Windows Kernel Internals NTFS

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Windows Kernel Development

Microsoft Corporation

Basic Design Points

- Aries Logging
- Meta-data via Cache Manager
- Self describing meta-data
- B-trees for fast index lookup
- Multiple user data streams

Disk Basics

- Volume exported via device object
- Addressed by byte offset and length
- Enforced on sector boundaries
- NTFS allocation unit - clusters
- Round size down to clusters

NTFS Knows Files

- Partition is collection of files
- Common routines for all meta-data
- Utilizes MM and Cache Manager
- No specific on-disk locations

Some System Files

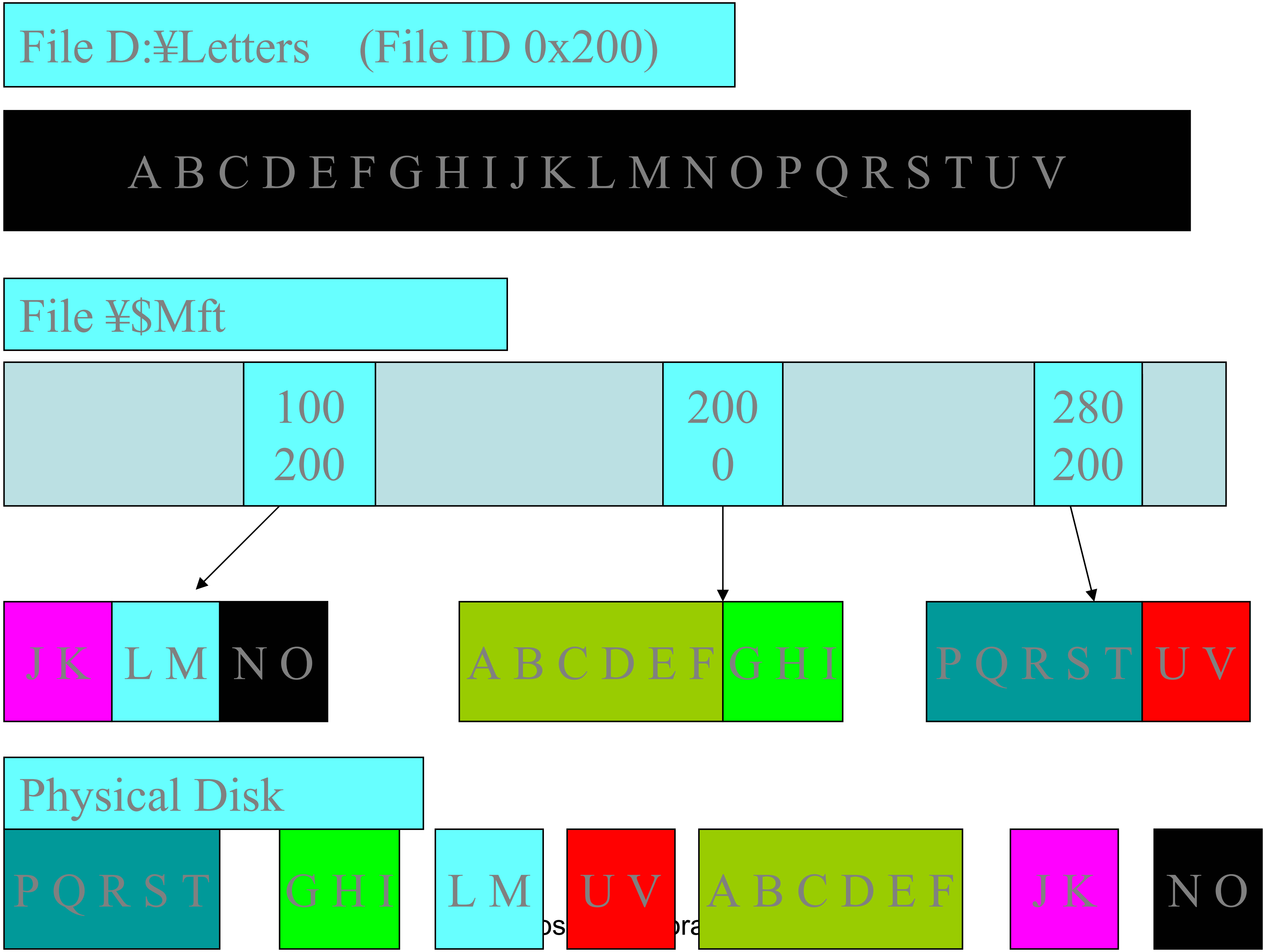
- $Bitmap
- $BadClus
- $Boot
- . (root directory)
- $Logfile
- $Volume

MFT File

- Data is entirely File Records
- File Records are fixed size
- Every file on volume has a File Record
- File records are recycled
- Reserved area for system files

File Records

- ‘Base’ file record for each file
- Header followed by ‘Attributes’
- Additional file records as needed
- Update Sequence Array
- ID by offset and sequence number



File D:¥Letters (File ID 0x200)

A B C D E F G H I J K L M N O P Q R S T U V

File ¥$Mft

100
200 | 200
0 | 280
200

J K | L M | N O

A B C D E F | G H I

P Q R S T | U V

Physical Disk

P Q R S T | G H I | L M | U V | A B C D E F | J K | N O

File Basics

- Timestamps
- File attributes (DOS + NTFS)
- Filename (+ hard links)
- Data streams
- ACL
- Indexes

File Building Blocks

- File Records
- Ntfs Attributes
- Allocated clusters

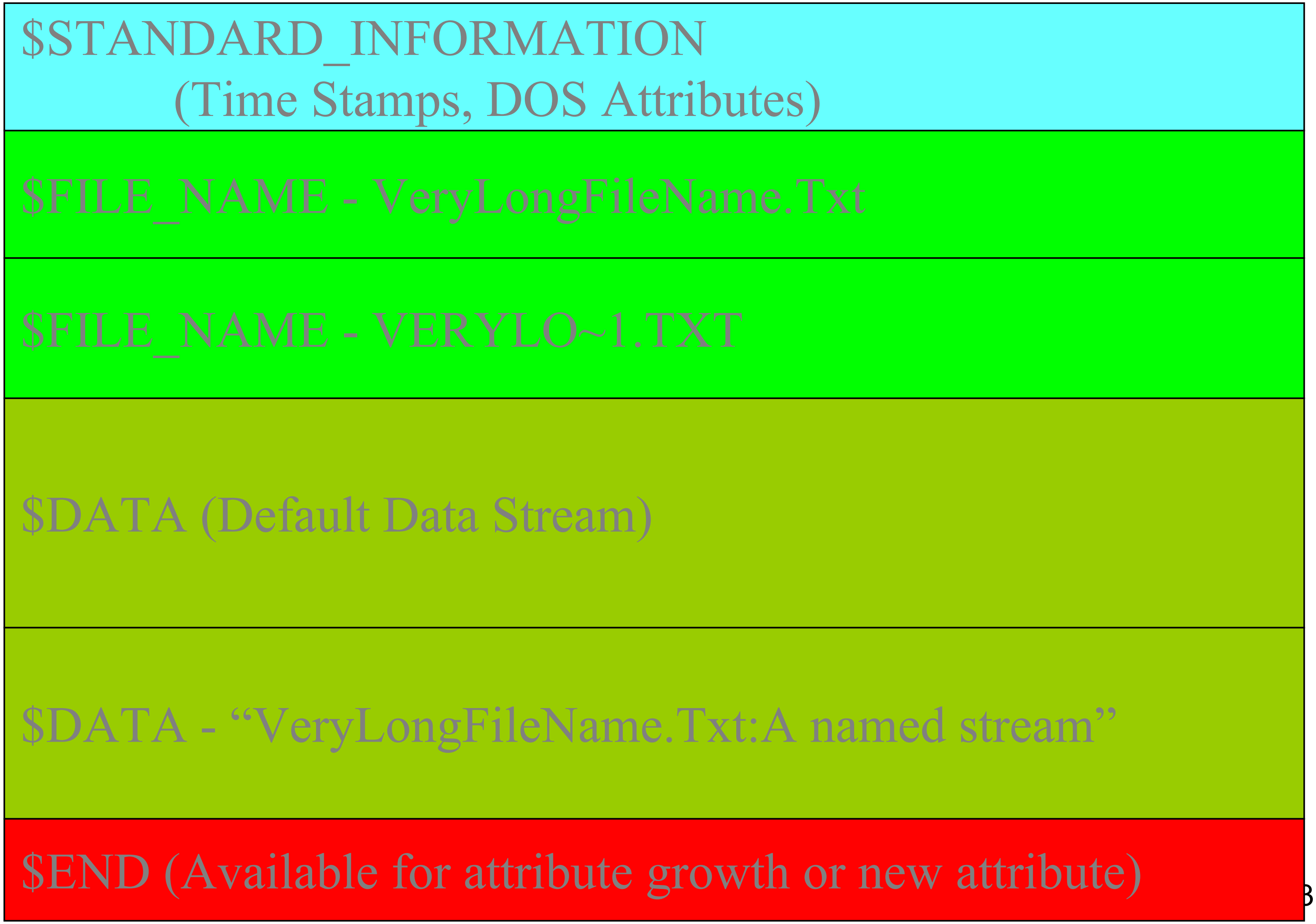
File Record Header

- USA Header
- Sequence Number
- First Attribute Offset
- First Free Byte and Size
- Base File Record
- IN_USE bit

NTFS Attributes

- Type code and optional name
- Resident or non-resident
- Header followed by value
- Sorted within file record
- Common code for operations

MFT File Record



$STANDARD_INFORMATION
(Time Stamps, DOS Attributes)

$FILE_NAME - VeryLongFileName.Txt

$FILE_NAME - VERYLO~1.TXT

$DATA (Default Data Stream)

$DATA - “VeryLongFileName.Txt:A named stream”

$END (Available for attribute growth or new attribute)

Attribute Header

- Length
- Form
- Name and name length
- Flags (Compressed, Encrypted, Sparse)

Resident Attributes

- Data follows attribute header
- ‘Allocation Size’ on 8-byte boundary
- May grow or shrink
- Convert to non-resident

Non-Resident Attributes

- Data stored in allocated disk clusters
- May describe sub-range of stream
- Sizes and stream properties
- Mapping pairs for on-disk runs

Some Attribute Types

$STANDARD_INFORMATION

$FILE_NAME

$SECURITY_DESCRIPTOR

$DATA

$INDEX_ROOT

$INDEX_ALLOCATION

$BITMAP

$EA

Mapping Pairs

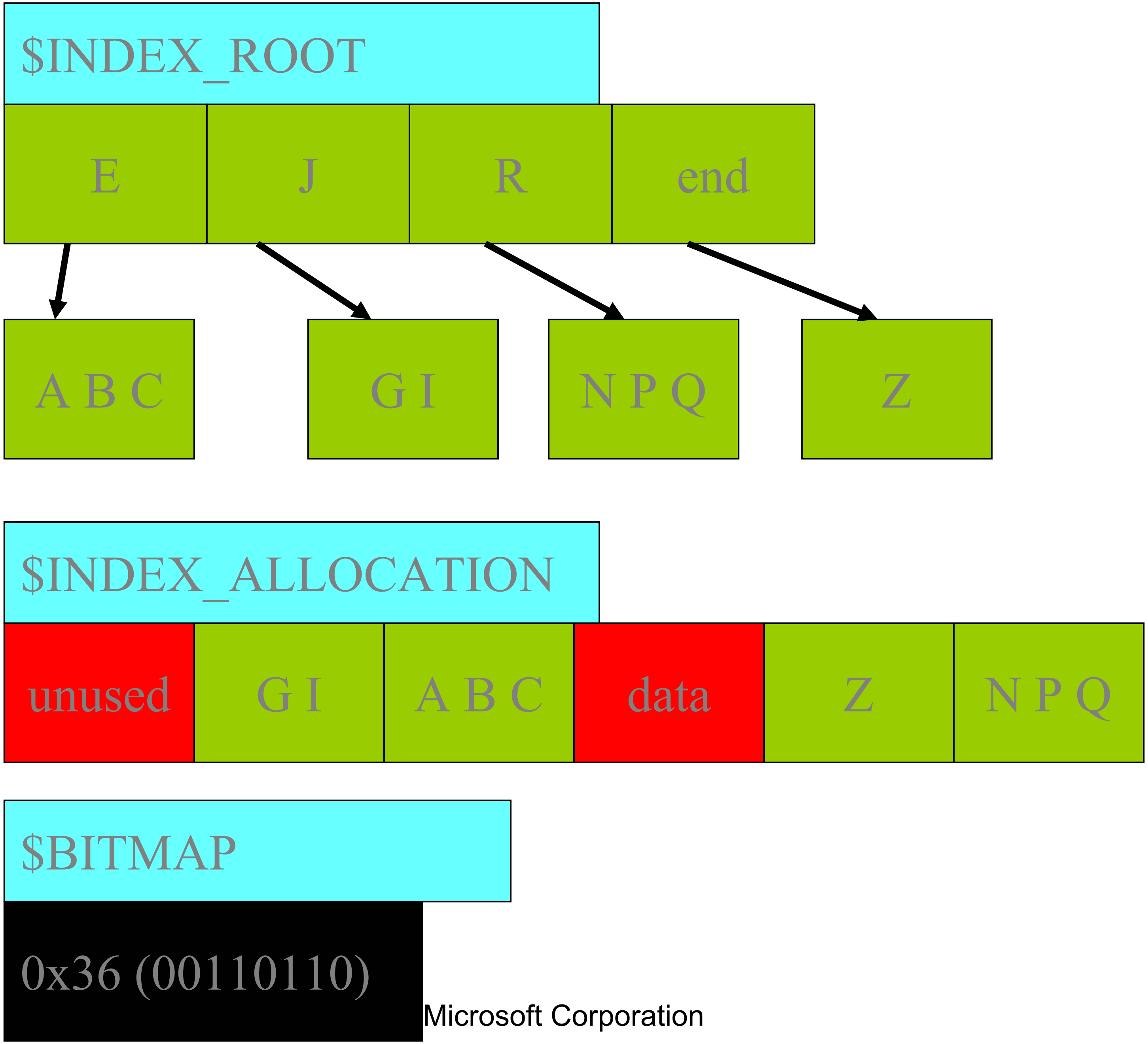
- Stored in a byte optimal format
- Represents allocation and holes
- Each pair is relative to prior run
- Used to represent compression/sparse

Indexes

- File name and view indexes
- Indexes are B-trees
- Entries stored at each level
- Intermediate nodes have down pointers
- $INDEX_ROOT
- $INDEX_ALLOCATION
- $BITMAP

Index Implementation

- Top level - $INDEX_ROOT
- Index buckets - $INDEX_ALLOCATION
- Available buckets - $BITMAP



$INDEX_ROOT

E J R end

A B C

G I

N P Q

Z

$INDEX_ALLOCATION

unused | G I | A B C | data | Z | N P Q

$BITMAP

0x36 (00110110)

$ATTRIBUTE_LIST

- Needed for multi-file record file
- Entry for each attribute in file
- Resident or non-resident form
- Must be in base file record

Attribute List (example)

- Base Record - 0x200
- 0x10 - Standard
- 0x20 - Attribute List
- 0x30 - FileName
- 0x80 - Default Data
- 0x80 - Data1 “Owner”

- Aux Record - 0x180
- 0x30 - FileName
- 0x80 - Data “Author”
- 0x80 - Data0 “Owner”
- 0x80 - Data “Writer”

Attribute List (example cont.)

Code	FR	VCN	Name	(Not Present)
0x10	0x200			$Standard
0x30	0x200			$Filename
0x30	0x180			$Filename
0x80	0x200	0		$Data
0x80	0x180	0	“Author”	$Data
0x80	0x180	0	“Owner”	$Data
0x80	0x200	40	“Owner”	$Data
0x80	0x180		“Writer”	$Data

Discussion