Different Interpretations of ISO9660 File Systems

By

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Different Interpretations of ISO9660 File Systems

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Agenda

- Basics of ISO9660
- Test Description and Results

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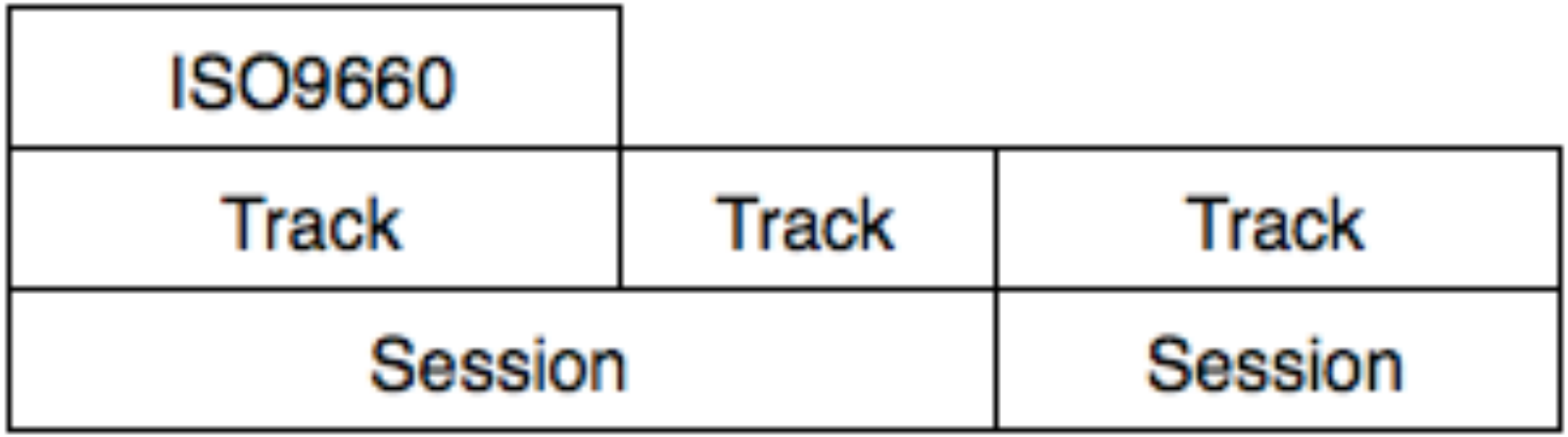
Sessions vs. File Systems

- A physical CD can have one or more sessions.
- A session can have one or more tracks.
- A track can contain an ISO9660 file system.



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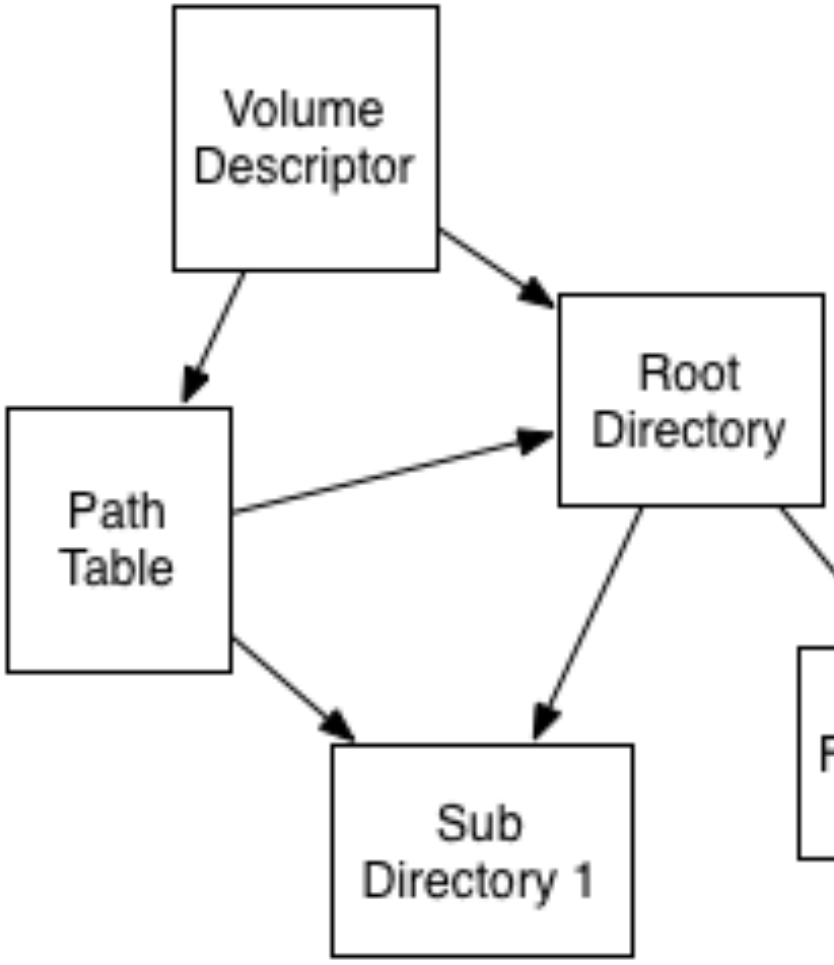
Very High Level Overview



- **Volume Descriptor** is located at fixed offset in the beginning of the FS.
- **Path Table** has an entry for each directory in FS.
- **Directories** contain a list of entries. One for each of its files and sub-directories.

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Basic Limitations

- File names are restricted to 8 characters in the name and 3 in the extension.
- Use of non-English file names is limited.
- Solution:
  - Create a separate directory hierarchy and store alternative forms of file names in it.
  - Joliet extension allows for longer names in Unicode.

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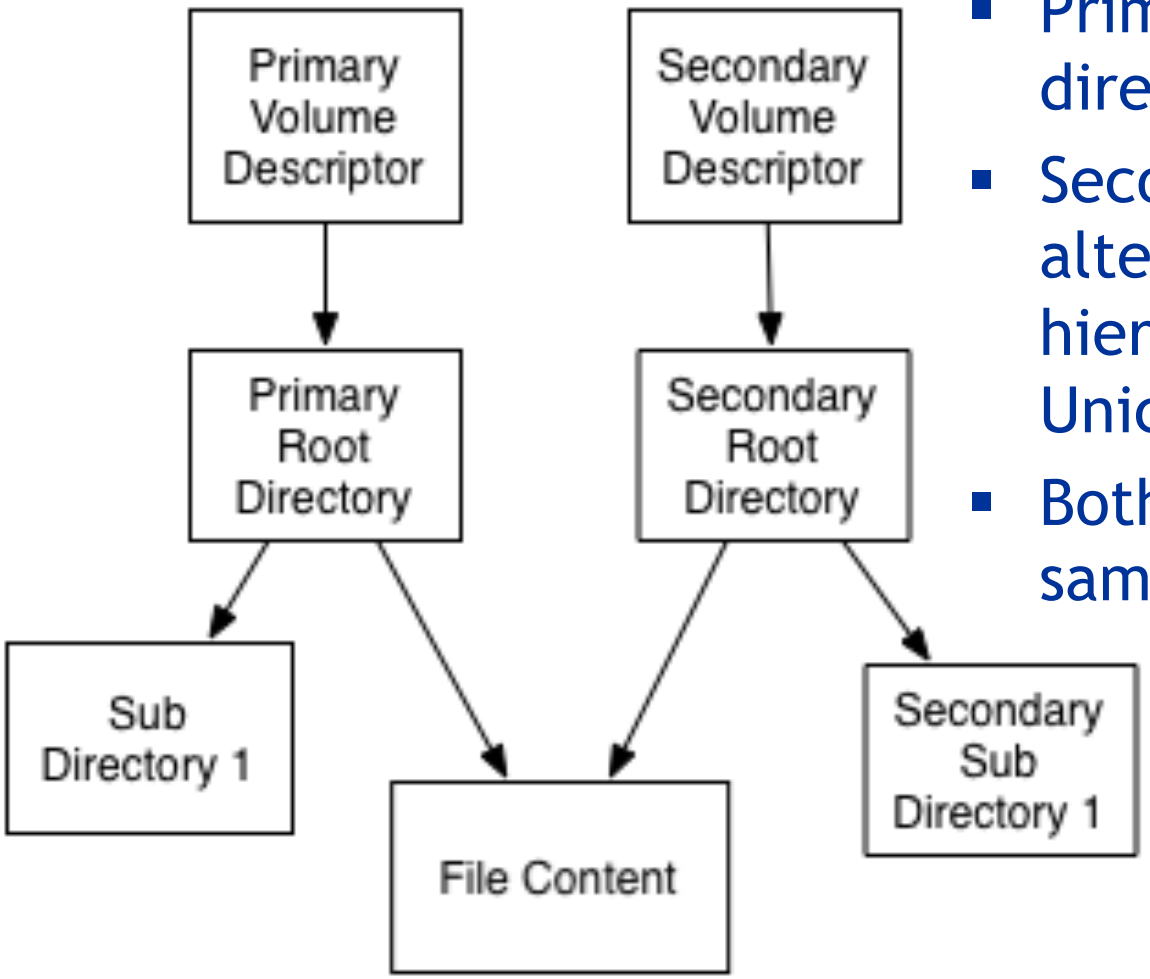
Multiple Volume Descriptors



- Primary points to 8.3 directory hierarchy.
- Secondary points to alternative directory hierarchies (i.e. Joliet / Unicode)
- Both can refer to the same file content.

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File Content

- Files on a CD are, generally, not fragmented.
  - Some have a consistent and defined interleave
- Location of file content is specified with only two values:
  - Starting block address
  - File size

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Endian Ordering

- File systems generally store data in a single endian byte ordering:
  - Big Endian: `12 34 56 78`
  - Little Endian: `78 56 34 12`
- ISO9660 stores most of its values in both big and little endian ordering:
  - FS block sizes and block count
  - File size and starting block location
  - …

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ISO9660 Interpretations

- The design of ISO9660 allows for multiple interpretations:
  - Multiple directory hierarchies
  - Multiple endian orderings
- If a forensic tool chooses only one of multiple interpretations, then it may miss evidence.
- This work created disk images to test what interpretations that the tools were choosing.
- Test images will be made available at

  http://dftt.sf.net

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Tools Tested

- Import disk image file:
  - EnCase 6.15
  - Forensic Tool Kit (FTK) 1.60
  - ISOBuster 2.7
  - Sleuth Kit (TSK) 3.1.0
  - WinHex Forensics: With and without “Read ISO9660 even if Joliet Present” option.
- Linux 2.6: Physical CD and mounted disk image in loopback:
  - Default options
  - Nojoliet option
  - Norock option
- OS X 10.4.11 (Power PC) and OS X 10.6.2 (Intel): Physical CD and mounted disk image with Disk Utility
- Windows XP and Vista: Physical CD

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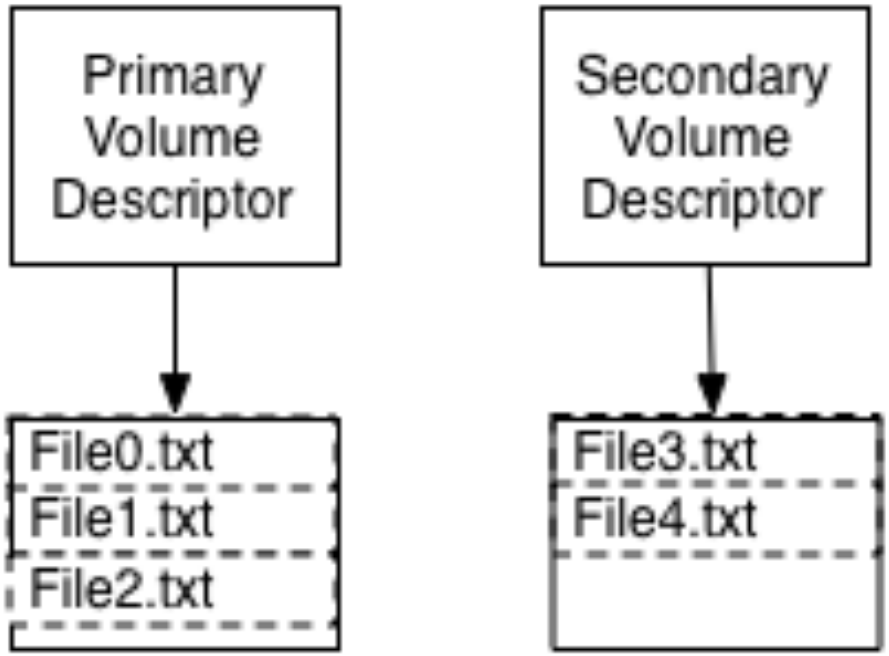
Test #1: Inconsistent Directories

- There is no requirement that the multiple directory hierarchies are consistent.
- Test: Place different files in each root directory and see what is displayed in each tool.



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Test #1 Creation

- Create a Joliet image with two files in root directory: File1.txt and File2.txt.
- Used fsstat in TSK to locate the primary and secondary root directories.
- Used hex editor to:
  - Zero out the File2.txt entry in the primary hierarchy.
  - Overwrite the File1.txt entry in the secondary hierarchy with the File2.txt entry.

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Test #1 Results

- Displayed both files:
  - FTK
  - ISOBuster
  - TSK
  - WinHex Forensics ("Read ISO9660 even if Joliet Present" option enabled)
- Displayed only File1 (Primary Descriptor):
  - Linux (via CD, default mount options, nojoliet options)
  - OS X (via CD, Disk Utility mount)

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Test #1 Results (contd.)

- Displayed only File2 (Secondary Descriptor):
  - EnCase
  - Linux (norock mount option)
  - Windows XP and Vista
  - WinHex Forensics (default options)
- Summary:
  - 28% showed both files
  - 36% showed only File1.txt
  - 36% showed only File2.txt

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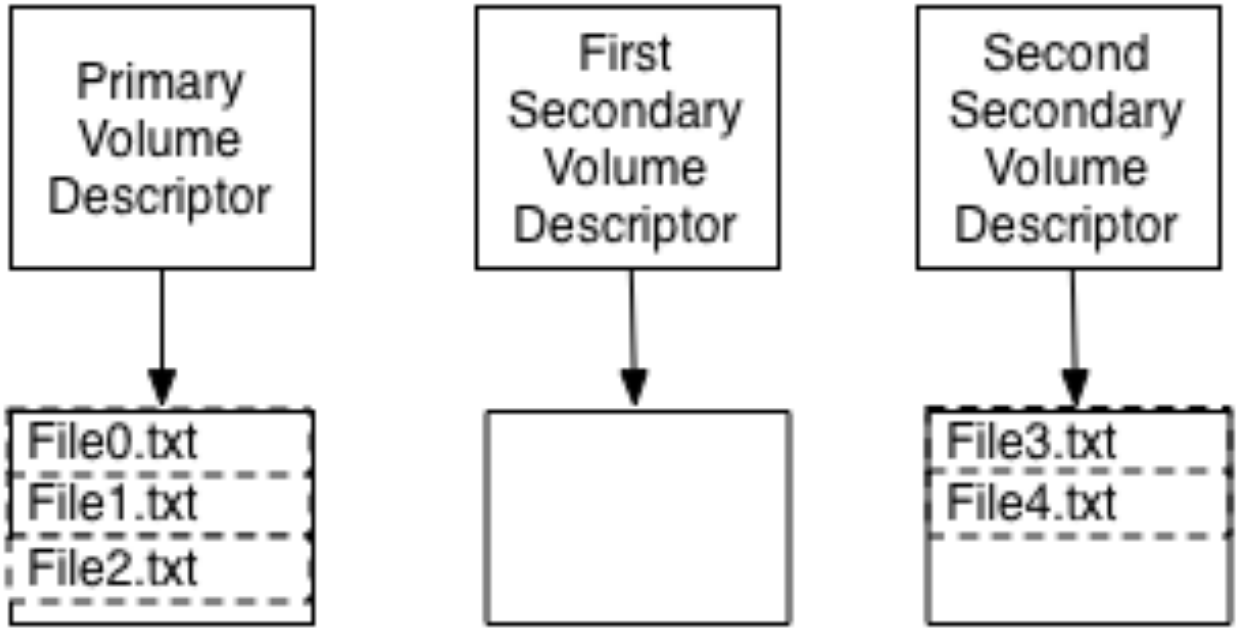
Test #2: Three Hierarchies

- Several of the tools seem to look only at the second hierarchy.
- Test: Have three hierarchies with the second one being empty and different files in others.



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Test #2 Creation

- Started with image from Test #1.
- Manually created third hierarchy using the second one as a base:
  - Used ‘blkls’ in TSK to identify unused blocks to store new root directory and path table.
  - Copied existing root directory and path table into them.
  - Copied existing secondary volume descriptor to make the second secondary descriptor and adjusted root directory and path table values.
- Zeroed out contents of second root directory.

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Test #2 Results

- Showed both File1.txt and File2.txt (same as test #1):
  - FTK, ISOBuster, TSK, WinHex Forensics (with ISO9660 option)
- Showed only File1.txt (same as test #1):
  - Linux (CD, default mount, nojoliet mount), OS X
- Showed only File2.txt (subset of test #1):
  - WinHex Forensics (default options)
- Showed no files:
  - EnCase, Linux (norock option), Windows XP and Vista
- Summary:
  - 28.5% showed both files
  - 36% showed only File1.txt
  - 7% showed only File2.txt
  - 28.5% showed no files

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Test #3: Endian Ordering

- Many values are stored in both big- and little-endian orderings.
- Test: Have a file with different starting block address values in the different orderings.

Name	Starting Block (big-endian)	Starting Block (little-endian)
File1.txt	00 00 00 20	30 00 00 00

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Test #3 Creation

- Create an image with a single file whose contents are “This tool uses the little-endian value”.
- Locate the root directory and file contents using TSK.
- Copy the file contents to a free block and edit with a hex editor to have “This tool uses the big-endian value”.
- Edit the file entry so that its big-endian starting block value is the above block.

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Test #3 Results

- Displays Both Files:
  - ISOBuster (with non-default settings)
- Displays Big Endian:
  - FTK, ISOBuster (with default settings), TSK
- Displays Little Endian:
  - EnCase, Linux (all variations), OS X (all variations and platforms), Windows (all variations), WinHex (all variations)
- Summary:
  - 6% show both values
  - 19% use only big-endian value
  - 75% use only little-endian value
  - 0% report any type of warning

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Test Summary

- Many tools choose only one interpretation:
  - 72% show only one file in the first two tests.
  - 65% don't look beyond the first secondary descriptor
  - 29% failed to show either file in test 2
  - None of the tools warned about inconsistent endian ordering values.
- The tools are not consistent about which interpretation they choose

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Data Hiding Implications

- These techniques could work, but it would be risky because some of the tools may show the hidden files.
- The file content can still be found from carving and keyword searching unallocated space.

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Recommendation

- Use one of the tools that considers multiple interpretations.
- Use multiple tools that consider different interpretations.
  - Somehow merge the results together…
- Urge the tool vendors to consider multiple interpretations.

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User Interface Challenge

- ISO9660 is so different from typical file systems that it creates an interface challenge.
- How to show multiple directory hierarchies in the analysis tool?
  - FTK, ISOBuster, and WinHex showed each of the hierarchies in their entirety.
  - TSK showed the Secondary descriptor as the default hierarchy and showed files from the other hierarchies as orphan files that could not be reached from the root directory.
- How to show keyword search results when a file has a different path in each hierarchy (show it as one hit or two)?
- How to allow user to view both big- and little-endian interpretation of the data?

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Possible Future Work

- Analyze popular disk mastering software to determine if they use techniques similar to these:
  - Maybe different endian values are used to refer to endian-specific file content.
  - Could help to evaluate if existence of these techniques on a CD implies malicious intent.
- Define a standard procedure for analyzing ISO9660 file systems.

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