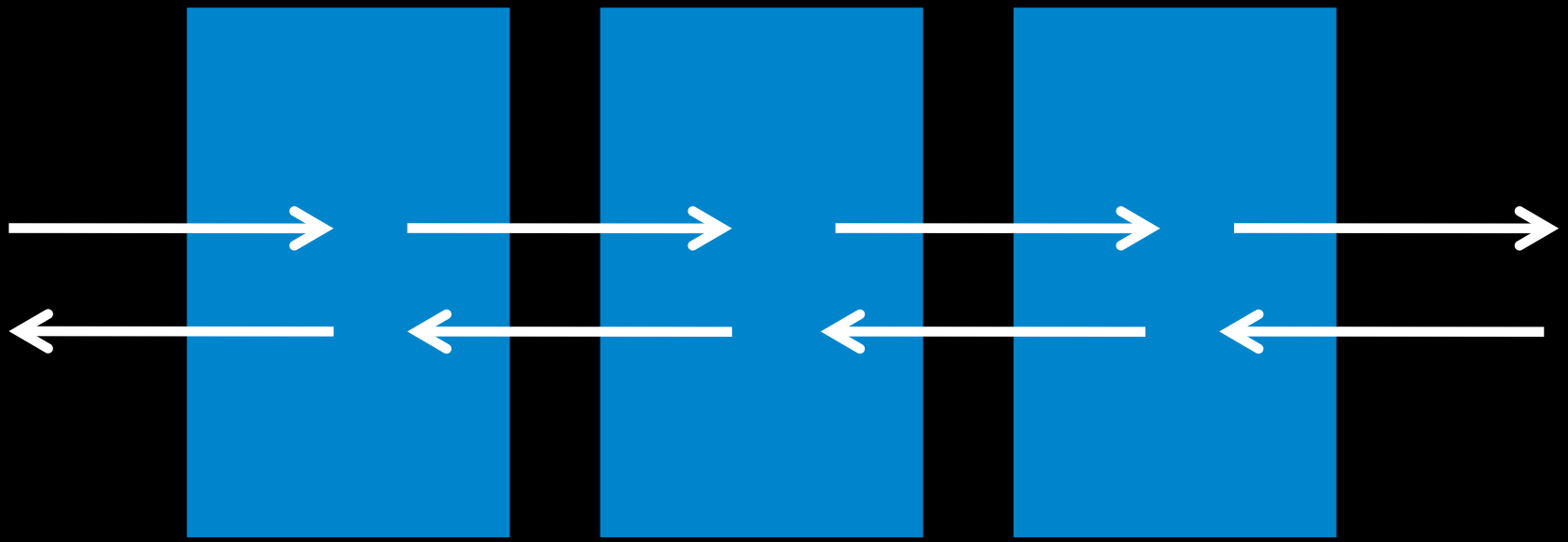
- Lots of lists
- Linked lists
- Each item points to the next item in the list



KYRUS TECHNOLOGY

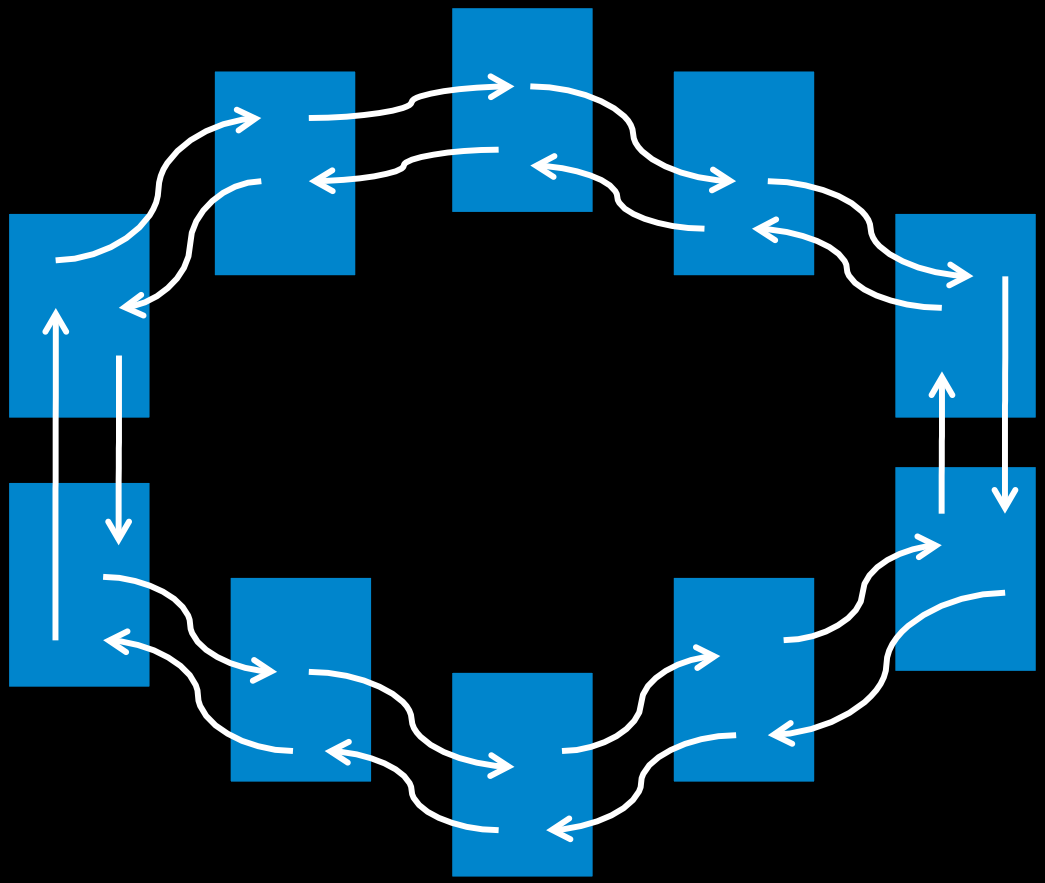
The Kernel

- Doubly linked lists
- Each item points to the next and previous items in the list



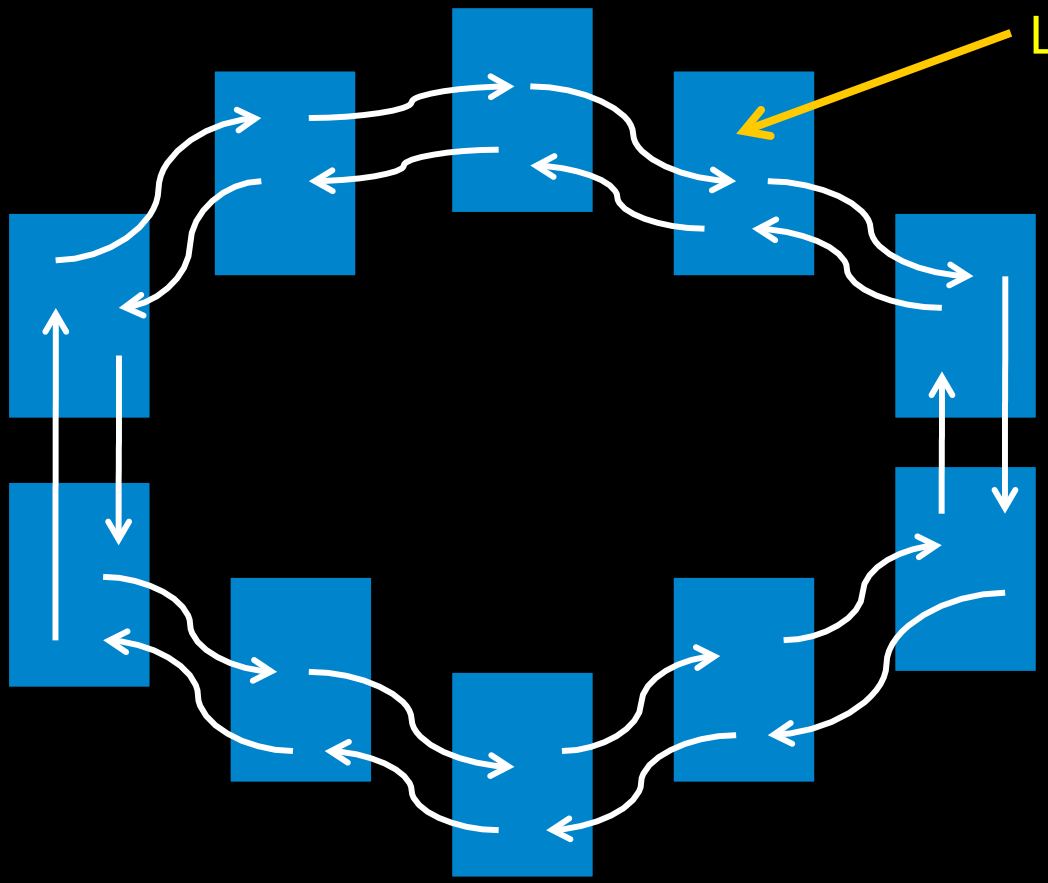
KYRUS TECHNOLOGY

How it's Supposed to Work



KYRUS TECHNOLOGY

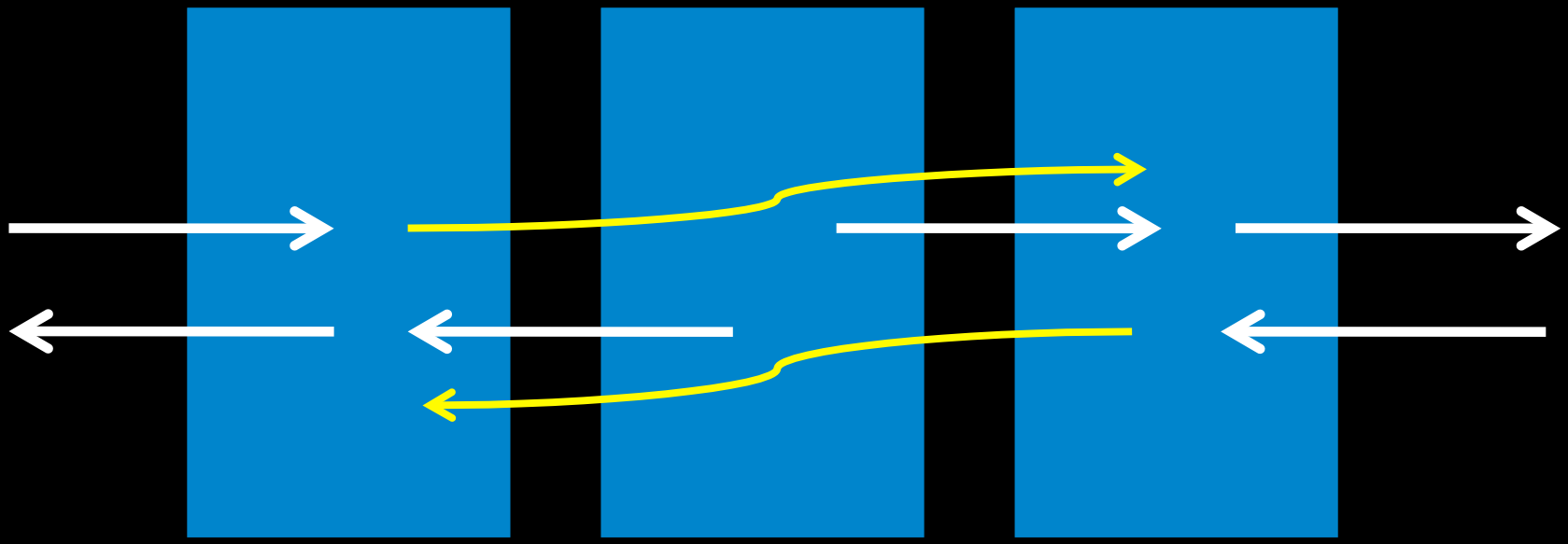
How it's Supposed to Work



KYRUS TECHNOLOGY

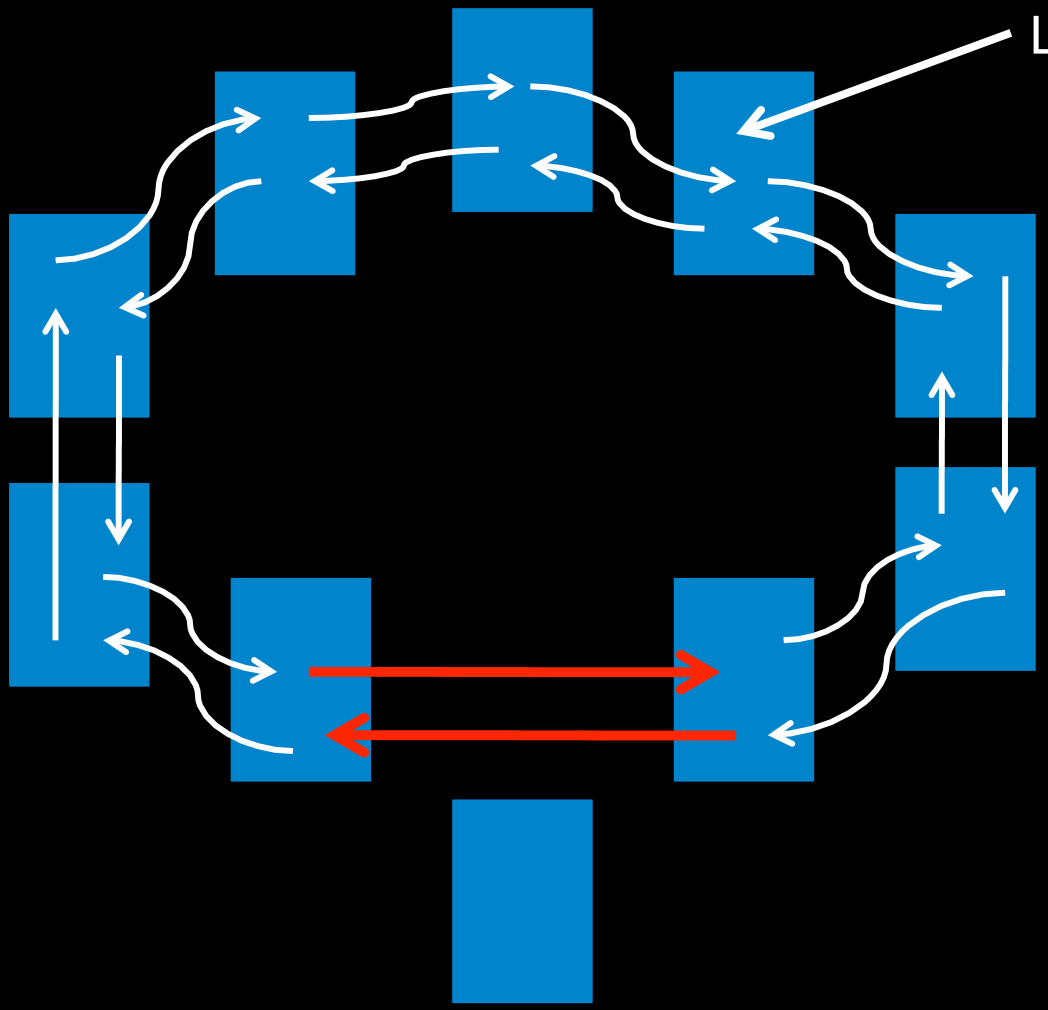
DKOM Example

- Unlink a process to hide it
- Adjust forward and back links to skip an item



KYRUS TECHNOLOGY

Standard DKOM



KYRUS TECHNOLOGY

Detecting Standard DKOM

- High-low analysis
  - Follow process links, record all processes
  - Brute force search for processes
- Compare the results
- Any process that shows up in one list but not the other is suspicious

α β γ δ ε ζ η θ κ λ π σ φ ψ

α β γ δ ε ζ η θ κ λ σ φ ψ

KYRUS TECHNOLOGY

Devious DKOM

- How do you do a brute force search?
- Most modern tools looks for a magic value
- Magic values may not be required
- Some can be replaced with arbitrary values
  - System still runs

KYRUS TECHNOLOGY

Process Structures

- Execute Process structure
  - EPROCESS
- Consists of several substructures
- Lives in pool memory
- Starts with a POOL_HEADER
  - You don't need to know what this is
  - Contains values set by kernel
  - But not referenced while running

Image courtesy Flickr user leozaza and licensed under the Creative Commons

KYRUS TECHNOLOGY

Devious DKOM

- On Windows XP the POOL_HEADER starts with
  50 72 6f e3 (“Proã” in ASCII)

- Can be replaced with, for example
  00 00 00 00

KYRUS TECHNOLOGY

Devious DKOM Demo

- Using Volatility Framework
  - https://www.volatilesystems.com/default/volatility
- Not picking on Volatility
  - All existing tools use magic values
  - Best free memory forensics tool
- Demo…

KYRUS TECHNOLOGY

Detecting Devious DKOM

- Two approaches
  - Get better magic
  - Detect using something else

KYRUS TECHNOLOGY

Better Magic

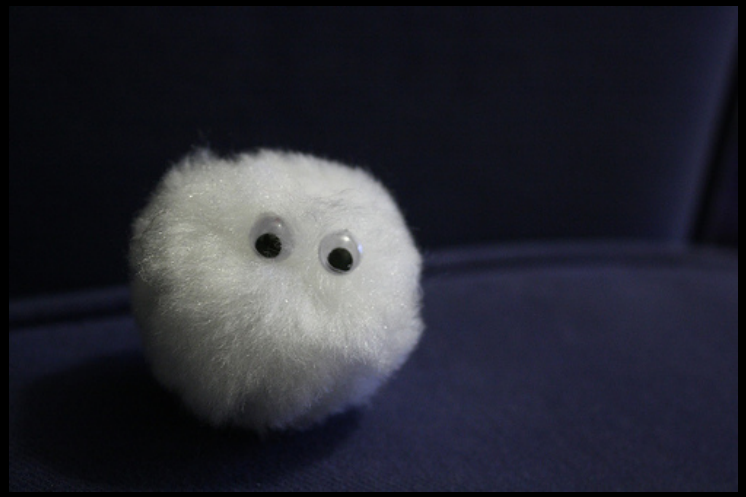


Image courtesy Flickr user LaMenta3 and licensed under the Creative Commons

- Better Magic Through Fuzzing™
- Fuzzing means inputting random data and seeing what happens
- Use automated tools to only report the interesting inputs

KYRUS TECHNOLOGY

Better Magic

- Method by Brendan Dolan-Gavitt et al.
- Fuzzing to find magic values
  - Fire up virtual machine and start a process
  - Pause VM
  - Change EPROCESS values at random
  - Resume VM
  - Record if change made the process or machine crash
  - Repeat
- Do mathy stuff to generate rules for which values cannot be changed without a crash

- Full citation at the end, http://www.cc.gatech.edu/~brendan/ccs09_siggen.pdf

KYRUS TECHNOLOGY

Better Magic

- Examples from EPROCESS
- Pcb.ReadyListHead
  - List Head of threads ready to execute
  - val & 0x80000000 == 0x80000000 AND val % 0x8 == 0
- Peb
  - Address of Process Environment Block
  - val == 0 OR
  - (val & 0x7ffd0000 == 0x7ffd0000 AND val % 0x1000 == 0)

KYRUS TECHNOLOGY

Problems with Better Magic

- These rules are for 32-bit Windows XP Service Pack 2 only
- Fuzzing must be repeated for each configuration
- Rules will be different for each configuration
  - Especially 64-bit systems

KYRUS TECHNOLOGY

Detecting Devious DKOM

- Two approaches
  - Get better magic
  - Detect using something else

KYRUS TECHNOLOGY

Kernel Objects

- Use inherent organization of the kernel
- The kernel is massive
  - Lots of structures to choose from
- Particularly focus on the connections between these objects

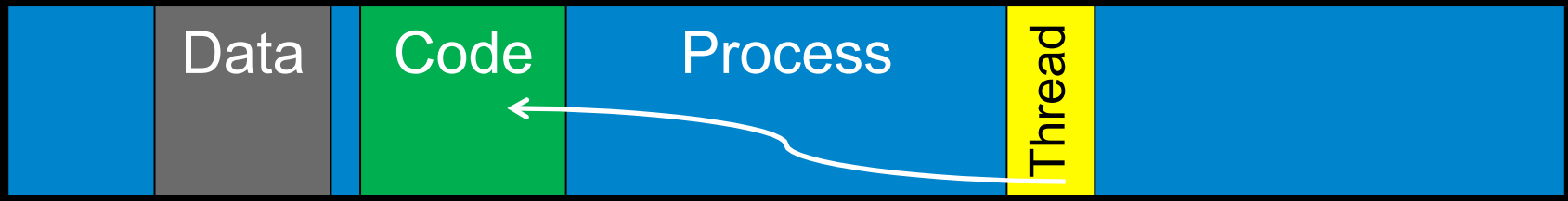
KYRUS TECHNOLOGY

Processes

- A process is a container
  - Holds threads, handles, DLLs, and many other structures
- Let's talk about threads
  - Threads are paths of execution
  - Have a stack
  - Work off common code base
  - Can interact with other threads
- Every process starts with one thread
  - Can start more threads
- Could have a process with no threads, but it wouldn't do anything

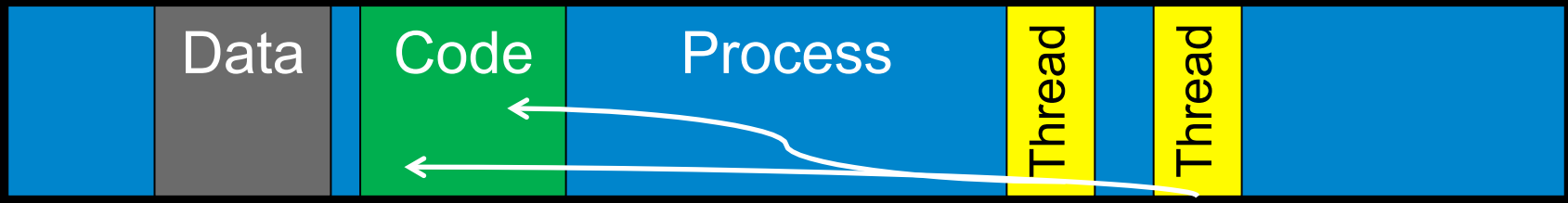
KYRUS TECHNOLOGY

Threads



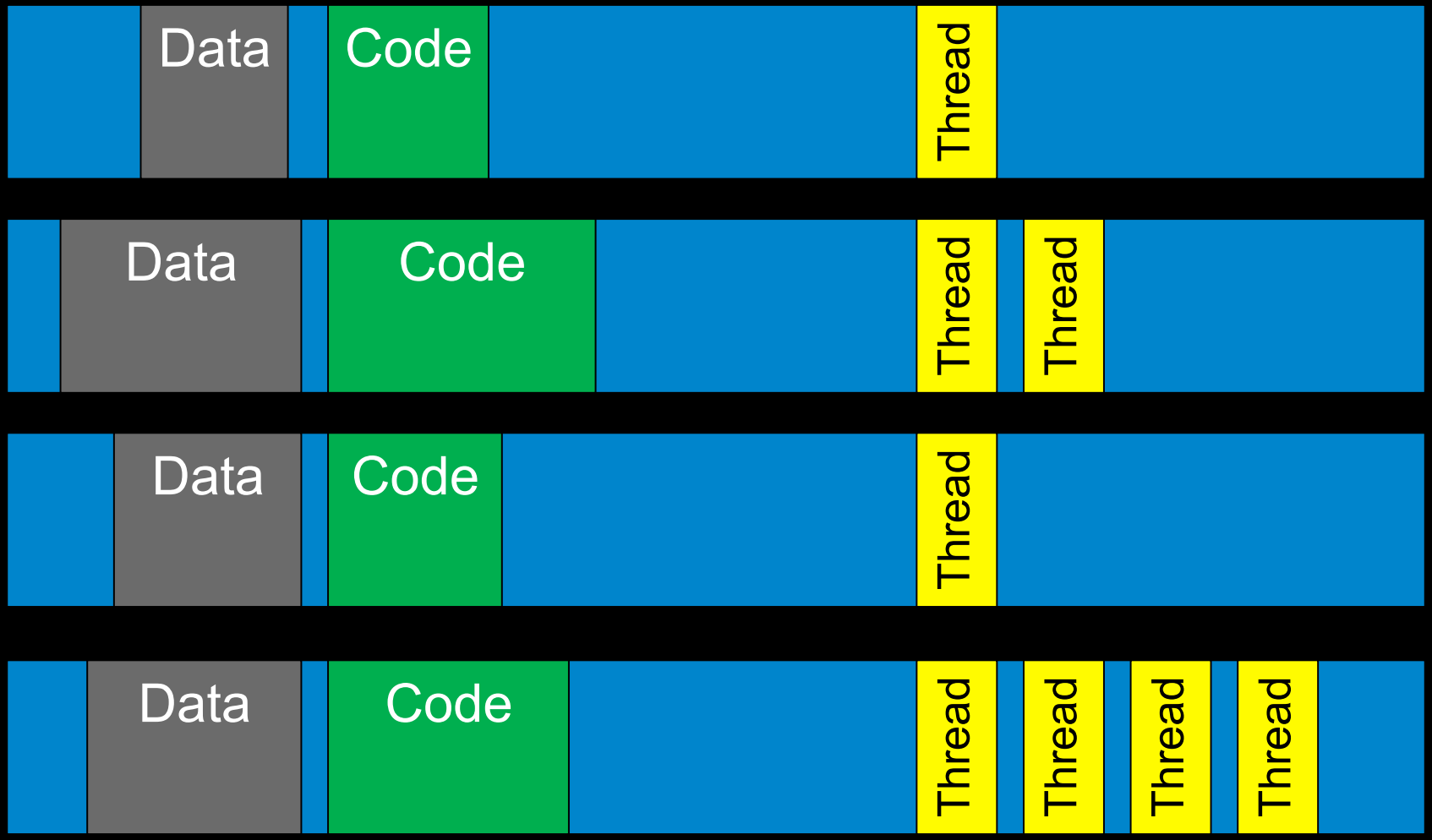
KYRUS TECHNOLOGY

Threads



KYRUS TECHNOLOGY

Threads



KYRUS TECHNOLOGY

The Kernel

- The Kernel is just another process on the system
  - Starts first
  - Gets to talk to the hardware
  - Schedules threads

- Tells hardware to transfer execution to a thread for a given time
- When finished, hardware interrupts the thread
  - Allow it to store its data gracefully
- Return control to kernel

KYRUS TECHNOLOGY

The Kernel

KYRUS TECHNOLOGY

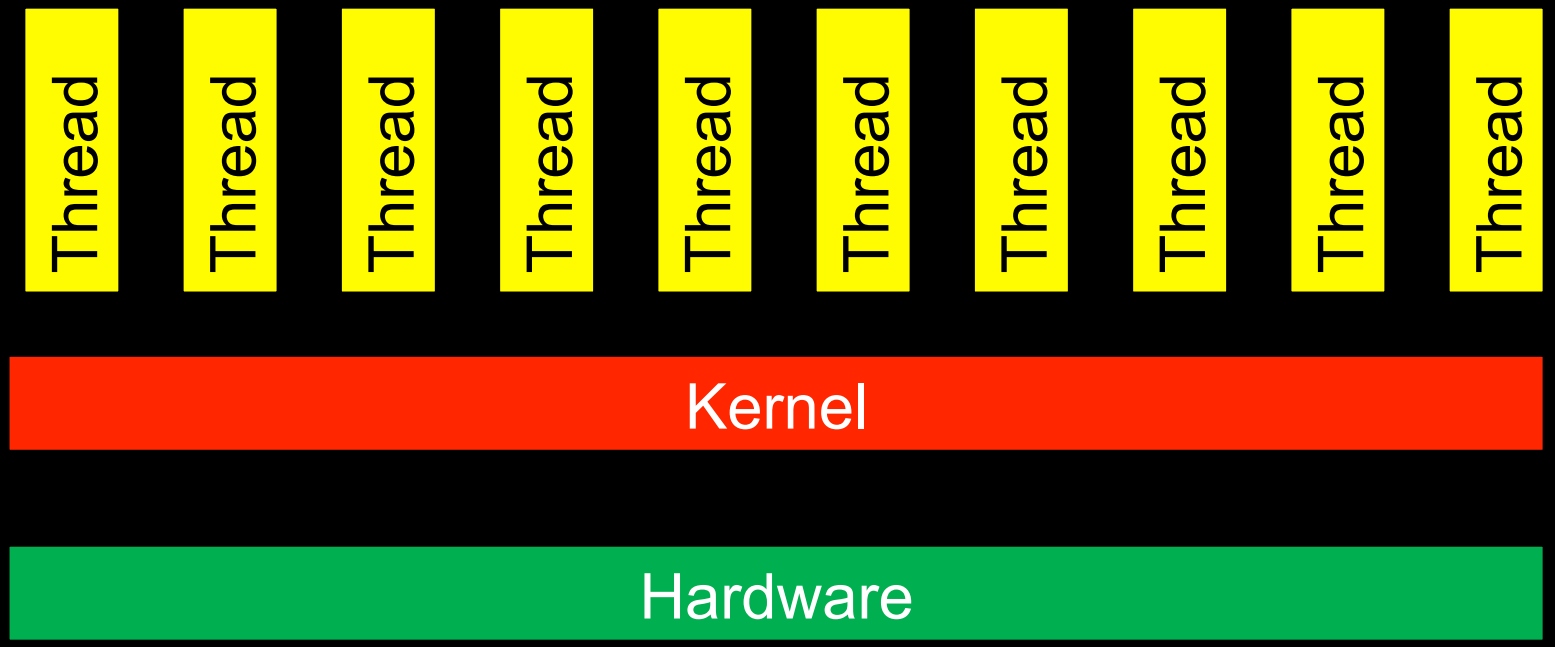
Why Manage Thread Scheduling?

- Some threads are higher priority
  - Video playback
- Some are lower priority
  - Prefetching content
  - Indexing service

- Threads can also be interrupted by hardware
  - Key press
  - Network packet received
- Thread currently executing may not handle the event

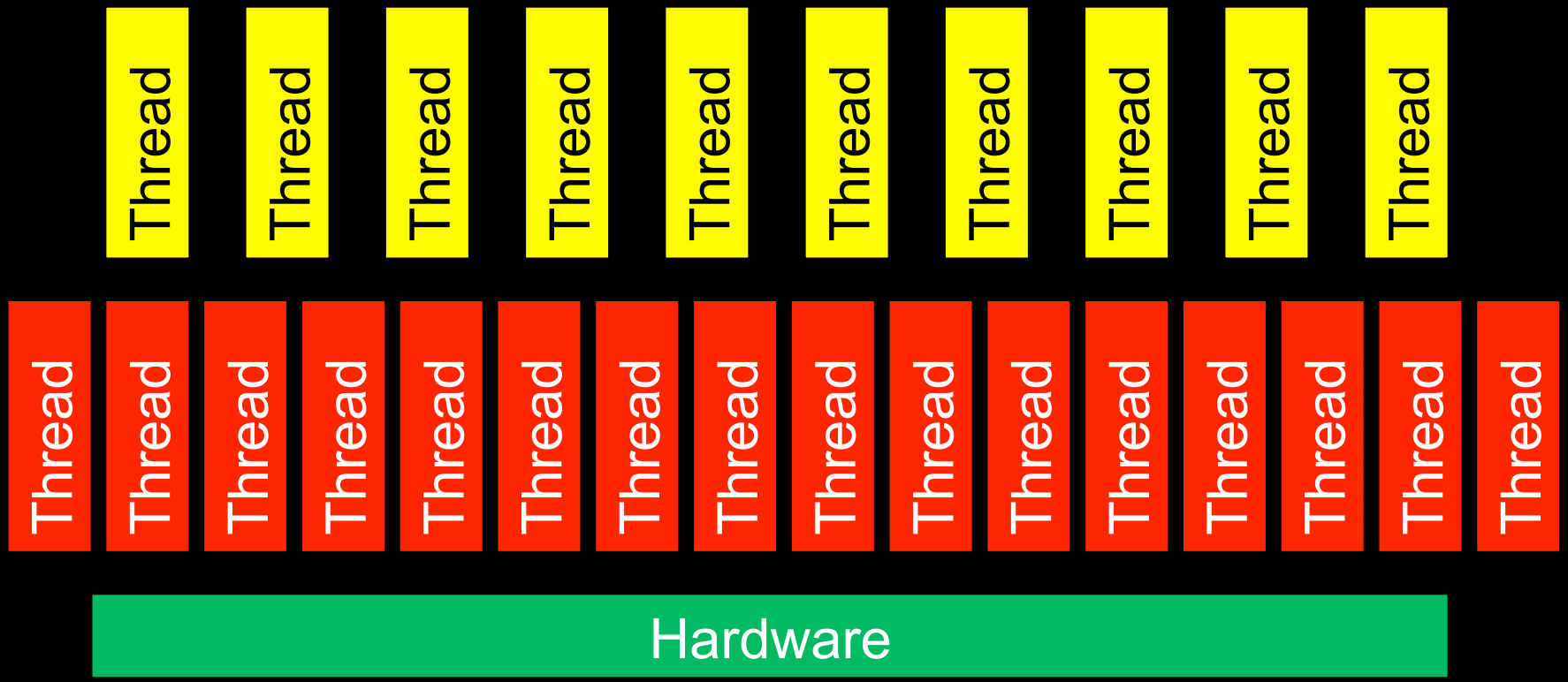
KYRUS TECHNOLOGY

The Kernel



KYRUS TECHNOLOGY

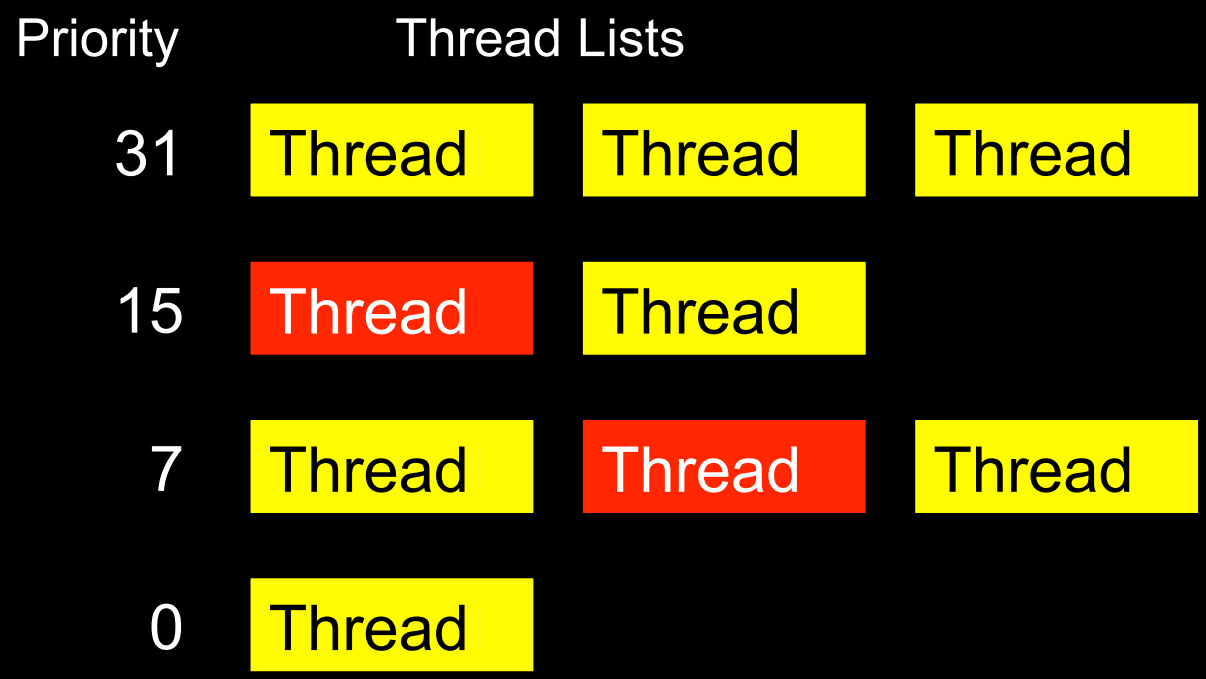
The Kernel



KYRUS TECHNOLOGY

Windows Scheduler

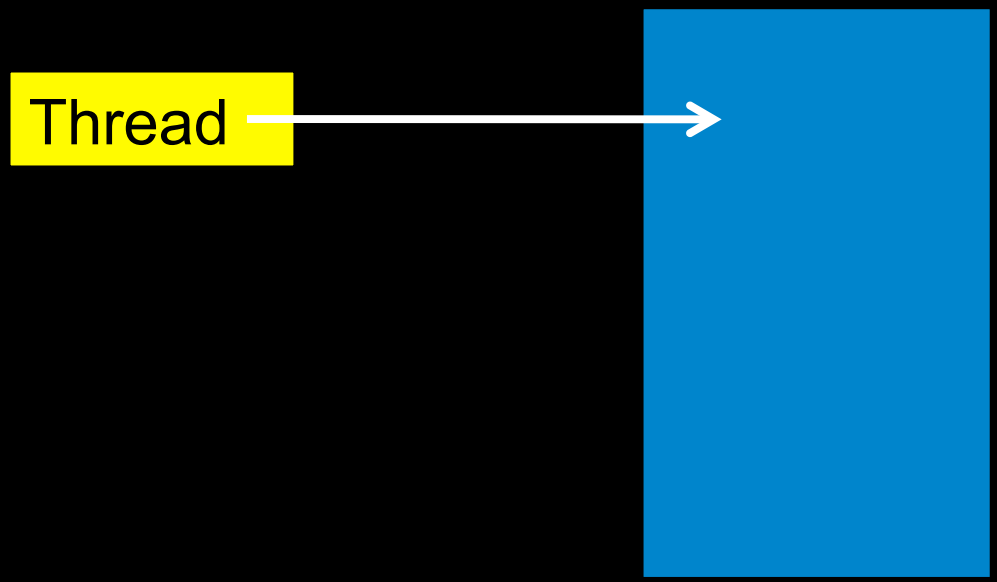
- Structure used by Windows to schedule threads
- Organized by priority
- One doubly linked list for each priority level



KYRUS TECHNOLOGY

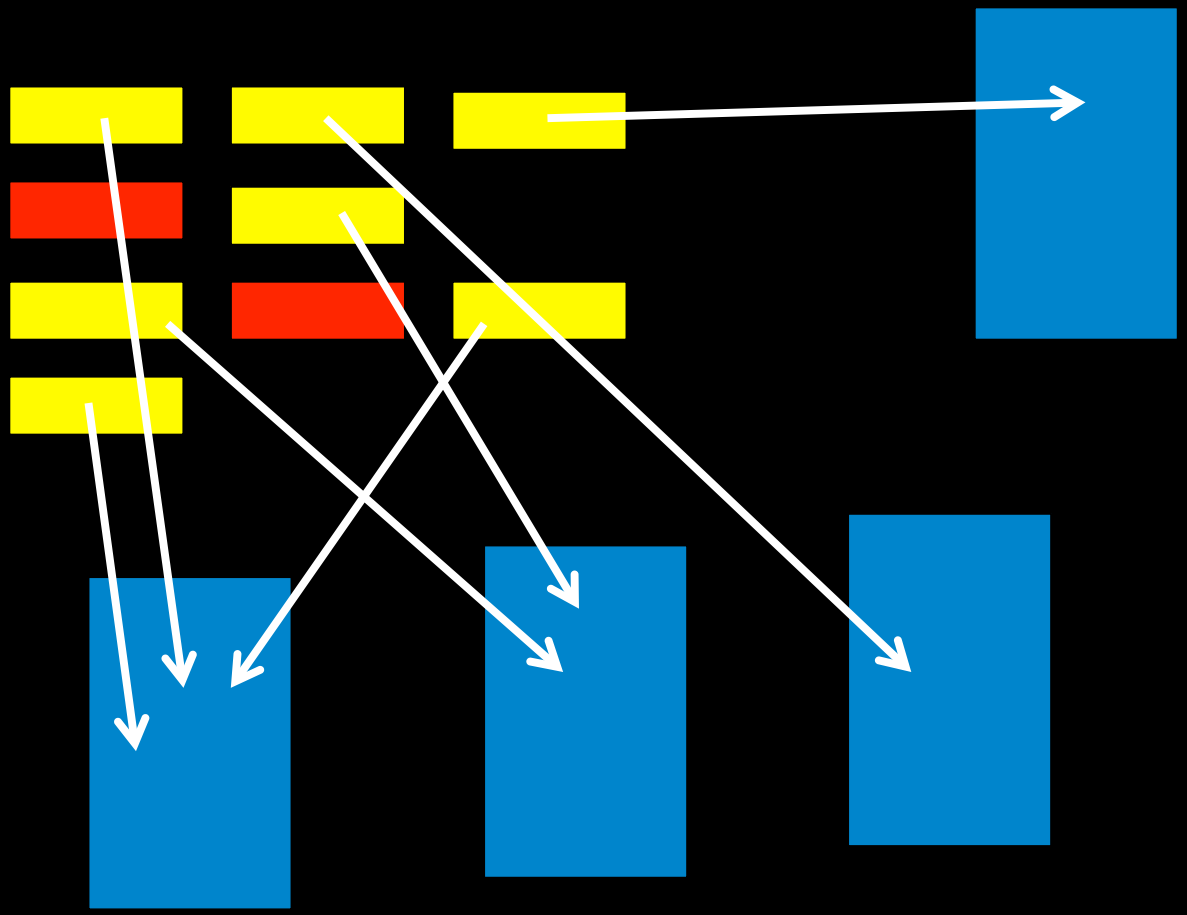
Windows Scheduler

- Lists of threads
- Each points to an ETHREAD
- Each ETHREAD points to its EPROCESS



KYRUS TECHNOLOGY

Windows Scheduler



The Rootkit Paradox

- Rootkits want to run
- Rootkits don’t want to be seen

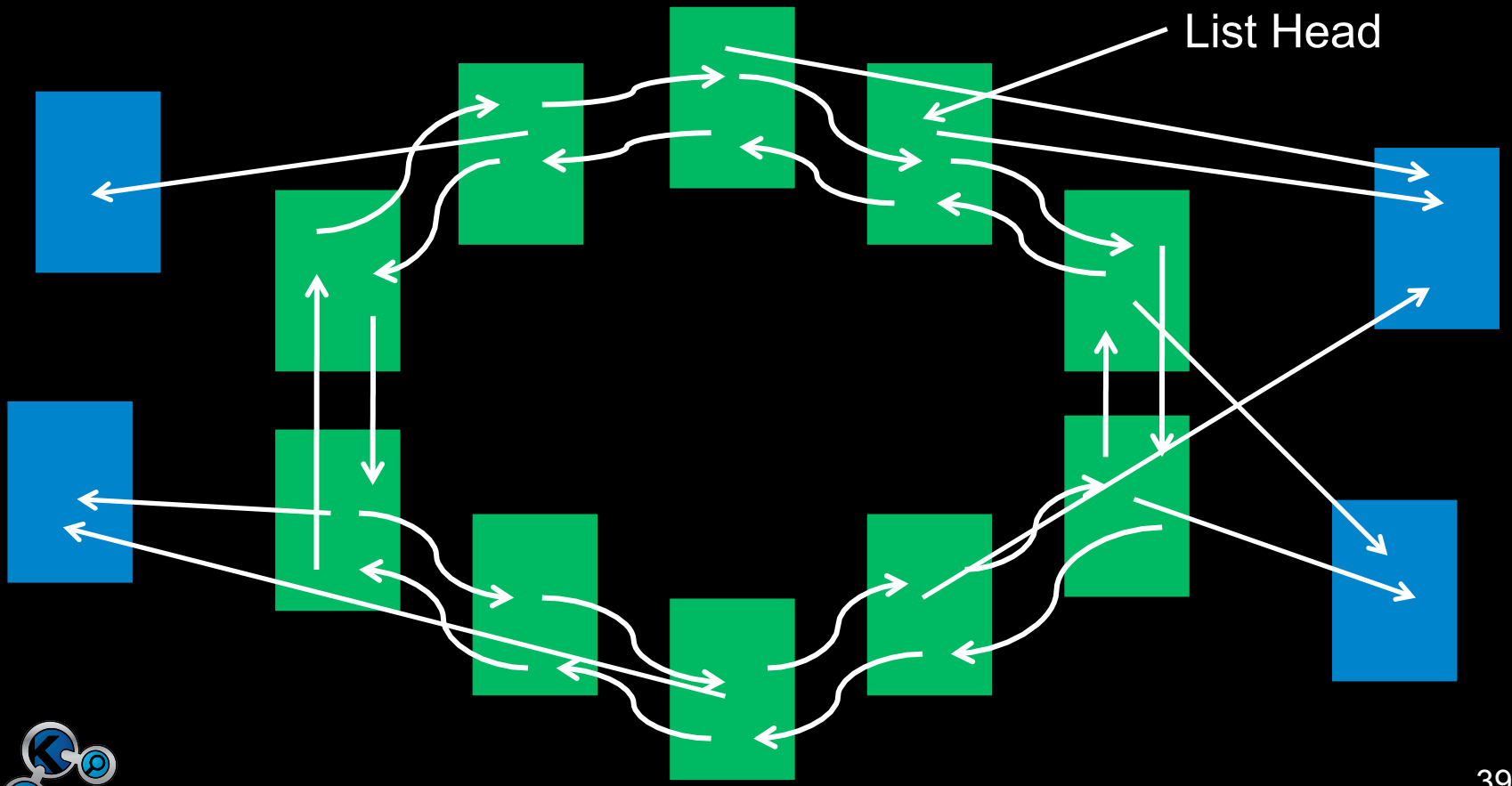
- But to have the former, they must violate the latter

- Full paper http://tinyurl.com/rootkitparadox

KYRUS TECHNOLOGY

But wait, there's more!

- File handles also point to processes
- Kernel maintains list of handles



KYRUS TECHNOLOGY

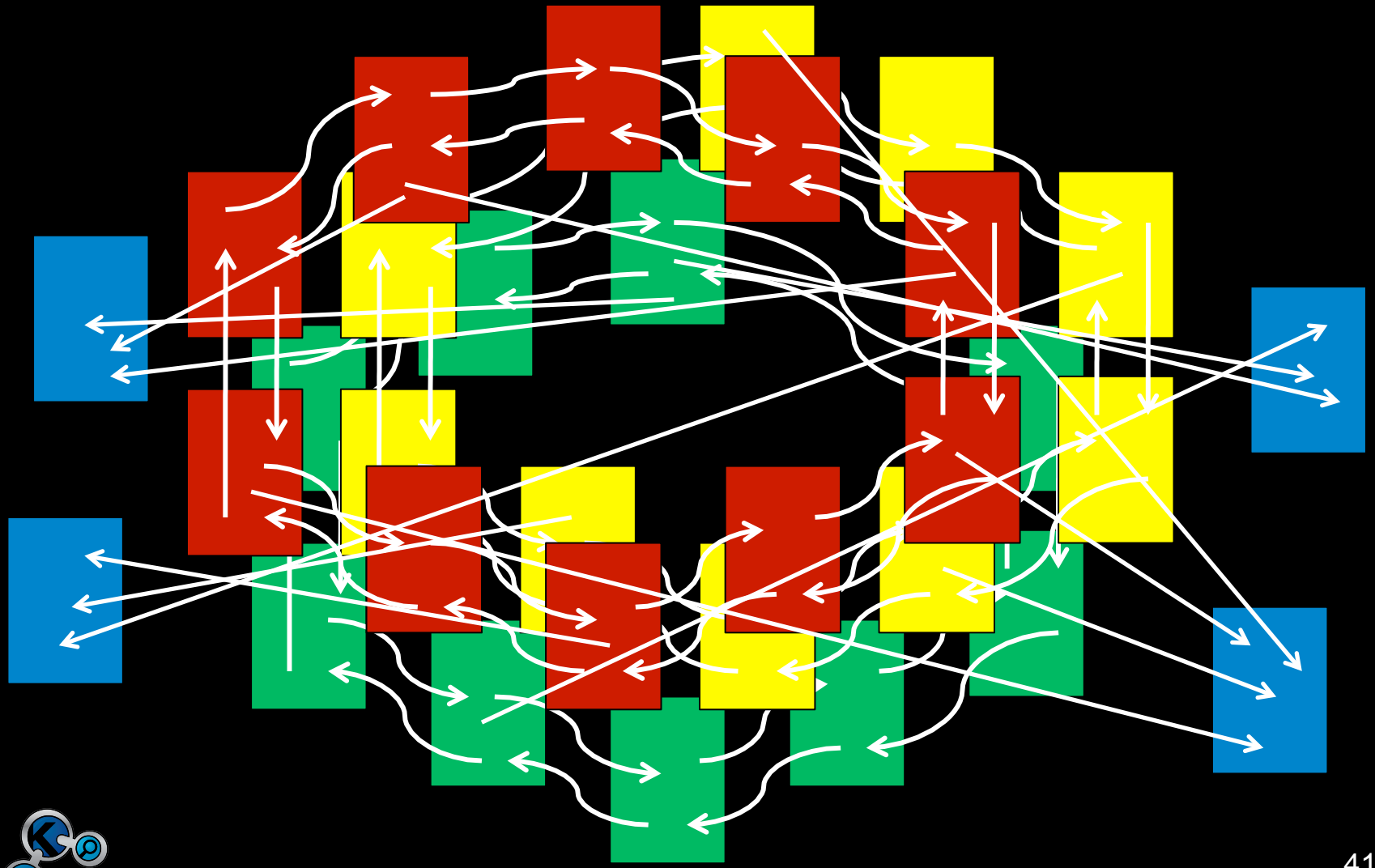
But wait, there's more!

- Processes point to threads
- Network connections point to processes
- And on and on and on…

- For an attacker to hide, they have to update everything
- We just have to validate everything
  - Any inconsistency means we win

KYRUS TECHNOLOGY

But wait, there's more!



KYRUS TECHNOLOGY

Coming Soon

- Unfortunately, no tools use either better magic or kernel objects
  - Yet

KYRUS TECHNOLOGY

Outline

- Introduction
- The Kernel
- Direct Kernel Object Manipulation
- Standard DKOM
- Devious DKOM
- Better Magic
- Relations Between Kernel Objects
- Questions

KYRUS TECHNOLOGY

References

- Brendan Dolan-Gavitt, Abhinav Srivasta, Patrick Traynor, and Jonathon Giffin, Robust Signatures for Kernel Data Structures. Proceedings of the ACM Conference on Computer and Communications Security (CCS), November 2009, http://www.cc.gatech.edu/~brendan/ccs09_siggen.pdf

- Jesse Kornblum, Exploiting the Rootkit Paradox with Windows Memory Analysis, International Journal of Digital Evidence, Fall 2006, http://tinyurl.com/rootkitparadox

KYRUS TECHNOLOGY

Questions?

Jesse Kornblum
jesse.kornblum@kyrus-tech.com

KYRUS TECHNOLOGY