

# Forensic Analysis of Internet Explorer Activity Files

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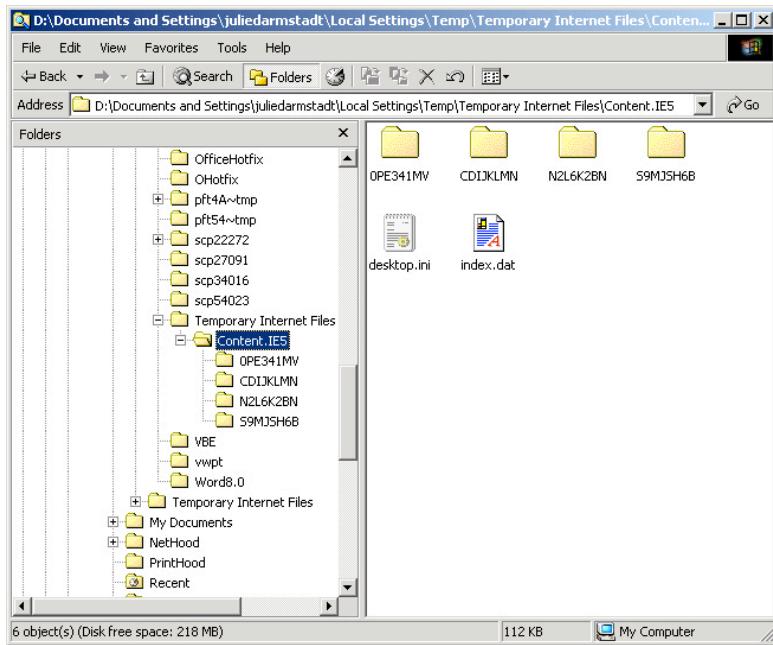
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## 1. Introduction

There are many types of investigations that you may conduct as a computer forensic specialist. During many of these investigations, you may want to obtain compelling evidence to suggest a predisposition to conduct some action, implying intent. One of the potential sources of information that helps you prove an event occurred, or to determine the predisposition of a computer user is to review the Web sites that individual visited. Nearly every computer user is familiar with Web browsers such as *Internet Explorer* and the *Netscape*. Both of these Web browsers maintain history files that reveal the Web Sites (or Uniform Resource Locators -URLs) visited by users of the system. Since these *browser history files* are in binary form, special tools are required to review them. Since *Internet Explorer* is the most popular application used to browse the Web, we have first created a tool, called *Pasco*, to reconstruct the history files that *Internet Explorer* maintains.

*Internet Explorer* caches URLs that a user visits. When a user visits any Web Site, *Internet Explorer* checks to see if it has already stored (*cached*) a local copy of that Web Site on the hard drive first. If a local copy exists, *Internet Explorer* uses the local cached file instead of downloading the information from the Internet. *Internet Explorer* stores cached files in the Temporary Internet Folders on the local hard drive. It also assigns each cached file with an alphanumeric name, and maps the new filenames to the actual filenames in system files. The system files used to map the cached alphanumeric names to the actual URLs and filenames is the `Index.dat` files. These `Index.dat` files record the URL, the date the Web page was last modified by the server and the date that the URL was last accessed by the user. *Internet Explorer* maintains many of these `Index.dat` files, which are binary (not humanly readable) files. Unfortunately, the internal structures for the *Internet Explorer* history files (really cache files) are not well known. This White Paper reverse engineers the structure of these files using a basic hex editor.



**Figure 1 – One location for an Index.dat file**

The following table lists additional areas of the file system other `index.dat` files may be located:

**Table 1 - Common Index.dat File Locations for Internet Explorer**

<i>Operating System</i>	<i>File Path(s)</i>
Windows 95/98/Me	\Windows\Temporary Internet Files\Content.IE5\ \Windows\Cookies\ \Windows\History\History.IE5\<
Windows NT	\Winnt\Profiles\<username>\Local Settings\Temporary Internet Files\Content.IE5\ \Winnt\Profiles\<username>\Cookies\ \Winnt\Profiles\<username>\Local Settings\History\History.IE5\<
Windows 2K/XP	\Documents and Settings\<username>\Local Settings\Temporary Internet Files\Content.IE5\ \Documents and Settings\<username>\Cookies\ \Document and Settings\<username>\Local Settings\History\History.IE5\<

This research was performed to give the computer forensic community an open source, reproducible, forensically sound, and documented method to reconstruct Internet Explorer activity. The relevant data introduced in this paper was discovered while analyzing the internal structures for a cache file and comparing the results to known output generated from IE History ([www.phillipsponder.com](http://www.phillipsponder.com)), a popular commercial tool to reconstruct Internet Explorer activity, on the same file.

## 2. The Index.dat File Header

The `index.dat` file contains a header that harbors important information about the file's properties. Specifically, the header will contain the `index.dat` file length, the HASH table offset, and the internet cache directory names.

The first field we notice is the *file size*. The file size is given in the file header immediately following the NULL (0x00) terminated version string<sup>1</sup>. In this case it is “00 C0 01 00”. With most of the numerical values found in the `index.dat` file, one must swap the bytes from left to right when reading the value. In the example below, the file size is 0x0001C000. This translates to a value of 114688 bytes, which is correct for the file used in this demonstration.

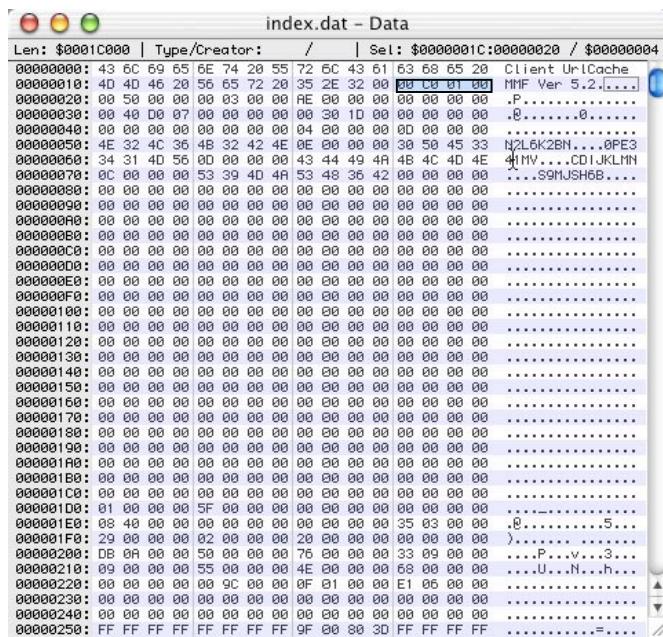


Figure 2 – The Index.dat File Size

Immediately following the file size is the location of the *HASH Table*. The HASH table is an array of data that contains entries pointing to the relevant activity data within the `index.dat` file. We will use these pointers, or offsets, to find the relevant data within the `index.dat` file. The HASH table is important enough that it will be described in its own upcoming section.

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<sup>1</sup> This string will indicate which version of IE created this index.dat file. This paper will focus on v5, but appropriate notes will be made for v4 differences.

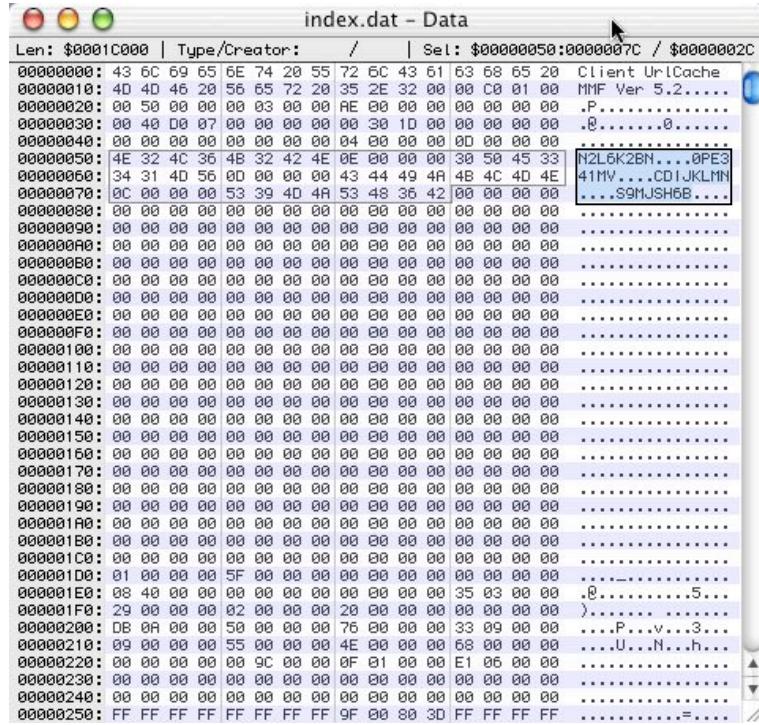
index.dat - Data										
Len:	\$0001C000	Type/Creator:	/		Sel:	\$00000020:00000024	/	\$00000004		
	00000000: 43 6C 69 65 6E 74 20 55 72 6C 43 61	63 68 65 20	Client UriCache							
	00000010: 4D 4D 46 20 56 65 72 20	35 2E 32 00	00 C8 01 00	MNF Ver 5.2...						
	00000020: 00 50 00 00	00 03 00 00	AE 00 00 00	00 00 00 00	[P...]					
	00000030: 00 40 D0 07 00 00 00 00	00 38 1D 00	00 00 00 00	00 00 00 00	[B.....0...]					
	00000040: 00 00 00 00 00 00 00 00	00 04 00 00	00 00 00 00	00 00 00 00						
	00000050: 4E 32 4C 36 4B 32 42 4E	0E 00 00 00	00 30 50 45	33 N2L6K2BN...8PE3						
	00000060: 34 31 4D 56 0D 00 00 00	00 43 44 49	4A 4B 4C 4D	4E 41MV...CD1JKLMN						
	00000070: 0C 00 00 00 53 39 4D 4F	53 48 36 42	00 00 00 00	00 00 00 00	[...S9IJSH6B...]					
	00000080: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000090: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000000A0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000000B0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000000C0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000000D0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000000E0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000000F0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000100: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000110: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000120: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000130: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000140: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000150: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000160: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000170: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000180: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000190: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000001A0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000001B0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000001C0: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000001D0: 01 00 00 00 5F 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	000001E0: 08 40 00 00 00 00 00 00	00 00 00 00	00 00 00 35	03 03 00 00	[0.....5...]					
	000001F0: 29 00 00 00 02 00 00 00	20 00 00 00	00 00 00 00	00 00 00 00						
	00000200: DB 0A 00 00 50 00 00 00	75 00 00 00	33 09 00 00	00 00 00 00	[...P...v...3...]					
	00000210: 09 00 00 00 55 00 00 00	4E 00 00 00	00 00 00 00	00 00 00 00	[...U...N...h...]					
	00000220: 00 00 00 00 00 9C 00 00	0F 01 00 00	E1 00 00 00	00 00 00 00						
	00000230: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000240: 00 00 00 00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00						
	00000250: FF FF FF FF FF FF 9F 00 80 3D	FF FF FF FF	FF FF FF FF	FF FF FF FF	[.....=....]					

Figure 3 – The HASH Table Offset

In this case the starting value for the HASH table is “00 50 00 00” and after the byte flip translates to 0x5000. The following screen capture shows the beginning of the HASH table at offset 0x5000. Notice the starting byte, ending bytes, and selected byte counts at the top right corner of the hex editor for easy reference.

index.dat - Data											
Len:	\$0001C000	Type/Creator:	/		Sel:	\$00005000:00005004	/	\$00000004			
	00004F10: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F20: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F30: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F40: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F50: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F60: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F70: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F80: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004F90: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004FA0: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004FB0: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004FC0: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004FD0: FF FF FF FF FF FF	FF FF FF FF FF FF	FF FF FF FF FF FF	FF FF FF FF FF FF	FF FF FF FF FF FF						
	00004FE0: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00004FF0: 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00005010: 48 41 53 48 20 00 00 00 00 20 01	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	HASH					
	00005010: 01 00 00 00 00 FA 00 00 01 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	00005030: 01 00 00 00 00 66 00 00 03 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	f...					
	00005040: 03 00 00 00 00 03 00 00 00 01 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	j...					
	00005050: 01 00 00 00 00 88 00 00 01 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	!					
	00005060: 01 00 00 00 00 88 28 01 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	(...					
	00005070: 03 00 00 00 00 03 00 00 00 03 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00					
	00005080: 01 00 00 00 00 87 00 00 01 00 00 00	00 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	95 00 00 00 00 00 00 00 00 00 00					
	00005090: 01 00 00 00 00 80 F5 00 00 01 00 00	00 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00					
	000050A0: 01 00 00 00 00 AA 00 00 03 00 00	00 00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00 00 00 00						
	000050B0: 03 00 00 00 00 03 00 00 00 04 00 00	00 00 00 00 00 00 00 00 00 00 00 00	00 00 00								

After the HASH table offset is a listing of directories that this `index.dat` file uses to store the locally cached files on the user's computer. Notice that in Figure 5 the four directories correlate exactly with Figure 1.



**Figure 5 – The Index.dat Directories**

In this case, the `index.dat` file is responsible for the following directories:

- N2L6K2BN
- 0PE341MV
- CD1JKLMN
- S9MJSH6B

These directories contain the files that were actually downloaded from the web. We can use the files in these web pages and those referenced in the `index.dat` file to reconstruct web pages a user visited. Filename information is typically missing from most commercial tools used to reconstruct Internet Explorer activity.

The fields in the `index.dat` header are summarized in the following table:

**Table 2 - Relevant Fields in the Index.dat File Header**

<b>Field Name</b>	<b>Offset (in bytes)</b>	<b>Size (bytes)</b>	<b>Description</b>
File Length	0x1C	4	This field contains the length of the index.dat file, in 0x80 byte sized records.
HASH Table Offset	0x20	4	This field contains the offset (in bytes) for the beginning of the HASH Table.
Cache Directories	0x50	12	This field contains the directories where files are stored that make up the content of the cache. Each directory is 12 bytes long, where only the first 8 bytes are relevant.

### 3. The HASH Table

The HASH table is our “master lookup table” to find valid activity records within the index.dat file. It is very similar to a FAT table for a file system. Furthermore, if an index.dat file is large enough, it can have multiple HASH tables. Each HASH table contains a pointer to the next HASH table, making it a linked list. This section will discuss the important data fields within one of the HASH tables such as the HASH table length, the pointer to the next HASH table used to create the linked list, the activity record flags, and the activity record pointers.

This first field is the length of the HASH table. Figure 4 presents the first set of 4 bytes after the name “HASH” having the value of “20 00 00 00” which translates to 0x20, or 32. Upon observation, each record with the index.dat file is a multiple of 0x80 (128) bytes long. Therefore, we find that the HASH table is  $32 * 128 = 4096$  (0x1000) bytes long. For the example given in Figure 4, the HASH table ends at 0x6000, which is the expected value because it began at 0x5000.

It is important to note that there can be more than one HASH table within an index.dat file. The next field within the HASH table is a pointer, or offset in bytes, to the next HASH table. The next HASH table pointer will be zero for the last HASH table in the file.

index.dat - Data	
Len: \$0001C000	Type/Creator: /
Sel: \$00005008:0000500C / \$00000004	
00004FE0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	.....
00004FF0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	.....
00005000: 48 41 53 48 20 00 00 00 00 20 01 00 00 00 00 00	HSH ..[...]
00005010: 01 00 00 00 00 00 FA 00 00 01 00 00 00 00 00 00	.....88 00 00
00005020: 01 00 00 00 00 00 AA 00 00 01 00 00 00 00 00 00	.....B2 00 00
00005030: 01 00 00 00 00 00 66 00 00 03 00 00 00 03 00 00 00	.....f
00005040: 03 00 00 00 00 03 00 00 00 01 00 00 00 00 00 00 00	.....j
00005050: 01 00 00 00 00 00 B8 00 00 01 00 00 00 00 00 21 01 00	.....!
00005060: 01 00 00 00 00 00 28 01 00 03 00 00 00 00 00 03 00 00	.....(
00005070: 03 00 00 00 00 03 00 00 00 03 00 00 00 00 00 03 00 00	.....)
00005080: 01 00 00 00 00 00 87 00 00 01 00 00 00 00 00 89 95 00 00	.....
00005090: 01 00 00 00 00 00 80 F5 00 00 01 00 00 00 00 00 10 01 00	.....
000050A0: 01 00 00 00 00 AA 00 00 03 00 00 00 00 03 00 00 00	.....
000050B0: 03 00 00 00 00 00 03 00 00 00 40 39 12 70 00 00 79 00 00	.....09,p,y
000050C0: 01 00 00 00 00 00 CD 00 00 01 00 00 00 00 00 80 EF 00 00	.....
000050D0: 01 00 00 00 00 00 F3 00 00 03 00 00 00 00 00 03 00 00 00	.....
000050E0: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
000050F0: 00 87 7E 69 80 74 00 00 01 00 00 00 00 00 80 E1 00 00	..*i,t..
00005100: 01 00 00 00 00 00 FA 00 00 03 00 00 00 00 03 00 00 00	.....
00005110: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
00005120: 03 00 00 00 00 00 03 00 00 00 00 73 00 AD 00 80 00 00	.....s
00005130: 05 AE 7F CA 00 A2 00 00 01 00 00 00 00 00 00 D0 00 00	.....
00005140: 01 00 00 00 00 00 80 C4 00 00 03 00 00 00 00 00 03 00 00 00	.....
00005150: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
00005160: 01 00 00 00 00 00 D7 00 00 01 00 00 00 00 00 00 D1 00 00	.....
00005170: 01 00 00 00 00 00 F2 00 00 01 00 00 00 00 00 00 F6 00 00	.....
00005180: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
00005190: 03 00 00 00 00 00 03 00 00 00 01 00 00 00 00 00 00 72 00 00	.....r..
000051A0: 01 00 00 00 00 00 00 15 01 00 01 00 00 00 00 BF 00 00	.....
000051B0: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
000051C0: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
000051D0: 01 00 00 00 00 00 00 08 01 00 01 00 00 00 00 00 00 00 01 00	.....
000051E0: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
000051F0: 03 00 00 00 00 00 03 00 00 00 03 00 00 00 00 03 00 00 00	.....
00005200: 03 00 00 00 00 03 00 00 00 85 78 34 9E 00 60 00 00	.....x4..`
00005210: 40 F8 21 7F 00 85 00 00 01 00 00 00 00 00 80 92 00 00	.....@,!..
00005220: 01 00 00 00 00 00 00 00 00 01 00 00 00 00 00 62 00 00	.....b..
00005230: 01 00 00 00 00 00 00 00 00 01 00 00 00 00 00 52 01 00	.....R..

Figure 6 – The HASH Table Linked List

In this example, the next HASH table should be at “00 20 01 00”, which is 0x12000 after the byte flip. Looking at offset 0x12000 from the beginning of the file shows us the next

HASH table. This HASH table is empty in this example, but could contain the same structured data described in this section and linked to another HASH table, and so on.

index.dat - Data	
Len:	Type/Creator:
00011EE0: 00	F0 AD 0B 0D F0 AD 0B 0D
00011EF0: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F00: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F10: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F20: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F30: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F40: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F50: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F60: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F70: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F80: 00	F0 AD 0B 0D F0 AD 0B 0D
00011F90: 00	F0 AD 0B 0D F0 AD 0B 0D
00011FA0: 00	F0 AD 0B 0D F0 AD 0B 0D
00011FB0: 00	F0 AD 0B 0D F0 AD 0B 0D
00011FC0: 00	F0 AD 0B 0D F0 AD 0B 0D
00011FD0: 00	F0 AD 0B 0D F0 AD 0B 0D
00011FE0: 00	F0 AD 0B 0D F0 AD 0B 0D
00011FF0: 00	F0 AD 0B 0D F0 AD 0B 0D
00012000: 48 41 53 48	20 00 00 00 00 00 00 01 00 00 00 HSH
00012010: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012020: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012030: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012040: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012050: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012060: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012070: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012080: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012090: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
000120A0: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
000120B0: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
000120C0: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
000120D0: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
000120E0: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
000120F0: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012100: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012110: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012120: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	
00012130: 03 00 00 00 03 00 00 00 03 00 00 00 03 00 00 00	

**Figure 7 – The Second Hash Table**

The following data in the HASH table are pointers to the relevant activity data within this history file. Each entry in the HASH table is 8-bytes long. There seems to be three unique options for the first 4 bytes of these 8-bytes:

- 1) The value is “01 XX XX XX”, where XX can be any value.
- 2) The value is “03 XX XX XX”, where XX can be any value.
- 3) The value is “YY XX XX XX”, where YY is not 0x01 or 0x03 and XX can be any value.

It would be logical for the second 4 bytes to point to a record containing Internet activity history. In option 1 above, the 4-byte value that immediately follows the first four bytes *does not* point to an activity record. Additionally, if the pointer is to a memory location 0xBADF00D, then we know it is not valid. 0xBADF00D is an invalid memory location because that value is used by default when the `index.dat` file is created and populated. Therefore, we must ignore these entries when we examine the HASH table.

In the case of the second and third options previously presented, the second set of 4 bytes point to the start of a *valid* activity record. In Figure 8 it is shown that a valid activity record should be found at “00 A2 00 00”, which is 0xA200.

index.dat - Data									
Len:	\$0001C000	Type/Creator:	/		Sel:	\$00005134:\$00005138	/	\$00000004	
00005000:	48 41 53 48 20 00 00 00 00 20	01 00 00 00 00 00 00 00 00 00	HASH	.....					
00005010:	01 00 00 00 00 00 FA 00 00	01 00 00 00 00 00 00 00 00 00	00 8B 00 00	.					
00005020:	01 00 00 00 00 00 00 AA 00 00	01 00 00 00 00 00 00 00 00 00	00 82 00 00	.....					
00005030:	01 00 00 00 00 00 00 66 00 00	03 00 00 00 00 00 00 00 00 00	03 00 00 00	.....f.					
00005040:	03 00 00 00 00 03 00 00 00 00	01 00 00 00 00 00 00 00 00 00	00 6A 00 00	.....j.					
00005050:	01 00 00 00 00 00 00 B8 00 00	01 00 00 00 00 00 00 00 00 00	00 21 01 00	.....!					
00005060:	01 00 00 00 00 00 00 80 28 01	00 03 00 00 00 00 00 00 00 00	03 00 00 00	.....<					
00005070:	03 00 00 00 00 00 00 03 00 00	00 00 00 00 00 00 00 00 00 00	03 00 00 00	.....					
00005080:	01 00 00 00 00 00 00 00 87 00	00 01 00 00 00 00 00 00 00 00	00 95 00 00	.....					
00005090:	01 00 00 00 00 00 00 00 F5 00	00 01 00 00 00 00 00 00 00 00	00 10 01 00	.....					
000050A0:	01 00 00 00 00 00 00 AA 00 00	00 03 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
000050B0:	03 00 00 00 00 00 00 00 00 00	00 40 00 00 00 00 00 00 00 00	00 39 12 70	00 79 00 00	.....89.p.y..				
000050C0:	01 00 00 00 00 00 00 CD 00 00	00 01 00 00 00 00 00 00 00 00	00 EF 00 00	.....					
000050D0:	01 00 00 00 00 00 00 F3 00 00	00 03 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
000050E0:	03 00 00 00 00 00 03 00 00 00	00 00 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
000050F0:	00 87 7E 59 80 74 00 00	00 01 00 00 00 00 00 00 00 00	00 E1 00 00	.....i.t..					
00005100:	01 00 00 00 00 00 00 FA 00 00	00 03 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
00005110:	03 00 00 00 00 00 03 00 00 00	00 00 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
00005120:	03 00 00 00 00 03 00 00 00 00	00 00 73 00 AD 00 00 00 00 00	00 00 00 00	.....s..					
00005130:	05 AE 7F CA 00 A2 00 00	00 01 00 00 00 00 00 00 00 00	00 D8 00 00	.....[...]					
00005140:	01 00 00 00 00 00 C4 00 00	00 03 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
00005150:	03 00 00 00 00 03 00 00 00 00	00 00 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
00005160:	01 00 00 00 00 00 D7 00 00	00 01 00 00 00 00 00 00 00 00	00 00 01 00 00	.....					
00005170:	01 00 00 00 00 00 F2 00 00	00 01 00 00 00 00 00 00 00 00	00 F6 00 00	.....					
00005180:	03 00 00 00 00 03 00 00 00 00	00 00 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
00005190:	03 00 00 00 00 03 00 00 00 00	00 01 00 00 00 00 00 00 00 00	00 00 72 00 00	.....r..					
000051A0:	01 00 00 00 00 00 15 01 00	00 01 00 00 00 00 00 00 00 00	00 BF 00 00	.....					
000051B0:	03 00 00 00 00 03 00 00 00 00	00 03 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
000051C0:	03 00 00 00 00 03 00 00 00 00	00 00 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
000051D0:	01 00 00 00 00 00 00 05 01 00	00 01 00 00 00 00 00 00 00 00	00 00 0A 01 00	.....					
000051E0:	03 00 00 00 00 03 00 00 00 00	00 00 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
000051F0:	03 00 00 00 00 03 00 00 00 00	00 00 00 00 00 00 00 00 00 00	00 03 00 00 00	.....					
00005200:	03 00 00 00 00 03 00 00 00 00	00 00 85 78 34 9E 00 00 00 00	00 60 00 00	.....x4~					
00005210:	40 F8 21 7F 00 00 85 00 00	00 01 00 00 00 00 00 00 00 00	00 92 00 00	00 !.....					
00005220:	01 00 00 00 00 00 00 00 00 00	00 01 00 00 00 00 00 00 00 00	00 62 00 00	.....b..					
00005230:	01 00 00 00 00 00 00 05 00 00	00 01 00 00 00 00 00 00 00 00	00 52 01 00	.....R..					
00005240:	01 00 00 00 00 00 00 EB 00 00	00 01 00 00 00 00 00 00 00 00	00 12 01 00	.....					
00005250:	01 00 00 00 00 00 E1 00 00	00 01 00 00 00 00 00 00 00 00	00 E4 00 00	.....					

**Figure 8 – A Valid Activity Record in the HASH Table**

After we jump to offset 0xA200 within the file, we see that a valid<sup>2</sup> activity record is present.

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<sup>2</sup> The specific properties of a valid activity record will be clearly defined later in this paper.

index.dat - Data			
Len: \$0001C000	Type/Creator:	/	Sel: \$0000A200:0000A204 / \$00000004
000001A100: 00 F0 AD 0B .			
000001B00: 00 F0 AD 0B .			
000001C00: 00 F0 AD 0B .			
000001D00: 00 F0 AD 0B .			
000001E00: 00 F0 AD 0B .			
000001F00: 00 F0 AD 0B .			
000002000: 52 45 44 52 93 00 00 00 A8 5B 00 00 00 AC 55 19 FEDR.....[....U.			
000002100: 68 74 74 70 3A 2F 6C 6F 67 59 6E 2E 79 51 68 http://login.yah			
000002200: 6F 62 2E 63 6F 60 2F 63 6E 56 59 57 2F 6C 6F oo.com/config/lo			
000002300: 67 69 6E 3F 2E 74 72 69 65 73 3D 31 26 2E 73 72 gin?.tries=18.sr			
000002400: 63 3D 79 60 26 2E 6D 64 35 3D 26 2E 68 61 73 68 c=ym&.md5=&.hash			
000002500: 3D 26 2E 6A 73 3D 31 26 2E 6C 61 73 74 3D 26 70 =&.js=1&.last=&p			
000002600: 72 6F 6D 6F 3D 26 2E 69 6E 74 6C 3D 75 73 26 2E romo=&.intl=us&.			
000002700: 62 79 70 61 73 73 3D 26 2E 70 51 72 74 6E 55 72 bypass=&.partner			
000002800: 3D 26 2E 75 3D 37 34 39 68 76 71 67 75 73 35 32 =&.u=t749hvqgu52			
000002900: 33 6C 26 2E 76 3D 30 26 2E 63 68 61 6C 65 6E 31&.v=0&.challen			
000002A00: 67 65 3D 43 5A 79 6A 62 41 63 6C 46 45 46 6E 5A ge=C2yjbAcLFEFnZ			
000002B00: 76 62 34 46 4E 6F 2E 67 45 72 6B 71 35 36 48 26 vb4FMnogErkq5H&			
000002C00: 2E 79 70 6C 75 73 3D 26 2E 65 60 61 69 6C 43 6F .ypius=&.emailCo			
000002D00: 64 65 3D 26 68 61 73 4D 73 67 72 30 31 26 2E 63 de=&hasMsgr=1&c			
000002E00: 68 6B 50 3D 59 26 2E 64 6F 6E 65 3D 68 74 74 70 HkP=Y&.done=http			
000002F00: 25 33 41 2F 6C 6F 67 69 6E 2E 79 61 68 6F 6F %3A//login.yahoo			
000003000: 2E 63 6F 6D 2F 63 6F 6E 66 69 57 2F 60 6F 57 59 .com/config/logi			
000003100: 6E 26 6C 66 67 69 6E 3D 64 61 72 60 73 74 61 54 r&login=darmstad			
000003200: 74 6A 26 70 61 73 73 77 64 3D 35 34 61 65 62 66 tj&			
000003300: 39 33 38 65 34 33 36 37 63 39 30 33 62 63 56 51 .pers			
000003400: 33 66 36 35 65 30 35 63 64 37 26 2E 70 65 72 73 istent=y&.save=1			
000003500: 69 73 74 65 6E 74 3D 79 26 2E 73 61 76 65 3D 31			
000003600: 26 2E 68 61 73 68 3D 31 26 2E 60 64 35 3D 31 00 &.hash=1&.md5=1.			
000003700: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .			
000003800: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			
000003900: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			
000003A00: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			
000003B00: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			
000003C00: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			
000003D00: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			
000003E00: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			
000003F00: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .			

Figure 9 – A Valid Activity Record

The relevant fields in the HASH table are summarized in the following table:

Table 3 - Relevant Fields in the HASH Table Header

Field Name	Offset (in bytes) from the beginning of the HASH Table	Size (bytes)	Description
HASH Table Length	4	4	This field contains the length of the HASH Table, in 0x80 byte blocks.
Next HASH Table	8	4	This field contains the offset (in bytes, from the beginning of the file) where the next HASH Table can be located. If the value is zero, this is the last HASH Table in the index.dat file.
Activity Record Flags	16 + 8*n; where n=0,1,2,3...	4	This 4 byte field contains the flags for the activity record. If the first byte equals 01, the following field does not represent a valid activity record pointer.

Activity Record Pointers	$20 + 8*n$ ; where $n=0,1,2,3\dots$	4	This is an activity record offset, in bytes, from the beginning of the file.
-----------------------------	--	---	--

## 4. The Activity Records

The activity records contain the main information we are attempting to recover from the `index.dat` file. The activity records follow a generic structure type:

*TYPE, LENGTH, DATA*

- The “`TYPE`” field is a 4 byte field that represents one of the following activities:
  - `REDR`
  - `URL`
  - `LEAK`
- The “`LENGTH`” field contains the length of the activity record, measured in `0x80` (128) byte sized blocks. The “`LENGTH`” field is 4 bytes long.
- The “`DATA`” field is dependent upon the *type* of activity record. The most common types and what values exist in the `DATA` field will be discussed in the following subsections.

#### **4.1. The URL Activity Record**

The URL activity record is a set of data that represents the website a user visited. Figure 10 is an example of one such record. A URL record will contain the record length, the last access and modified times for the activity, the URL offset and data with the record, the filename offset and data within the record, the cache directory number, and the http headers offset and data.

**Figure 10 – A URL Activity Record**

We see that this record reports a length of “03 00 00 00”, or 0x03 blocks of 0x80 bytes in size. This is  $0x03 * 0x80 = 0x180$  bytes which makes sense because we see the next URL activity record starts at offset 0x7180. Next, we see that the actual URL the user visited is located at offset 0x68 from the beginning of the activity record. Observe that the offset of this URL is located at 0x34 bytes (see Figure 11) from the beginning of the activity record. Therefore, we must first read the value at offset 0x34 and jump to that position in the activity record to read the NULL terminated URL string<sup>3</sup>.

<sup>3</sup> The URL offset for v4 index.dat files is found at offset 0x38.

index.dat - Data	
Len: \$0001C000	Type/Creator: /
Sel: \$00007000:00007068 / \$00000068	
00006FE0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .	
00006FF0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .	
00007000: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 URL	.0]{u.....
00007010: A0 30 5D 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 00 .0]	.....h.....
00007020: 93 0A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .0]	A.....}....
00007030: 50 00 00 00 00 00 00 00 00 00 10 10 94 00 00 00 00 D.....D.	D.....D.
00007040: 41 00 00 00 A4 00 00 00 7D 00 00 00 00 00 00 00 00 00 .0]	.....http://w
00007050: 44 2E EE 8D 01 00 00 00 00 00 00 00 00 00 00 00 00 00 .0]	.....http://w
00007060: 00 00 00 00 00 F0 AD 0B 00 58 74 74 70 3A 2F 2F 77 .0]	.....http://w
00007070: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/	.....http://w
00007080: 64 59 73 74 72 59 62 75 74 69 6F 6E 2F 77 69 6E distribution/win	.....http://w
00007090: 33 32 2F 00 77 69 6E 33 32 58 31 50 2E 68 74 6D 32/win32[1].htm	.....http://w
000070A0: 6C 00 AD 0B 48 54 58 2F 31 2E 31 20 32 30 30 1...HTTP/1.1 200	.....http://w
000070B0: 20 4F 4B 00 0A 4B 65 65 78 20 41 6C 69 76 65 3A OK..Keep-Alive:	.....http://w
000070C0: 20 74 69 6D 65 6F 75 74 30 31 35 2C 20 6D 61 78 timeout=15, max	.....http://w
000070D0: 30 31 30 38 00 00 0A 54 72 61 6E 73 66 65 72 2D 45 =100..Transfer-E	.....http://w
000070E0: 6E 63 6F 64 69 6E 67 3A 20 63 68 75 6E 6B 65 64 nencoding: chunked	.....http://w
000070F0: 00 0A 43 6F 6E 74 65 6E 74 20 54 79 70 65 3A 20 ..Content-Type:	.....http://w
00007100: 74 65 78 74 2F 68 74 60 6C 00 00 00 00 00 00 00 00 text/html....U:	.....http://w
00007110: 6A 75 6C 69 65 64 61 72 60 73 74 61 64 74 00 0A juliedarmstadt..	.....http://w
00007120: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007130: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007140: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007150: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007160: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007170: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007180: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 URL	.....n.Q...
00007190: 70 7F 66 78 75 CC C2 01 00 00 00 00 00 00 00 00 00 p.f{u.....	.....n.Q...
000071A0: 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .	.....n.Q...
000071B0: 60 00 00 00 00 00 00 00 00 00 00 01 10 10 90 00 00 00 ^...h.....	.....n.Q...
000071C0: 41 00 00 00 9C 00 00 00 00 00 00 00 00 00 00 00 00 A.....	.....n.Q...
000071D0: 44 2E EE 8D 01 00 00 00 00 00 00 00 00 00 00 00 00 00 D.....D.	.....n.Q...
000071E0: 00 00 00 00 00 F0 AD 0B 00 58 74 74 70 3A 2F 2F 77 .....http://w	.....http://w
000071F0: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/	.....http://w
00007200: 69 63 6F 6E 73 2F 62 61 63 6B 2E 67 69 66 00 48 54 54 50 back[1].gif..	.....http://w
00007210: 62 61 63 6B 5B 31 50 2E 67 69 66 00 48 54 54 50 back[1].gif..	.....http://w
00007220: 2F 31 2E 31 28 32 38 30 2A 4F 4B 00 0A 45 54 61 /1.1 200 OK..ETa	.....http://w
00007230: 67 3A 20 22 32 63 35 64 30 20 64 38 2D 33 31 32 g: "2c5d0-d8-312	.....http://w

Figure 11 – The URL Activity Record Web Site Offset

We know that the URL can be a variable length strings and thus terminated by a NULL (0x00) byte. Therefore, to quickly look up the fields that come after the URL there must be an offset somewhere in the activity record's header. If we look at the file name for the locally cached file stored on the hard disk, we see that it is 0x94 bytes from the beginning of the activity record.

index.dat - Data	
Len: \$0001C000	Type/Creator: /
Sel: \$00007000:00007094 / \$00000094	
00006FE0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .	
00006FF0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .	
00007000: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 URL	.0]{u.....
00007010: A0 30 5D 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 .0]	.....h.....
00007020: 93 0A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .0]	A.....}....
00007030: 50 00 00 00 00 00 00 00 00 00 10 10 94 00 00 00 00 D.....D.	D.....D.
00007040: 41 00 00 00 A4 00 00 00 7D 00 00 00 00 00 00 00 00 00 .0]	.....http://w
00007050: 44 2E EE 8D 01 00 00 00 00 00 00 00 00 00 00 00 00 00 .0]	.....http://w
00007060: 00 00 00 00 00 F0 AD 0B 00 58 74 74 70 3A 2F 2F 77 .0]	.....http://w
00007070: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/	.....http://w
00007080: 69 63 6F 6E 73 2F 62 61 63 6B 2E 67 69 66 00 48 54 54 50 back[1].gif..	.....http://w
00007090: 33 32 2F 00 77 69 6E 33 32 58 31 50 2E 68 74 6D 32/win32[1].htm	.....http://w
000070A0: 6C 00 AD 0B 48 54 58 2F 31 2E 31 20 32 30 30 1...HTTP/1.1 200	.....http://w
000070B0: 20 4F 4B 00 0A 4B 65 65 78 20 41 6C 69 76 65 3A OK..Keep-Alive:	.....http://w
000070C0: 20 74 69 6D 65 6F 75 74 30 31 35 2C 20 6D 61 78 timeout=15, max	.....http://w
000070D0: 30 31 30 38 00 00 0A 54 72 61 6E 73 66 65 72 2D 45 =100..Transfer-E	.....http://w
000070E0: 6E 63 6F 64 69 6E 67 3A 20 63 68 75 6E 6B 65 64 nencoding: chunked	.....http://w
000070F0: 00 0A 43 6F 6E 74 65 6E 74 20 54 79 70 65 3A 20 ..Content-Type:	.....http://w
00007100: 74 65 78 74 2F 68 74 60 6C 00 00 00 00 00 00 00 00 text/html....U:	.....http://w
00007110: 6A 75 6C 69 65 64 61 72 60 73 74 61 64 74 00 0A juliedarmstadt..	.....http://w
00007120: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007130: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007140: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007150: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007160: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007170: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .	.....http://w
00007180: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 URL	.....n.Q...
00007190: 70 7F 66 78 75 CC C2 01 00 00 00 00 00 00 00 00 00 p.f{u.....	.....n.Q...
000071A0: 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .	.....n.Q...
000071B0: 60 00 00 00 00 00 00 00 00 00 00 01 10 10 90 00 00 00 ^...h.....	.....n.Q...
000071C0: 41 00 00 00 9C 00 00 00 00 00 00 00 00 00 00 00 00 A.....	.....n.Q...
000071D0: 44 2E EE 8D 01 00 00 00 00 00 00 00 00 00 00 00 00 00 D.....D.	.....n.Q...
000071E0: 00 00 00 00 00 F0 AD 0B 00 58 74 74 70 3A 2F 2F 77 .....http://w	.....http://w
000071F0: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/	.....http://w
00007200: 69 63 6F 6E 73 2F 62 61 63 6B 2E 67 69 66 00 48 54 54 50 back[1].gif..	.....http://w
00007210: 62 61 63 6B 5B 31 50 2E 67 69 66 00 48 54 54 50 back[1].gif..	.....http://w
00007220: 2F 31 2E 31 28 32 38 30 2A 4F 4B 00 0A 45 54 61 /1.1 200 OK..ETa	.....http://w
00007230: 67 3A 20 22 32 63 35 64 30 20 64 38 2D 33 31 32 g: "2c5d0-d8-312	.....http://w

Figure 12 – The URL Activity Record Filename Data

In searching through the header of the activity record, we see “94 00 00 00” (0x94) exists 0x3C bytes from the beginning of the activity record<sup>4</sup>.

Len: \$00010000   Type/Creator: /   Sel: \$00007000:\$0000703C / \$0000003C
00006FE0: 00 F0 AD 0B . . . . .
00006FF0: 00 F0 AD 0B . . . . .
00007000: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 URL . . . . .
00007010: A0 30 5D 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 00 00 00 00 .0]{u . . . . .
00007020: 93 0A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .
00007030: 00 00 00 00 68 00 00 00 00 00 00 18 18 94 00 00 00 00 00 00 00 [...]h . . . . .
00007040: 41 00 00 00 R4 00 00 00 70 00 00 00 00 00 00 00 00 00 00 00 00 A . . . . .
00007050: 44 2E EE 8D 01 00 00 00 00 00 00 00 44 2E EE 8D D . . . . .
00007060: 00 00 00 00 00 F0 AD 0B 68 74 74 70 3A 2F 2F 77 . . . . .http://w . . . . .
00007070: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/ . . . . .
00007080: 64 69 73 74 72 69 62 75 74 69 6F 6E 2F 77 69 6E distribution/win . . . . .
00007090: 33 32 2F 00 77 69 6E 33 32 5B 31 5D 2E 68 74 6D 32/.win32[1].htm . . . . .
000070A0: 6C 00 AD 0B 48 54 54 50 2F 31 2E 31 20 32 30 30 I...HTTP/1.1 200 . . . . .
000070B0: 20 4F 4B 00 0A 4B 65 65 70 2D 41 6C 69 76 65 3A OK..Keep-Alive: . . . . .
000070C0: 20 74 69 6D 65 6F 75 74 3D 31 35 2C 20 6D 61 78 timeout=15, max . . . . .
000070D0: 3D 31 30 30 0D 0A 54 72 61 6E 73 66 65 72 20 45 =100..Transfer-E . . . . .
000070E0: 6E 63 6F 64 69 6E 67 3A 20 63 68 75 6E 6B 65 64 ncoding: chunked . . . . .
000070F0: 00 0A 43 6F 6E 74 65 6E 74 2D 54 79 78 65 3A ..Content-Type: . . . . .
00007100: 74 65 78 74 2F 68 74 6D 6C 0A 0D 0A 7E 55 3A text/html...~U: . . . . .
00007110: 5A 75 6C 69 65 64 61 72 60 73 74 61 64 74 8D 0A juliedarmstadt.. . . . .
00007120: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B . . . . .
00007130: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B . . . . .
00007140: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B . . . . .
00007150: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B . . . . .
00007160: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B . . . . .
00007170: 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B . . . . .
00007180: 55 52 4C 20 03 00 00 00 80 6E BE 51 1B 01 BB 01 URL . . . . .
00007190: 70 7F 66 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 p.f{u . . . . .
000071A0: D8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .
000071B0: 60 00 00 00 68 00 00 00 00 00 00 01 10 10 90 00 00 00 . . . . .
000071C0: 41 00 00 00 9C 00 00 00 90 00 00 00 00 00 00 00 00 00 A . . . . .
000071D0: 44 2E EE 8D 01 00 00 00 00 00 00 00 00 44 2E EE 8D D . . . . .
000071E0: 00 00 00 00 00 F0 AD 0B 68 74 74 70 3A 2F 2F 77 . . . . .http://w . . . . .
000071F0: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/ . . . . .
00007200: 69 63 6F 6E 73 2F 62 61 63 6B 2E 57 69 66 00 0B icons/back.gif.. . . . .
00007210: 62 61 63 6B 5B 31 5D 2E 67 69 66 00 48 54 54 50 back[1].gif.HTP . . . . .
00007220: 2F 31 2E 31 20 32 30 30 20 4F 4B 0D 0A 45 54 61 /1.1 200 OK..ETa . . . . .
00007230: 67 3A 20 22 32 63 35 64 30 2D 64 38 2D 33 31 32 g: "2c5d0-d8-312 . . . . .

**Figure 13 – The URL Activity Record Filename Data Offset**

Similarly, the HTTP headers are at offset 0xA4:

---

<sup>4</sup> IE version 4 index.dat files have filename offset starting at 0x40 from the beginning of the activity record.

index.dat - Data	
Len: \$0001C000	Type/Creator: /   Sel: \$00007000:000070A4 / \$000000A4
00005FE0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00005FF0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007000: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 00 URL .0}{u .	
00007010: A0 30 5D 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007020: 93 0A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007030: 60 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007040: 41 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007050: 44 2E EE 80 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 A.....}.....D..	
00007060: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 D.....}.....D..	
00007070: .....http://www.etherreal.com/distribution/win32/win32[1].htm	
00007080: 64 69 73 74 72 69 62 75 74 69 6F 6E 2F 77 69 6E 32/.../win32[1].htm	
00007090: 33 32 2F 00 77 69 6E 33 32 58 31 5D 2E 68 74 60 32/.HTTP/1.1 200	
000070A0: 6C 00 AD 0B 00 48 54 54 50 2F 31 2E 31 20 32 30 30 L...HTTP/1.1 200	
000070B0: 28 4F 4B 00 00 48 65 65 78 20 41 6C 69 76 65 3A OK..Keep-Alive: . . . . .	
000070C0: 20 74 69 60 65 6F 75 74 3D 31 35 2C 20 6D 61 78 timeout=15, max	
000070D0: 3D 31 30 30 00 00 54 72 61 6E 73 66 65 72 20 45 =100..Transfer-E	
000070E0: 6E 63 6F 64 69 6E 67 3A 28 63 68 75 6E 6B 65 64 nencoding: chunked	
000070F0: 00 00 43 6F 6E 74 65 6E 74 20 54 79 70 65 3A 20 ..Content-Type:	
00007100: 74 65 78 74 2F 68 74 60 6C 80 00 00 00 7E 55 3A text/html..~U:	
00007110: 6A 75 6C 69 65 64 61 72 60 73 74 61 64 74 00 00 juliedarmstadt..	
00007120: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007130: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007140: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007150: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007160: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007170: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007180: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 00 URL ..n.Q..	
00007190: 70 7F 66 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 00 p.f{u ..	
000071A0: D8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
000071B0: 60 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 `...h ..	
000071C0: 41 00 00 00 9C 00 00 00 00 00 00 00 00 00 00 00 00 00 A.....}.....D..	
000071D0: 44 2E EE 80 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 D.....}.....D..	
000071E0: 00 00 00 00 00 00 F0 AD 0B 0D 68 74 74 70 3A 2F 2F 77 .....http://w	
000071F0: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/	
00007200: 69 63 6F 6E 73 2F 62 61 63 6B 2E 67 69 66 00 0B icons/back.gif..	
00007210: 62 61 63 6B 5B 31 5D 2E 67 69 66 00 0B 48 54 54 50 back[1].gif.HTTP	
00007220: 2F 31 2E 31 20 32 30 30 20 4F 4B 00 00 45 54 61 /1.1 200 OK..ETa	
00007230: 67 3A 20 22 32 63 35 64 30 20 64 38 2D 33 31 32 g: "2c5d0-d8-312	

Figure 14 – The URL Activity Record HTTP Header Data

The HTTP header offset “A4 00 00 00” (0xA4) is 0x44 bytes from the beginning of the activity record<sup>5</sup>.

index.dat - Data	
Len: \$0001C000	Type/Creator: /   Sel: \$00007000:000070A4 / \$000000A4
00005FE0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00005FF0: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007000: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 00 URL .0}{u .	
00007010: A0 30 5D 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007020: 93 0A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007030: 60 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007040: 41 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
00007050: 44 2E EE 80 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 A.....}.....D..	
00007060: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 D.....}.....D..	
00007070: .....http://www.etherreal.com/distribution/win32/win32[1].htm	
00007080: 64 69 73 74 72 69 62 75 74 69 6F 6E 2F 77 69 6E 32/.../win32[1].htm	
00007090: 33 32 2F 00 77 69 6E 33 32 5B 31 5D 2E 68 74 60 32/.HTTP/1.1 200	
000070A0: 6C 00 AD 0B 00 48 54 54 50 2F 31 2E 31 20 32 30 30 L...HTTP/1.1 200	
000070B0: 28 4F 4B 00 00 48 65 65 78 20 41 6C 69 76 65 3A OK..Keep-Alive: . . . . .	
000070C0: 20 74 69 60 65 6F 75 74 3D 31 35 2C 20 6D 61 78 timeout=15, max	
000070D0: 3D 31 30 30 00 00 54 72 61 6E 73 66 65 72 20 45 =100..Transfer-E	
000070E0: 6E 63 6F 64 69 6E 67 3A 28 63 68 75 6E 6B 65 64 nencoding: chunked	
000070F0: 00 00 43 6F 6E 74 65 6E 74 20 54 79 70 65 3A 20 ..Content-Type:	
00007100: 74 65 78 74 2F 68 74 60 6C 80 00 00 00 7E 55 3A text/html..~U:	
00007110: 6A 75 6C 69 65 64 61 72 60 73 74 61 64 74 00 00 juliedarmstadt..	
00007120: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007130: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007140: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007150: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007160: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007170: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B . . . . .	
00007180: 55 52 4C 20 03 00 00 00 00 00 00 00 00 00 00 00 00 00 URL ..n.Q..	
00007190: 70 7F 66 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 00 p.f{u ..	
000071A0: D8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 . . . . .	
000071B0: 60 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 `...h ..	
000071C0: 41 00 00 00 9C 00 00 00 00 00 00 00 00 00 00 00 00 00 A.....}.....D..	
000071D0: 44 2E EE 80 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 D.....}.....D..	
000071E0: 00 00 00 00 00 00 F0 AD 0B 0D 68 74 74 70 3A 2F 2F 77 .....http://w	
000071F0: 77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/	
00007200: 69 63 6F 6E 73 2F 62 61 63 6B 2E 67 69 66 00 0B icons/back.gif..	
00007210: 62 61 63 6B 5B 31 5D 2E 67 69 66 00 0B 48 54 54 50 back[1].gif.HTTP	
00007220: 2F 31 2E 31 20 32 30 30 20 4F 4B 00 00 45 54 61 /1.1 200 OK..ETa	
00007230: 67 3A 20 22 32 63 35 64 30 20 64 38 2D 33 31 32 g: "2c5d0-d8-312	

Figure 15 – The URL HTTP Header Data Offset

<sup>5</sup> IE v4 index.dat files have a httpheader offset 0x48 bytes from the beginning of the activity record.

Two other important fields we would want to know when reconstructing a subject's Internet activity are last modified and last accessed time stamps. The last modified time field is when the information was changed on the web server. The last accessed time field is when the last time Internet Explorer visited the URL. Both of these fields are found directly after the length of the activity record and are each 8-byte values. The last modified field occurs first:

**Figure 16 – The URL Activity Record Last Modified Time Stamp**

We see this activity record has “00 00 00 00 00 00 00 00” as the last modified time. However, if we look at the next activity record in Figure 16, we see its last modified time was “80 6E BE 51 1B 01 BB 01” or 0x01BB011B51BE6E80. The fact that one activity record has all zeros for a last modified time stamp indicates it is unable to place a valid time stamp in this field. For most Internet activity reconstruction attempts, we are interested in the last time someone accessed a web page. The last accessed field is found in the next 8-byte field:

index.dat - Data	
Len:	Type/Creator:
00006FF0:	00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .
00007000:	55 52 4C 28 03 00 00 00 00 00 00 00 00 00 00 URL
00007010:	A0 30 50 7B 75 CC C2 01 00 00 00 00 00 00 00 00 00 .@{u..}
00007020:	93 0A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .
00007030:	60 00 00 00 68 00 00 00 00 00 10 10 94 00 00 00 .h.
00007040:	41 00 00 00 R4 00 00 00 70 00 00 00 00 00 00 00 00 A ..}.
00007050:	44 2E EE 80 01 00 00 00 00 00 00 44 2E EE 80 D ..}.
00007060:	00 00 00 00 00 F0 AD 0B 68 74 74 70 3A 2F 2F 77 .....http://u
00007070:	77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/
00007080:	64 69 73 74 72 69 62 75 74 69 6F 6E 2F 77 69 6E distribution/win
00007090:	33 32 2F 00 77 59 6E 33 32 5B 31 5D 2E 68 74 6D 32/win32[1].htm
000070A0:	6C 00 AD 0B 48 54 54 58 2F 31 2E 31 20 32 30 30 L..HTTP/1.1 200
000070B0:	20 4F 48 0D 0A 4B 65 65 78 20 41 6C 69 76 65 3A OK..Keep-Alive:
000070C0:	20 74 69 6D 65 6F 75 74 3D 31 35 2C 20 60 61 78 timeout=15, max
000070D0:	30 31 30 30 0D 0A 54 72 61 6E 73 66 65 72 2D 45 =100..Transfer-E
000070E0:	6E 63 6F 64 69 6E 57 3H 28 63 68 75 6E 6B 65 64 nencoding: chunked
000070F0:	0D 0E 43 6F 6E 74 65 6E 74 2D 54 79 70 65 3A 20 ..Content-Type:
00007100:	74 65 78 74 2F 68 74 60 6C 0D 0A 7E 55 3A text/html...U:
00007110:	6A 75 6C 69 65 64 61 72 60 73 74 61 64 74 0D 0A juliedarmstadt..
00007120:	00 F0 AD 0B 0D F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .
00007130:	00 F0 AD 0B 0D F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .
00007140:	00 F0 AD 0B 0D F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .
00007150:	00 F0 AD 0B 0D F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .
00007160:	00 F0 AD 0B 0D F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .
00007170:	00 F0 AD 0B 0D F0 AD 0B 00 F0 AD 0B 00 F0 AD 0B .
00007180:	55 52 4C 2B 03 00 00 00 80 6E BE 51 1B 01 BB 01 URL ..n.Q..
00007190:	70 7F 66 7B 75 CC C2 01 00 00 00 00 00 00 00 00 p..f(u..)
000071A0:	D8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .
000071B0:	60 00 00 00 68 00 00 00 00 01 10 10 90 00 00 00 .h.
000071C0:	41 00 00 00 9C 00 00 00 90 00 00 00 00 00 00 00 A ..}.
000071D0:	44 2E EE 80 01 00 00 00 00 00 00 44 2E EE 80 D ..}.
000071E0:	00 00 00 00 00 F0 AD 0B 68 74 74 70 3A 2F 2F 77 .....http://u
000071F0:	77 77 2E 65 74 68 65 72 65 61 6C 2E 63 6F 6D 2F www.etherreal.com/
00007200:	69 63 6F 6E 73 2F 62 61 63 6B 2E 67 69 66 00 0B icons/back.gif..
00007210:	62 61 63 6B 5B 31 5D 2E 67 69 66 00 48 54 54 50 back[1].gif.HTTP
00007220:	2F 31 2E 31 2B 32 30 3B 20 4F 4B 0D 0A 45 54 61 /1..200 OK..ETag
00007230:	67 3A 2B 22 32 63 35 54 3B 2D 54 3B 2D 33 31 32 g: "2c5d0-d8-312
00007240:	63 35 37 37 31 22 0D 0A 43 6F 6E 74 65 6E 74 2D c5771..Content-

**Figure 17 – The URL Activity Record Last Accessed Time Stamp**

Now that we know which fields are time stamps we must translate them to something a human can understand. Windows saves time stamps in what has been defined as “FILETIME” format. FILETIME format is the number of ticks, in 100ns increments, since 00:00 1 Jan, 1601 (UTC). Since the rest of the world uses the Unix definition of time, which is the number of seconds since 00:00 1 Jan 1970, we must be able to translate the FILETIME format to the Unix time format. This is done with the following simple equation:

$$(Unix\ Time) = A * (NT\ Time) + B$$

Since the ticks in FILETIME are at 100ns intervals, we know that “A” is  $10^{-7}$ . The trick is finding “B”. “B” is the number of seconds between 1 Jan 1601 and 1 Jan 1970. We do not have to painstakingly calculate that value because it is well documented with Microsoft Developer Network (MSDN) and open source initiatives that “B” is 11644473600.

The last piece of information in the activity record that may be useful is in which directory, from Figure 5, the locally cached filename discovered in Figure 12 resides. Experimentation shows the offset value is found 0x39 bytes from the beginning of the activity record<sup>6</sup>.

<sup>6</sup> IE v4 index.dat files have the directory number located at offset 0x3C from the beginning of the activity record.

index.dat - Data	
Len:	Type/Creator:
000003270:	6E 61 5C 79 7A 65 72 2E 70 6F 6C 69 74 6F 2E 69 analyzer.polito.i
000003280:	74 2F 69 6E 73 74 61 6C 2F 64 65 66 61 75 6C t/install/default[
000003290:	74 2E 68 74 6D 00 AD 0B 64 65 66 61 75 6C 74 5B t.htm...default[
0000032A0:	31 5D 2E 68 74 6D 00 0B 48 54 54 50 2F 31 2E 31 ]].htm..HTTP/1.1
0000032B0:	2B 32 30 38 2B 4F 4B 00 0F 45 54 61 67 3B 2B 22 200 OK..ETag: "
0000032C0:	31 32 63 65 65 20 66 64 39 2B 63 39 33 32 32 63 12cee-fd9-c9322e
0000032D0:	38 3B 22 00 0F 43 6F 6E 74 65 6E 74 2D 4C 65 6E 80"...Content-Len
0000032E0:	67 74 68 3B 2B 34 30 35 37 0B 0A 4B 65 65 70 2D gth: 4857..Keep-
0000032F0:	41 6C 69 76 65 3B 20 74 65 60 65 6F 75 74 3D 31 Alive: timeout=1
000003300:	35 2C 20 66 61 78 3D 39 37 0B 0A 43 6F 6E 74 65 5, max=97..Conte
000003310:	6E 74 2D 54 79 70 65 3B 2B 74 65 78 74 2F 68 74 nt-Type: text/ht
000003320:	60 6C 3B 20 63 68 61 72 73 65 74 3D 49 53 4F 2D m; charset=ISO-
000003330:	38 3B 35 39 2D 31 0D 0B 0B 7E 55 3B 6A 75 6C 8859-1...."U;jul
000003340:	69 65 64 61 72 60 73 74 61 64 74 00 0B 0B 0D 0B iedarmstadt....
000003350:	80 F0 AD 0B 0D F0 AD 0B 0F AD 0B 0F AD 0B 0B .....
000003360:	80 F0 AD 0B 0D F0 AD 0B 0F AD 0B 0F AD 0B 0B .....
000003370:	80 F0 AD 0B 0D F0 AD 0B 0F AD 0B 0F AD 0B 0B .....
000003380:	55 52 4C 2B 03 00 00 00 7B 0B 9C 4C B1 C0 01 URL ....p...L...
000003390:	18 4B 9C D5 75 CC C2 01 00 00 00 00 00 00 00 00 ..H..u.....
0000033A0:	A9 03 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
0000033B0:	6A 00 00 00 6A 00 00 00 03 01 10 98 00 00 00 00 ..h.....
0000033C0:	41 00 00 00 A9 00 00 00 91 00 00 00 00 00 00 00 00 A.....
0000033D0:	44 2E 41 8B 03 00 00 00 00 00 00 00 44 2B 19 8E D.A.....D..
0000033E0:	00 00 00 00 00 00 F0 AD 0B 68 74 74 70 3B 2F 2F 61 .....http://a
0000033F0:	6E 61 5C 79 7A 65 72 2E 70 6F 6C 69 74 6F 2E 69 analyzer.polito.i
000003400:	74 2F 69 60 61 67 65 73 2F 63 61 70 74 75 72 65 t/images/capture[
000003410:	2E 67 59 66 00 F0 AD 0B 63 61 70 74 75 72 65 .gif...capture[
000003420:	31 5D 2E 67 69 66 00 0B 48 54 54 50 2F 31 2E 31 ]].gif..HTTP/1.1
000003430:	2B 32 30 3B 2B 4F 4B 00 0A 45 54 61 67 3B 2B 22 200 OK..ETag: "
000003440:	31 32 63 65 33 2D 33 61 39 2D 36 3B 61 65 31 3B 12ce3-3a9-00ae18
000003450:	3B 3B 22 00 0F 43 6F 6E 74 65 6E 74 2D 4C 65 6E 00"...Content-Len
000003460:	67 74 68 3B 2B 33 37 0B 0A 4B 65 65 70 2D 41 gth: 937..Keep-A
000003470:	6C 69 76 65 3B 2B 74 69 60 65 6F 75 74 3D 31 35 live: timeout=15
000003480:	2C 2B 6D 61 7B 65 3B 2B 69 60 61 67 65 2F 67 69 t-Type: image/gi
000003490:	74 2D 54 79 7B 65 3B 2B 69 60 61 67 65 2F 67 69 f...."U;juliedar
0000034A0:	66 8D 00 00 0F 7E 55 3B 6A 75 6C 69 65 64 61 72 mstadt.....
0000034B0:	6D 73 74 61 64 74 0D 0A 0B 0F AD 0B 0F AD 0B mstadt.....

**Figure 18 - Location of the Directory Number**

In the example above, the “capture[1].gif” file was located within the “S9MJS6B” directory. This is consistent because we see 0x03 at offset 0x38 from the beginning of the activity record. The value 0x03 says the file is located in the fourth folder because the first folder starts with an index of zero. The fourth folder in Figure 5 is “S9MJS6B” and the results are consistent.

The following table summarizes the relevant fields within the URL activity record:

**Table 4 - Relevant Fields in the URL Activity Record**

<i><b>Field Name</b></i>	<i><b>Offset (in bytes) from the beginning of the URL Activity Record (v5)</b></i>	<i><b>Offset (in bytes) from the beginning of the URL Activity Record (v4)</b></i>	<i><b>Size (bytes)</b></i>	<i><b>Description</b></i>
Record Type	0x0	0x0	4	This is the field that contains the string “URL”.
Record Length	0x4	0x4	4	This is the number of 0x80 byte blocks that the URL record contains.
Last Modified Time Stamp	0x08	0x08	8	This is the Last Modified time stamp, in FILETIME format.
Last Accessed Time Stamp	0x10	0x10	8	This is the Last Accessed time stamp, in FILETIME format.
URL Offset	0x34	0x38	4	This is the URL Offset, from the beginning of the record.
Filename Offset	0x3C	0x40	4	This is the Filename Offset, from the beginning of the record.
Local Cache Directory Index	0x38	0x3C	1	This is the index (starting with zero) of the local directories containing the cache files.
HTTP Header Offset	0x44	0x48	4	This is the offset, from the beginning of the record, where the HTTP Headers are located.

## 4.2. The REDR Activity Record

The REDR activity record is very simple because it is just a statement that the subject's browser was redirected to another site. The generic *TYPE*, *LENGTH*, *DATA* format still holds true for the REDR activity record. The only field of interest is where the user's browser was redirected. The following figure shows a REDR activity record:

index.dat - Data	
Len:	Type/Creator:
00001C000	/
00000F10:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F20:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F30:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F40:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F50:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F60:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F70:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F80:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000F90:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000FA0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000FB0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000FC0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000FD0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000FE0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
00000FF0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A000:	52 45 44 52 01 00 00 00 40 56 00 00 40 09 53 04 REDR...@v...s.
0000A010:	68 74 74 70 3A 2F 2F 77 77 77 2E 76 65 72 69 7A http://www.veriz...
0000A020:	6F 6E 77 69 72 65 6C 65 73 73 2E 63 6F 6D 2F 7A onwireless.com/z
0000A030:	69 70 2F 70 6C 73 71 6C 2F 76 7A 77 5F 7A 69 70 ip/plsql/vzw_zip
0000A040:	2E 7A 69 70 3F 70 5F 61 6C 69 61 73 3D 65 63 5F .zip?p_alias=ec...
0000A050:	63 6F 6E 74 61 67 74 73 5F 62 00 0B 0D F0 AD 0B contacts_b....
0000A060:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A070:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A080:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A090:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A0A0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A0B0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A0C0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A0D0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A0E0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A0F0:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A100:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A110:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A120:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A130:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A140:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A150:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....
0000A160:	00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....

Figure 19 – A REDR Activity Record

The length of this example is "01 00 00 00" which is 0x01. That makes this record 0x80, or 128, bytes long.

## **Figure 20 – The REDR Activity Record Length**

The next 8-byte field would seem to be a time stamp if it were similar to the URL activity records. We know that is not the case because the right most byte (the most significant byte after the flip) is “04” and it should be a “01” to fit in with this example (This was figured out by knowing that all of the web sites listed in the sample `index.dat` file were visited within the same day). Therefore, this field is probably flag values or similar data. Lastly, the URL is located at offset 0x10 from the beginning of the record and is NULL terminated with a 0x00 byte.

**Figure 21 – The URL in a REDR Activity Record**

The following table summarizes the relevant fields in the REDR activity Record:

**Table 5 - Relevant Fields in the REDR Activity Record**

<b>Field Name</b>	<b>Offset (in bytes) from the beginning of the URL Activity Record</b>	<b>Size (bytes)</b>	<b>Description</b>
Record Type	0x00	4	This is the field that contains the “REDR” string.
Record Length	0x04	4	This is the field that contains the number of 0x80 byte sized blocks that make up the REDR record.
URL	0x10	<i>Variable</i>	This is the URL, terminated by a NULL (0x00) character.

### 4.3. The LEAK Activity Record

The LEAK activity record has exactly the same internal structure as the URL activity record. At the time this document was written, it is still difficult to tell the difference between a “URL” and a “LEAK” activity record other than the different value for the *TYPE* in the header.

index.dat - Data	
Len:	Type/Creator:
00000538: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	/
00000548: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000558: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000568: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000578: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000588: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000598: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000005A8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000005B8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000005C8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000005D8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000005E8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000005F8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000608: 4C 45 41 4B 03 00 00 00 00 00 00 00 00 00 00 00 00 00 LEAK	
00000618: E0 19 22 5D 5E CC C2 01 00 00 00 00 00 00 00 00 00 00 00 .."ln.....	
00000628: 25 2E 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 %.....	
00000638: 60 00 00 00 68 00 00 00 02 00 10 10 C4 00 00 00 00 00 00 ..h.....	
00000648: 41 28 00 00 E4 00 00 00 75 00 00 00 00 00 00 00 00 00 A .."u.....	
00000658: 44 2E 10 87 01 00 00 00 00 00 00 44 2E F0 87 D .....D...	
00000668: 00 00 00 00 F0 AD 0B 0D 68 74 74 70 3F 2F 79 .....http://p	
00000678: 72 64 6F 77 6E 6C 6F 61 64 73 2E 73 6F 75 72 63 rdownloads.sourc	
00000688: 65 66 6F 72 67 65 2E 66 65 74 2F 65 74 68 65 72 eforge.net/ether	
00000698: 65 61 6C 2F 65 74 68 65 72 65 61 62 73 65 72 eal/etherreal-set	
000006A8: 75 78 2D 30 2E 39 2E 39 2E 65 78 65 3F 75 73 65 up-0.9.9.exe?use	
000006B8: 5F 64 65 66 61 75 6C 74 3D 65 61 73 79 6E 65 77 _default=easynew	
000006C8: 73 00 AD 0B 65 74 68 65 72 65 61 6C 2D 73 65 74 s...etherreal-set	
000006D8: 75 79 2D 30 2E 39 2E 39 58 31 50 2E 68 74 60 6C up-0.9.9.11.html	
000006E8: 00 F0 AD 0B 48 54 54 58 2F 31 2E 31 20 32 38 38 .....HTTP/1.1 200	
000006F8: 28 4F 4B 0D 00 58 2D 58 6F 77 65 72 65 64 2D 42 OK,X-Powered-B	
00000708: 79 3E 20 58 48 58 2D 58 2E 31 2E 32 0D 0E 54 72 y; PHP/4.1.2..Tr	
00000718: 61 6E 73 66 65 72 2D 45 6E 63 6F 64 69 6E 67 3A ansfer-Encoding:	
00000728: 20 63 68 75 6E 6B 65 64 0D 0A 43 6F 6E 74 65 6E chunked..Conten	
00000738: 74 2D 54 79 70 65 3A 20 74 65 78 74 2F 68 74 60 t-Type: text/htm	
00000748: 6C 6D 00 00 0E 7E 55 3A 6A 75 6C 69 65 64 61 72 I....U;juliedar	
00000758: 60 73 74 61 64 74 0D 0H 0E F0 AD 0B 0D F0 AD 0D mstdat.....	
00000768: 00 F0 AD 0B 0D F0 AD 0B F0 AD 0B F0 AD 0B F0 AD 0B .....	
00000778: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000788: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
00000798: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000007A8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000007B8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	
000007C8: 00 F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B 0D F0 AD 0B .....	

Figure 22 – A LEAK Activity Record

## **5. Deleted Activity Records**

It is important to recover as much information as possible about a user's internet activity. Through experimentation we were able to determine that activity records existed in the `index.dat` files that were not recorded in the HASH table. This was determined because we know that each record is a multiple of 0x80 bytes. Knowing this, if the first four bytes (the type) were compared against the known types of activity records listed previously in this paper (URL, REDR, LEAK), it would be logical that we would be able to reconstruct any records that do not exist in the HASH table.

It is important to note that the output of IE History did not contain the number of activity records that we recovered using the undeletion method described in this section.

## 6. Pasco – The IE Internet Activity Parser

Now that we understand the internal structure of the `index.dat` file, we can develop a tool to automate everything we have done by hand so far. The author developed a tool called *Pasco*, the Latin word for “browse”, to do just that. *Pasco* receives an `index.dat` file retrieved from a user’s computer and the output is returned as delimited text so that the investigator may import the results into his spreadsheet of choice for greater organization.

*Pasco* can be run in two different modes: the *standard* methodology outlined in this paper (which is the default processing for *Pasco*), or in an *undeletion* mode. The undeletion mode ignores the information in the HASH table and reconstructs any valid activity records at every 0x80 byte boundary. *This mode may retrieve activity that was previously unreported by other tools and methods.*

The command line usage for *Pasco* is relatively simple:

```
[kjones: pasco] kjones% ./pasco
Usage: pasco [options] <filename>
      -d Undelete Activity Records
      -t Field Delimiter (TAB by default)
```

The “-d” option enables the undeletion mode. The “-t” option will allow the investigator to change the field delimiter. The output will be sent to standard out (the console) by default. It is suggested that *Pasco* is run in the following manner:

```
./pasco index.dat > index.txt
```

Once `index.txt` is created, the results can be imported into an application like Microsoft Excel for further viewing, sorting, and formatting:

Workbook1						
A	B	C	D	E	F	
1 History File: index.dat						
2						
3	TYPE	URL	MODIFIED TIME	ACCESS TIME	FILENAME	DIRECTORY
4	URL	http://www.ethereal.com/distribution/win32/win32-README.txt	Mon Apr 15 20:46:34 2002	Tue Feb 4 12:47:27 2003	win32-README[1].txt	N2L6K2BN HTTP/1.1 200 OK
5	URL	http://www.ethereal.com/cns/folder.gif	Thu Feb 22 06:46:56 2001	Tue Feb 4 12:47:27 2003	folder[1].gif	OPRE341MV HTTP/1.1 200 OK
6	URL	http://analyzer.polito.it/images/background.gif	Tue Mar 20 09:46:56 2001	Tue Feb 4 12:50:00 2003	background[1].gif	OPRE341MV HTTP/1.1 200 OK
7	REDR	http://login.yahoo.com/config/login?tries=1&src=y&m&d5=b&hash=8js=1&last=8promo=8&int=us&bypass=&partner=u=7499uqgsz231&v=0&challenge=CzyAaIFFnz2b4FNzGk5h8xplu8&emailCode=sha	Tue Mar 20 09:46:56 2001	Tue Feb 4 12:50:00 2003	bypass=&partner=u=8397bicuz51f&v=0&challenge=spKVd4nqkHxqLNg1bx3Sg9yM3b.xplu8&emailCode=8&hash	OPRE341MV HTTP/1.1 200 OK
8	REDR	http://login.yahoo.com/config/login?tries=1&src=y&m&d5=b&hash=8js=1&last=8promo=8&int=us&bypass=&partner=u=8397bicuz51f&v=0&challenge=spKVd4nqkHxqLNg1bx3Sg9yM3b.xplu8&emailCode=8&hash	Tue Mar 20 09:46:56 2001	Tue Feb 4 12:50:00 2003	disk[1].gif	OPRE341MV HTTP/1.1 200 OK
9	URL	http://analyzer.polito.it/images/level_forget_pw?.src=pw&done=http://messenger.yahoo.com/				
10	REDR	http://www.ethereal.com/cns/folder.gif				
11	URL	https://www.verizonwireless.com/zips/vzw_zip.zip?p_alias=vzw_equipment	Thu Feb 22 06:46:04 1996	Tue Feb 4 12:47:27 2003	folder[1].gif	OPRE341MV HTTP/1.1 200 OK
12	REDR	http://www.ethereal.com/distribution/win32/				
13	URL	http://analyzer.polito.it/favicon.ico				
14	URL	http://www.ethereal.com/cns/folder.gif				
15	URL	http://www.ethereal.com/cns/folder.gif	Fri Jan 17 09:57:15 2003	Tue Feb 4 12:49:36 2003	shallow[1].gif	N2L6K2BN HTTP/1.1 200 OK
16	URL	http://www.ethereal.com/cns/folder.gif	Thu Feb 22 06:46:04 1996	Tue Feb 4 12:47:27 2003	fold[1].gif	OPRE341MV HTTP/1.1 200 OK
17	URL	http://www.ethereal.com/cns/folder.gif	Thu Feb 22 06:46:04 1996	Tue Feb 4 12:47:27 2003	fold[1].gif	OPRE341MV HTTP/1.1 200 OK
18	REDR	http://johannes.luedke.de/ethereal/0.9.9.505	Thu Feb 22 06:45:53 1996	Tue Feb 4 12:47:27 2003	binary[1].gif	OPRE341MV HTTP/1.1 200 OK
19	URL	http://www.ethereal.com/cns/binary.gif	Thu Feb 22 06:45:53 1996	Tue Feb 4 12:47:27 2003	back[1].gif	OPRE341MV HTTP/1.1 200 OK
20	URL	http://www.ethereal.com/cns/back.gif	Thu Feb 22 06:45:53 1996	Tue Feb 4 12:47:27 2003	back[1].gif	OPRE341MV HTTP/1.1 200 OK
21	REDR	http://www.ethereal.com/distribution/win32/ethereal-setup-0.9.9.exe	Fri Jan 17 09:57:15 2003	Tue Feb 4 12:47:27 2003	analyzer.polito[1]	N2L6K2BN HTTP/1.1 200 OK
22	REDR	http://analyzer.polito.it/cgi-bin/x?r0s=1148908n=1036179023513505				
23	LEAK	http://stds.osdn.com/1.html				
24	URL	http://www.ethereal.com/cns/test.gif	Tue Feb 22 06:46:28 1996	Tue Feb 4 12:47:27 2003	text[1].gif	OPRE341MV HTTP/1.1 200 OK
25	URL	http://analyzer.polito.it/style.css	Tue Mar 20 09:46:47 2001	Tue Feb 4 12:50:00 2003	style[1].css	N2L6K2BN HTTP/1.1 200 OK
26	URL	http://analyzer.polito.it/style.css				
27	LEAK	http://analyzer.polito.it/favicon.ico				
28	REDR	http://analyzer.polito.it/misc/help.htm	Wed Jan 09:14:51 2002	Tue Feb 4 12:49:46 2003	help[1].htm	N2L6K2BN HTTP/1.1 200 OK
29	LEAK	http://pdownload.sourceforge.net/theereal/ethereal-setup-0.9.9.exe?use_default=easynews				
30	URL	http://analyzer.polito.it/cgi-bin/Count.cgi#analyzerstat				
31	LEAK	http://pdownload.sourceforge.net/theereal/ethereal-setup-0.9.9.exe?use_default=easynews				
32	URL	http://analyzer.polito.it/cgi-bin/Count.cgi#analyzerstat				
33	URL	http://analyzer.polito.it/cgi-bin/Count.cgi#analyzerstat				
34	URL	http://analyzer.polito.it/style.css				
35	URL	http://analyzer.polito.it/favicon.ico				
36	URL	http://www.ethereal.com/cns/test.cgi	Sat Jan 11 09:52:34 2003	Tue Feb 4 12:48:39 2003	IPv6-enabled[1].gif	N2L6K2BN HTTP/1.1 200 OK
37	URL	http://www.ethereal.com/cns/test.cgi	Mon Feb 10 08:46:28 1996	Tue Feb 4 12:48:39 2003	text[1].gif	OPRE341MV HTTP/1.1 200 OK
38	REDR	http://address.mail.yahoo.com/yak2/us/1648545519/82c63498	Thu Feb 22 06:45:54 1996	Tue Feb 4 12:47:27 2003	blank[1].gif	OPRE341MV HTTP/1.1 200 OK
39	URL	http://www.ethereal.com/cns/folder.gif				
40	URL	http://www.ethereal.com/cns/back.gif				
41	REDR	http://www.verizonwireless.com/zips/vzw_zip.zip?p_alias=vzw_customer_care&p_url=8p_referer=VZW_ZIP_FORUM&p_code=222028_cookie[2]				
42	URL	http://www.ethereal.com/distribution/win32/				
43	REDR	http://www.ethereal.com/cns/blank.gif				
44	REDR	http://www.ethereal.com/cns/blank.gif				
45	REDR	http://sdb.bluestack.net/ice?r0s=1148916n=1036179023513505				
46	REDR	http://www.ethereal.com/cns/blank.gif				
47	URL	http://www.ethereal.com/cns/binary.gif				
48	URL	http://www.ethereal.com/cns/test.cgi				
49	REDR	http://www.ethereal.com/general/single_popup.html?search_string=%22theereal%22++and+download				
50	REDR	http://data.coremetrics.com/eliminate?id=83D6%26c1%3D9000339%26n2%3Dn3%26pc%3DY%26p%3DHOME%2520PAGE%26y%3D1.%26p%3D%y%26e%3Dtrue%26cp%3D%86%26p%3D1024%26				
51	REDR	http://ad.doubleclick.net/ad/f2335@yahoo1072270.2;sz=468&u0r=1036173795214003?				
52	URL	http://analyzer.polito.it/Pv6-enabled.cgi	Mon Sep 10 08:25:01 2001	Tue Feb 4 12:49:39 2003	IPv6-enabled[1].gif	OPRE341MV HTTP/1.1 200 OK
53	URL	http://www.ethereal.com/distribution/win32/win32-README.txt	Mon Apr 15 23:01:34 2002	Tue Feb 4 12:47:33 2003	win32-README[1].txt	N2L6K2BN HTTP/1.1 200 OK
54						
55						

Figure 23 - Pasco's Output

When running Pasco in the undeletion mode, it is possible that the numbers of records returned are less when compared with the standard mode's output:

```
[kjones: pasco] kjones% ./pasco index.dat | wc -l
      53
[kjones: pasco] kjones% ./pasco -d index.dat | wc -l
      36
```

This phenomena is experienced when multiple copies of activity records are inserted into the HASH table structure. If we are to return only the unique activity records using the sort -u command, we see that Pasco indeed returns more records when undeletion mode is enabled:

```
[kjones: pasco] kjones% ./pasco index.dat | sort -u | wc -l
      35
[kjones: pasco] kjones% ./pasco -d index.dat | sort -u | wc -l
      36
```

Pasco is open source and released under the liberal FreeBSD license.