PE/COFF

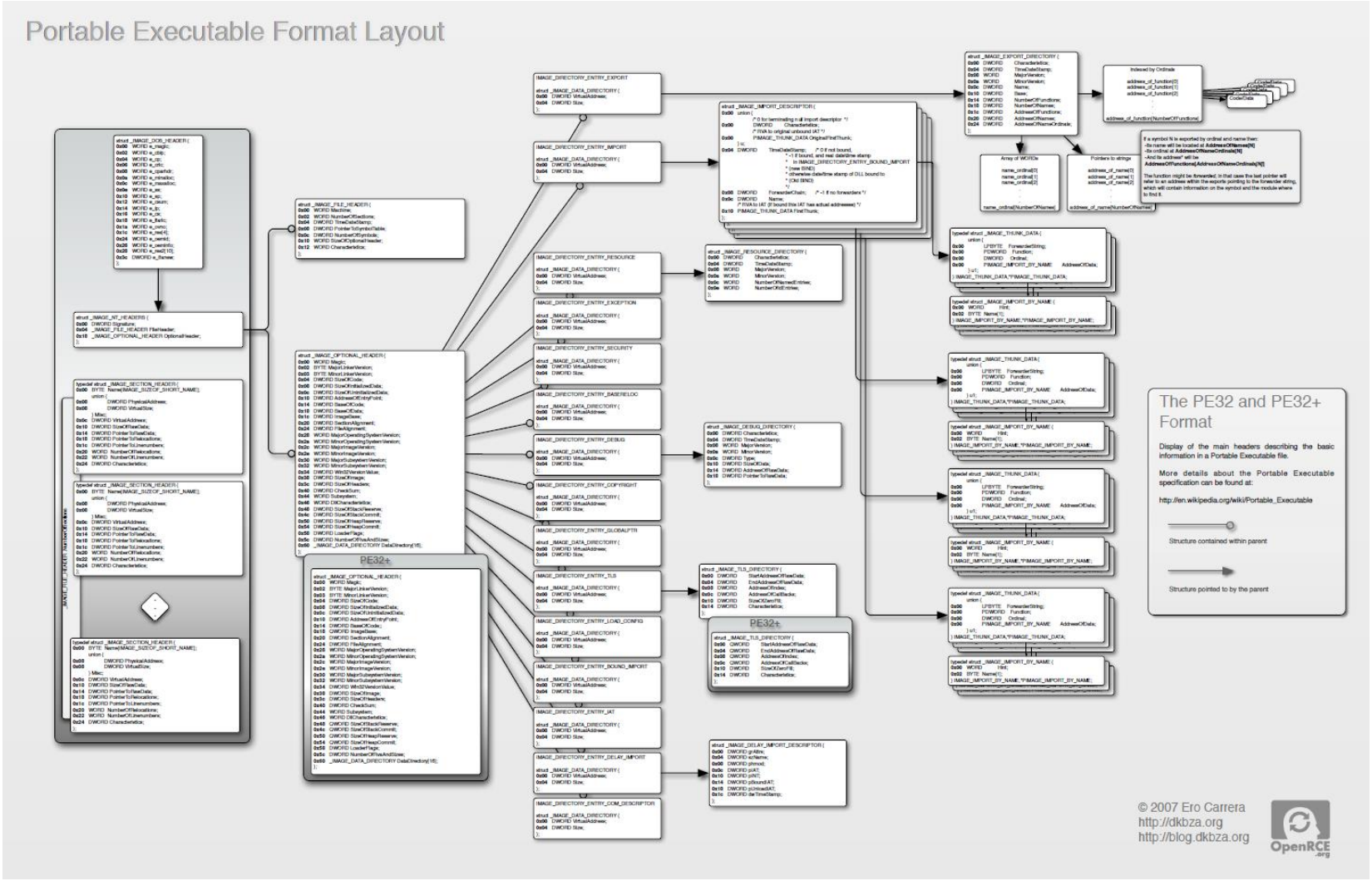
AN INTRODUCTION

Azlan Mukhtar

Introduction to PE/COFF

- PE stands for Portable Executable
- Microsoft introduced PE in Windows NT 3.1
- It originates from Unix COFF
- Features dynamic linking, symbol exporting/importing
- Can contain Intel, Alpha, MIPS and even .NET MSIL binary code
- 64-bit version is called PE32+

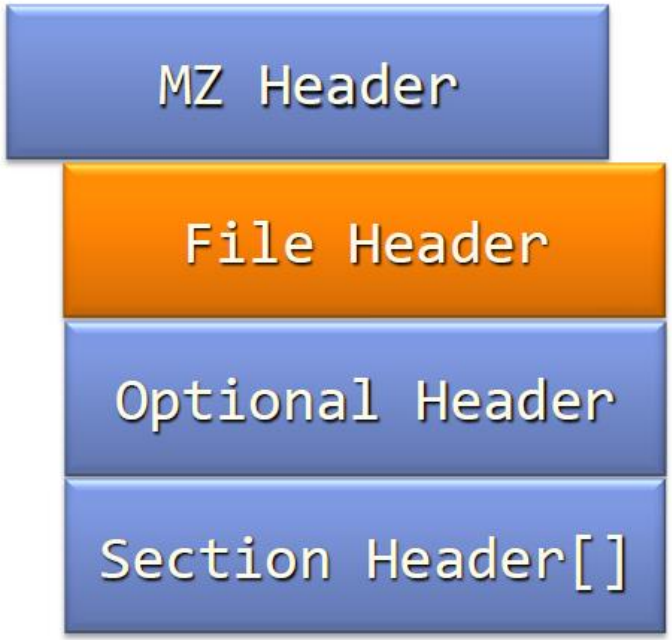
PE Format layout



MZ Header

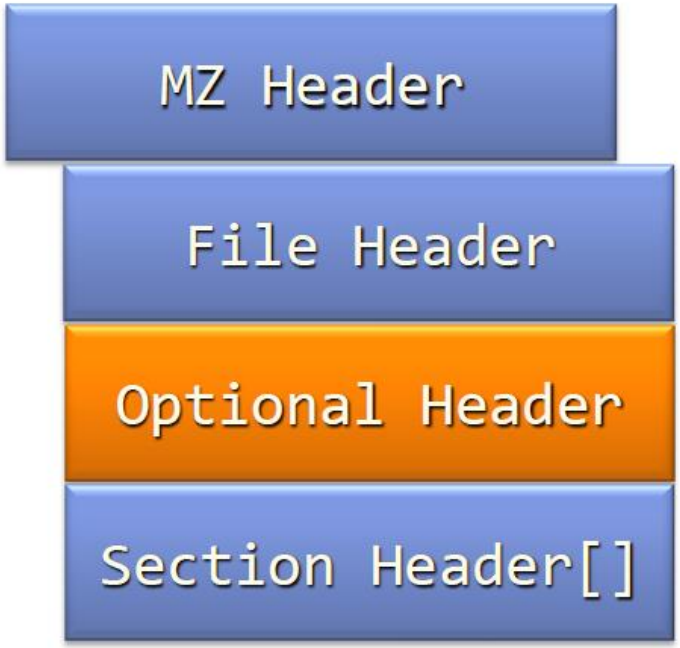

```
struct _IMAGE_DOS_HEADER {
0x00   WORD e_magic;
0x02   WORD e_cblp;
0x04   WORD e_cp;
0x06   WORD e_crlc;
0x08   WORD e_cparhdr;
0x0a   WORD e_minalloc;
0x0c   WORD e_maxalloc;
0x0e   WORD e_ss;
0x10   WORD e_sp;
0x12   WORD e_csum;
0x14   WORD e_ip;
0x16   WORD e_cs;
0x18   WORD e_lfarlc;
0x1a   WORD e_ovno;
0x1c   WORD e_res[4];
0x24   WORD e_oemid;
0x26   WORD e_oeminfo;
0x28   WORD e_res2[10];
0x3c   DWORD e_lfanew;
};
```

PE header – File header



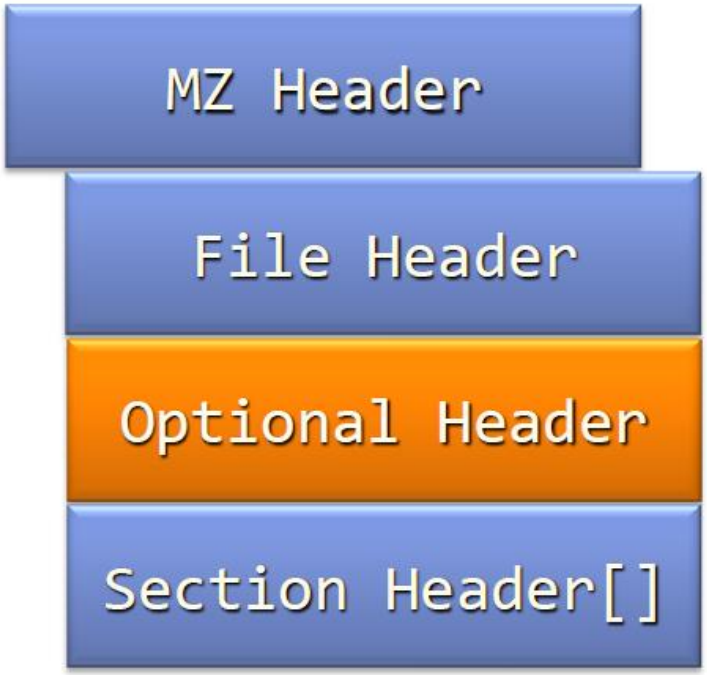

```
struct _IMAGE_FILE_HEADER {
0x00   WORD Machine;
0x02   WORD NumberOfSections;
0x04   DWORD TimeDateStamp;
0x08   DWORD PointerToSymbolTable;
0x0c   DWORD NumberOfSymbols;
0x10   WORD SizeOfOptionalHeader;
0x12   WORD Characteristics;
};
```

PE Header – optional header




```
struct _IMAGE_OPTIONAL_HEADER {
0x00  WORD Magic;
0x02  BYTE MajorLinkerVersion;
0x03  BYTE MinorLinkerVersion;
0x04  DWORD SizeOfCode;
0x08  DWORD SizeOfInitializedData;
0x0c  DWORD SizeOfUninitializedData;
0x10  DWORD AddressOfEntryPoint;
0x14  DWORD BaseOfCode;
0x18  DWORD BaseOfData;
0x1c  DWORD ImageBase;
0x20  DWORD SectionAlignment;
0x24  DWORD FileAlignment;
0x28  WORD MajorOperatingSystemVersion;
0x2a  WORD MinorOperatingSystemVersion;
0x2c  WORD MajorImageVersion;
0x2e  WORD MinorImageVersion;
0x30  WORD MajorSubsystemVersion;
0x32  WORD MinorSubsystemVersion;
0x34  DWORD Win32VersionValue;
0x38  DWORD SizeOfImage;
0x3c  DWORD SizeOfHeaders;
0x40  DWORD CheckSum;
0x44  WORD Subsystem;
0x46  WORD DllCharacteristics;
0x48  DWORD SizeOfStackReserve;
0x4c  DWORD SizeOfStackCommit;
0x50  DWORD SizeOfHeapReserve;
0x54  DWORD SizeOfHeapCommit;
0x58  DWORD LoaderFlags;
0x5c  DWORD NumberOfRvaAndSizes;
0x60  _IMAGE_DATA_DIRECTORY DataDirectory[16];
};
```

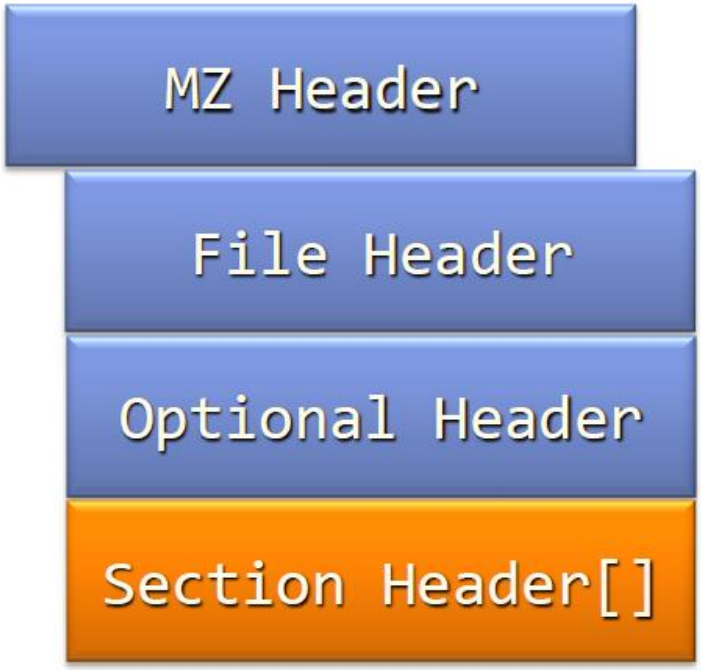
PE Header – optional header – data directory



IMAGE_DIRECTORY_ENTRY_EXPORT
IMAGE_DIRECTORY_ENTRY_IMPORT
IMAGE_DIRECTORY_ENTRY_RESOURCE
IMAGE_DIRECTORY_ENTRY_EXCEPTION
IMAGE_DIRECTORY_ENTRY_SECURITY
IMAGE_DIRECTORY_ENTRY_BASERELOC
IMAGE_DIRECTORY_ENTRY_DEBUG
IMAGE_DIRECTORY_ENTRY_COPYRIGHT
IMAGE_DIRECTORY_ENTRY_GLOBALPTR
IMAGE_DIRECTORY_ENTRY_TLS
IMAGE_DIRECTORY_ENTRY_LOAD_CONFIG
IMAGE_DIRECTORY_ENTRY_BOUND_IMPORT
IMAGE_DIRECTORY_ENTRY_IAT
IMAGE_DIRECTORY_ENTRY_DELAY_IMPORT
IMAGE_DIRECTORY_ENTRY_COM_DESCRIPTOR

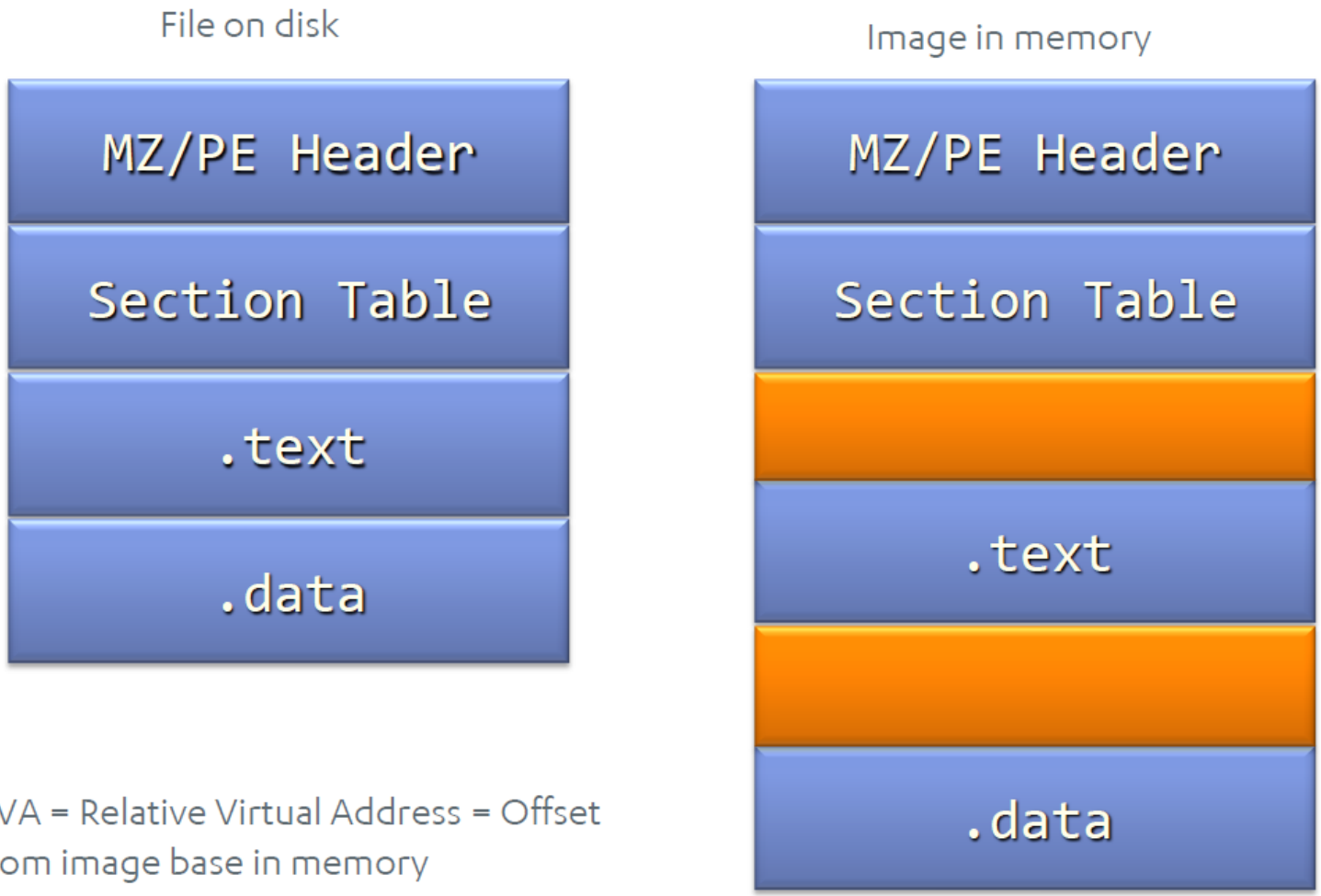
```
struct _IMAGE_DATA_DIRECTORY {
0x00   DWORD VirtualAddress;
0x04   DWORD Size;
};
```

PE Header – section header




```
typedef struct _IMAGE_SECTION_HEADER {
0x00    BYTE  Name[IMAGE_SIZEOF_SHORT_NAME];
        union {
0x08            DWORD PhysicalAddress;
0x08            DWORD VirtualSize;
        } Misc;
0x0c    DWORD VirtualAddress;
0x10    DWORD SizeOfRawData;
0x14    DWORD PointerToRawData;
0x18    DWORD PointerToRelocations;
0x1c    DWORD PointerToLinenumbers;
0x20    WORD  NumberOfRelocations;
0x22    WORD  NumberOfLinenumbers;
0x24    DWORD Characteristics;
};
```

PE Loading



RVA = Relative Virtual Address = Offset from image base in memory

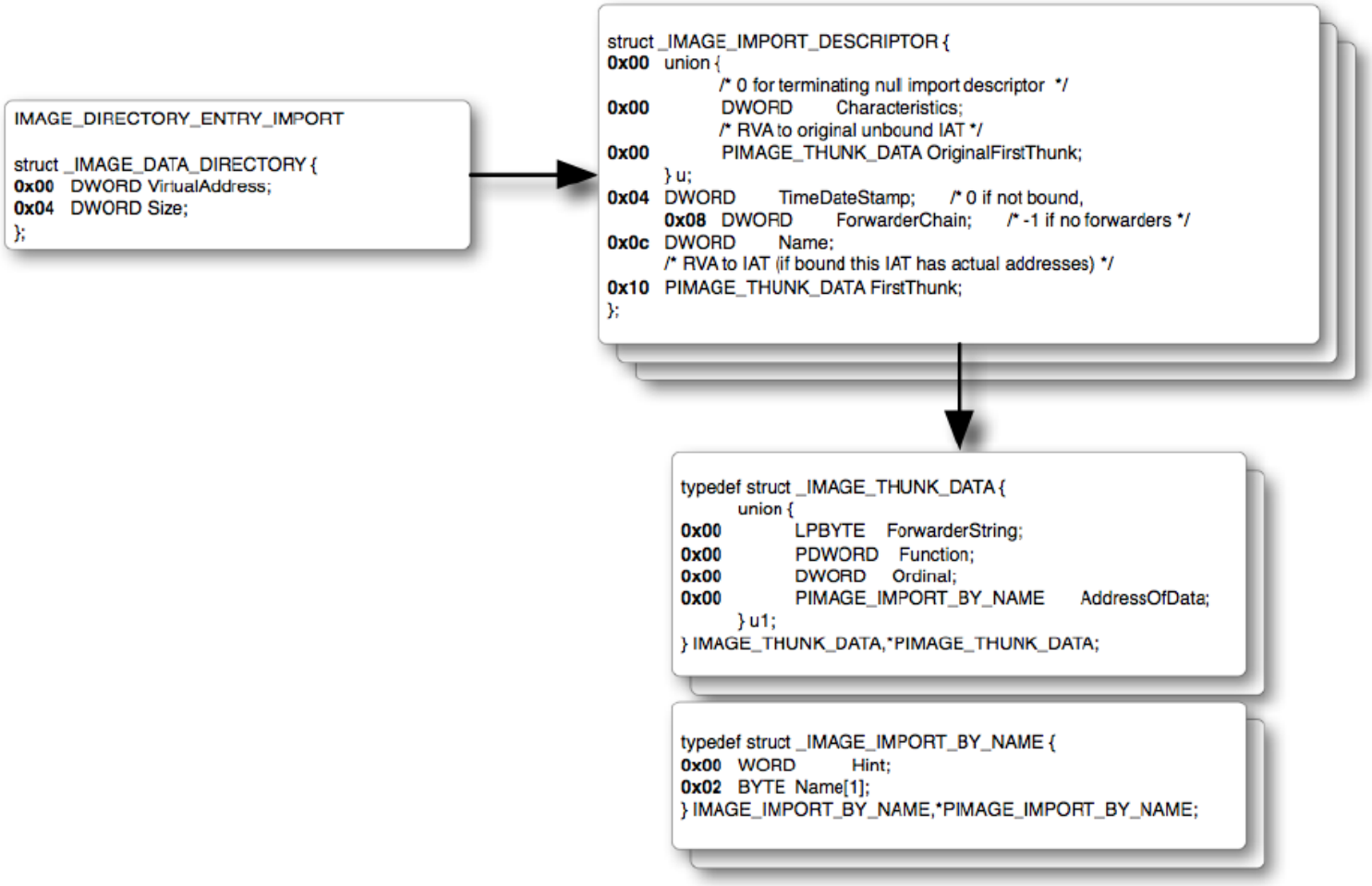
Importing Symbols

- Symbols (functions/data) can be imported from external DLLs
- The loader will load external DLLs automatically
- All the dependencies are loaded as well
- DLLs will be loaded only once
- External addresses are written to the Import Address Table (IAT)

Importing Symbols - continued

- Every PE has one IMAGE_IMPORT_DESCRIPTOR
- The descriptor points to two parallel lists of symbols to import
  - Import Address Table (IAT)
  - Import Name Table (INT)
- The primary list (IAT) is overwritten by the loader, the second one is not
- Executables can be pre-bound to DLLs to speed up loading
- Symbols can be imported by ASCII name or ordinal (usually by Name)

Import Descriptors



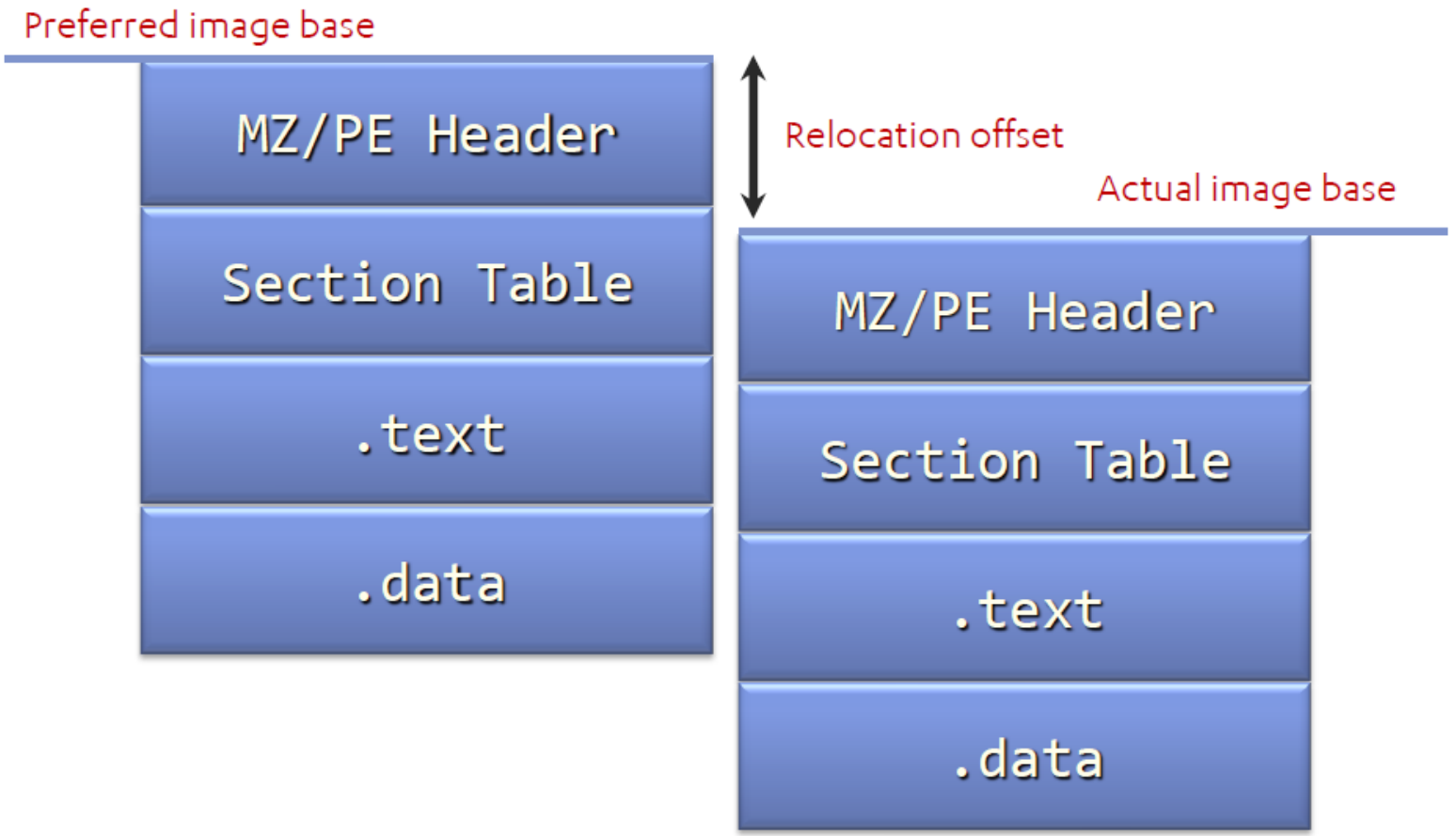
Exports

- Symbols can be exported with ordinals, names or both
- Ordinals are simple index numbers of symbols
- Name is a full ASCII name of the exported symbol
- Exports can be forwarded to another DLL
- Forwarded symbol’s address points to a name in the exports section

Resource

- Resources in PE are similar to an archive
- Resource files can be organized into directory trees
- The data structure is quite complex but there are tools to handle it
- Most common resources:
  - Icons
  - Version information
  - GUI resources

Base Relocation



References

- Microsoft PE and COFF Specification
  - https://msdn.microsoft.com/en-us/windows/hardware/gg463119.aspx
- PE Information
  - http://www.reverse-engineering.info/documents/43.html
- PE File Format Graphs
  - http://blog.dkbza.org/2012/08/pe-file-format-graphs.html
- Understanding RVAs and Import Tables
  - http://www.sunshine2k.de/reversing/tuts/tut_rvait.htm