

**Differences and similarities in I/O and provided functionalities between the Linux,
Windows, and FreeBSD Operating Systems**

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Contents

1	Windows	2
1.1	I/O	2
1.1.1	Similarities to Linux	2
1.1.2	Differences from Linux	2
1.2	Provided functionality	2
1.2.1	Similarities to Linux	2
1.2.2	Differences from Linux	3
2	FreeBSD	3
2.1	I/O	3
2.1.1	Similarities to Linux	3
2.1.2	Differences from Linux	3
2.2	Provided functionality	3
2.2.1	Similarities to Linux	3
2.2.2	Differences from Linux	3

1 Windows

1.1 I/O

1.1.1 Similarities to Linux

Both operating systems have a design goal to provide what [3] calls an "abstraction of devices", meaning a universal set of software tools by which the programmer can manage I/O functions. Additionally, both operating systems implement, in their own way, a *Hardware Abstraction Layer* (HAL), which is a generalized interface that allows programs to directly manipulate device hardware [4]. Note, with the HAL as a perfect example, both operating systems' inclusion of abstraction in their design decisions. Linux and Windows both desire to be able to manage the I/O requests of a large variety of devices and file systems, since they are intended to be commercially used operating systems. While they share this design principle, the way in which they approach this abstraction is the source of a lot of differences between the two systems. In terms of cryptography, both use things like *access control lists* (ACLs), PKI, and such to provide basic security.

1.1.2 Differences from Linux

A key difference between Windows and Linux that explains further differences is the fact that Windows and its kernel are separated and are only combined through the use of calls to the Application Binary Interface (ABI) [1], while Linux's device drivers are located within the kernel itself and not relying on calls to the ABI [2]. Programmatically speaking, in Windows, files and devices are managed as *objects* in the object-oriented paradigm, while in Linux files and devices are managed through the use of *file descriptors*, further exemplifying the classic UNIX saying that "Everything is a file". Additionally, Windows' I/O has three device driver layers that each I/O request can be subjected to (though a request can be handled by merely one of these layers). These three layers are *filter*, *function*, and *bus* [3]. Consider the following block of Microsoft C code courtesy of Microsoft's Github that initializes a function driver for a Bluetooth device:

```
NTSTATUS
DriverDeviceAdd(
    IN  WDFDRIVER      _Driver,
    IN  PWDFDEVICE_INIT _DeviceInit
)
```

On the other hand, Linux's drivers are defined as being *block*, *character*, or *network*, and an I/O request can't be processed by all three. Since Windows' kernel doesn't have any device driver development, it instead relies on the *Windows Driver Model* (WDM) to provide device drivers. When a piece of software in Windows requests an I/O operation, the Windows kernel dispatches the request to its *I/O Manager*, which translates the request into an *I/O Request Packet*, or IRP, which is then sent to the device driver layers. The function layer consists of the predominant drivers that map programming interfaces to specific devices, the bus layer helps out device hosting bus controllers, and the filter layer offers extra IRP processing. Meanwhile, in LinuxLand, these device drivers are wildly different: the character device driver type handles simple devices that can be read one byte at a time, the block device driver type handles complex devices whose requests come in the form of blocks of data, and networking options are there for moving data to and from a network.

1.2 Provided functionality

1.2.1 Similarities to Linux

In both operating systems, their respective *Application Programming Interfaces* (APIs) are written to respond to *events*, which is when a user wants something to happen or the device wants to

pass a message to the I/O manager. Windows has three provided functionalities for programmers to allow communication between Userland and I/O drivers: *buffered I/O*, *direct I/O*, and *memory mapping* [1]. Linux also provides these same three functionalities [2]. Both operating systems also provide system-defined data structures, algorithms, and cryptographic protocols, though there is some differences in which options are provided. For example, Linux and Windows kernels both have linked lists, though Windows provides both singly and double linked lists, while Linux only provides a doubly linked circular list by default. The Windows linked lists are included in the file "Ntdef.h", while the Linux kernel's list is included in the "list.h" file.

1.2.2 Differences from Linux

Windows linked lists come in either doubly linked or singularly linked varieties, while Linux only offers doubly linked lists by default, which means you must use a Linux patch file to change this functionality in the Linux kernel. Naturally, there are some differences in the two operating systems' APIs for when it comes to manipulating lists. For example, Windows offers routines like *RemoveHeadList()*, whose function signature is listed below, which can perform convenient operations such as removing the first element of a list.

```
PLIST_ENTRY RemoveHeadList(
    _Inout_ PLIST_ENTRY ListHead
);
```

The same removal of a list head can only be completed in Linux using its "List.h" file by doing the following:

```
if (!list_empty(myQueue->queue))
    list_del(myQueue->queue.next);
```

As we can see, there are different routines provided in the two different systems for performing basic data structure manipulation. In addition to differences in data structure implementation between the two kernels, there is a lot of difference in how the two systems handle encryption. Some of these differences are difficult to compare since Linux is open source and Windows is proprietary. For example, while both kernels provide things like access control lists to institute a level of security, Windows also uses security measures such as the *Microsoft crypto application programming interface* [1]. Therein lies a fundamental and interesting difference between Linux and Windows that is microcosmic of a common theme expressed throughout my writing this quarter: while we can look directly at how Linux implements things like security and criticize or laud them, Windows' source code is on lock down, so all we can do is look at helper routines and things of the like in order to assess how they might be used.

2 FreeBSD

2.1 I/O

2.1.1 Similarities to Linux

2.1.2 Differences from Linux

2.2 Provided functionality

2.2.1 Similarities to Linux

2.2.2 Differences from Linux

References

- [1] Johnson M. Hart. *Windows System Programming (3rd Edition)*. Addison-Wesley Professional, 2004.
- [2] Michael Kerrisk. *The Linux Programming Interface: A Linux and UNIX System Programming Handbook*. No Starch Press, San Francisco, CA, USA, 1st edition, 2010.
- [3] Mark E. Russinovich, Alex Ionescu, and David A. Solomon. *Windows internals, Part 2*. Microsoft, 2012.
- [4] Mark E. Russinovich, David A. Solomon, and Alex Ionescu. *Windows internals*. Microsoft Press, 2012.