Memory Consumption Analysis with liballoc/Heapchecker

Applies to:

Application Server kernel, C/C++ development and support. For more information, visit the Performance homepage.

Summary

SAP liballoc/Heapchecker is a memory analysis tool for C/C++ programs. It runs on 64 bit Linux, Solaris, HP-UX and as a prototype on Windows. *Heapchecker* is a fast and light weight solution, what makes its usage possible for development phase at SAP and also for troubleshooting on customer side. It helps in finding memory leaks, buffer overwrites and memory management anti-patterns.

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Why Heapchecker?

Well known situation: an executable on the server consumes a lot of main memory and nobody knows why. It get worse if support and development teams can't reproduce the issue on a test system. The question is, how can we localize the issue and identify the functions, classes or at least libraries which are responsible for high memory consumption?

We concentrate us here at this kind of memory management problems in C/C++ programs written at SAP, where are e.g. :

- *disp+work, message server, enqueue, ICM* – parts of ABAP AS
- *jstart* – Java AS launcher,
- *TREX IndexServer, NameServer, RFC Server* – parts of TREX engine
- and many other…

We discuss in this article dynamic memory allocation via malloc/new only. Shared memory consumption is not a topic of this article. Shared memory used by ABAP runtime can be checked with other SAP tools like ABAP Memory Inspector.

SAP Java AS memory can be explored with e.g. Java Memory Analyzer.

Functionality

Heapchecker does use the dynamic libraries preload mechanisms of the operating system. On the most of UNIX systems it can be done with an LD_PRELOAD environment variable setting to bring dynamic loader to bind a running executable against the user defined symbols. Example for a usage in a bash shell:

```
> export LD_PRELOAD=./liballoc.so
> sappfpar pf=SampleProfile
```

liballoc.so is the name of Heapchecker library and sappfpar is a simple SAP application to be analyzed here.

The following four functions are defined in liballoc/Heapchecker library for overloading standard libc memory managent:

```
void* malloc  (size_t size);
void  free    (void * ptr);
void* calloc  (size_t n, size_t sz);
void* realloc (void * old_ptr, size_t sz);
```

It is enough for (SAP) applications written in C and C++ as well as new/delete will be implemented internally via malloc/free by all the relevant compilers.

This way of function overloading does make "bookkeeping" of heap allocations possible to Heapchecker. It protocols the timestamp, size and other information about every allocation/deallocation and performs requested allocation/deallocation afterwards, so that it remains transparent for the application being analyzed. Recording will be done in main memory in a thread safe manner, reports will be written into log files if required.

Memory Statistics Output

Here are several log file fragments.

```
List of chunks sizes in process pid 16399. Time 22:54:49.160

        Size   Chunks        KB  LowPeak HighPeak        KB      Incr   AllocCount
           1        3         0        3        4         0         1         6012
           2       22         0       22       24         0         1          731
           3       31         0       31       34         0         1         3330
           4      697         2      697    37269       145         8     16179244
           5       38         0       38       42         0         1         9744
           6       53         0       53       56         0         1         6250
           7       17         0       17       21         0         1         5471
           8   668521      5222   668521  1438761     11240         3      8306936
           9       22         0       22       29         0         1         7680
          10       11         0       11       18         0         1         1167
          11       14         0       14       16         0         1          463
          12      100         1      100      478         5         7       699408
          13     2277        28     2277     4585        58         6      6614395
          14    16185       221    16185    18375       251         0     18424016
          15     6858       100     6858     7457       109         5      5225828
          16     2955        46     2955   143544      2242         8     10367315
...
...
    66767088        1     65202        1        1     65202         0            2
    67904000        2    132625        0        2    132625         0            2
...
...
Total: 55117 sizes, 2805961 chunks 6781 MB,  305 M allocs
```

The snippet above is a distribution statistic about allocation sizes of a running process. We can see e.g. that there are currently only 3 chunks (allocations) of size 1 Byte and exactly 668521 8-Byte-chunks. The number of 8-Byte-chunks have been even higher during the applications runtime: 1438761 was the peek value.

The largest chunk size is 67904000 Byte. There are 2805961 chunks allocated, they occupy 6781 MB net on the heap. This kind of information is useful then analyzing memory fragmentation issues.

The next snippet is an example of a memory leak suspicion report. Heapchecker concludes that the number of chunks with size 133104 has grown continuously. There are 44 of them currently at 19:30:40. This fact will be reported inclusive the call stack of the questionable allocation.

```
19:3:40.144 Leak state of size 133104: chunks 44 (lo 44, hi 46, incr 0), allocs 126
Queue:       35       36       37       38       39       40       41       42       43       44
       18:15:16  18:21:4. 18:23:46 18:28:38 18:29:14 18:32:29 18:33:18 18:38:59 18:42:33 19:3:40


Chunks all sizes: 2777809 6611.608 MB,  Chunks of size 133104: 45 5.729 MB

19:3:40.144 Number of allocated chunks per size
------+-------------------------------------------------------------------------------
up to |       1       2       4       8      16      32      64     128     256     512
------+-------------------------------------------------------------------------------
 Byte |       3      22    1011  663796   28199   60825    7802  255779  134107  305367
   KB | 1078412  220327    1719    2182    2407    3120    3511    3176    2261    1494
   MB |    1076     720     279     200       7       3       2       2       0       0
   GB |       0       0       0       0       0       0       0       0       0       0

19:3:40.144 *** StackTrace ***
[Thr 1109473600] ------------------ C-STACK ----------------------
/usr/sap/BAA/TRX00/exe/liballoc_mt.so[0x2b17bb96758e]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so(_Z10CTrcStack2P8_IO_FILEPv+0x5f)[0x2b17bb9679cb]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so(_Z9CTrcStackP8_IO_FILE+0x1a)[0x2b17bb967a26]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so(_Z10StackTraceP8_IO_FILE+0x15)[0x2b17bb955fdd]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so[0x2b17bb951f3f]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so[0x2b17bb952321]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so[0x2b17bb95285c]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so(_Z19MY_MALLOC_HEAPCHECKm+0x1645)[0x2b17bb953ed7]
/usr/sap/BAA/TRX00/exe/liballoc_mt.so(malloc+0x100)[0x2b17bb94bd38]
/usr/lib64/libstdc++.so.6(_Znwm+0x1d)[0x2b17c459dfcd]
/usr/sap/BAA/TRX00/exe/ims_search_api.so(_ZN8Executor11BwPopSearch10executePopERKN4_STL6vectorI
PNS_8PlanDataENS1_9allocatorIS4_EEEES9_RKNS_13ExecutionInfoE+0xd85)[0x2b17bdfadea3]
/usr/sap/BAA/TRX00/exe/executor.so(_ZN8Executor13PlanOperation10executePopERKN4_STL6vectorIPNS_
8PlanDataENS1_9allocatorIS4_EEEES9_RN17TRexCommonObjects12TRexApiErrorERKNS_13ExecutionInfoE+0x
16)[0x2b17bd55977e]
/usr/sap/BAA/TRX00/exe/executor.so(_ZN8Executor2X210runPopTaskERNS0_11PopTaskInfoERi+0x97c)[0x2
b17bd58825c]
/usr/sap/BAA/TRX00/exe/executor.so(_ZN8Executor2X212runPopThreadERNS0_11PopTaskInfoE+0xab)[0x2b
17bd589065]
/usr/sap/BAA/TRX00/exe/executor.so(_ZN8Executor8X2Thread3runEPv+0xa4)[0x2b17bd58a46c]
/usr/sap/BAA/TRX00/exe/TrexBase.so(_ZN11TrexThreads10PoolThread3runEv+0x976)[0x2b17bf706f3a]
/usr/sap/BAA/TRX00/exe/TrexBase.so[0x2b17bf708187]
/lib64/libpthread.so.0[0x2b17c494a143]
[Thr 1109473600] ------------------------------------------------
```

Such a pattern – growing number of allocations of determined size – is often an indicator for a memory leak. Heapchecker is also able to revert its memory leak suspicion if the number of allocations of the determined size get reduced.

Memory Corruption Output

Another operation area of Heapchecker are heap corruption issues like buffer overflow. Here a log example:

```
pid 11548 check malloc damaged adr        0x6608d90 size 100
eye_before        0x6608d88  MALL>>>>  4D 41 4C 4C 3E 3E 3E 3E
eye_after         0x6608df4  w<<<MALL  77 3C 3C 3C 4D 41 4C 4C
malloc chain error  detected
```

One of the challenges in buffer overflow finding is that an overflow may not cause a runtime error immediately, but some time later, maybe in another function, thread etc. The goal of the Heapchecker here is to assert an overflow immediately after it took place.

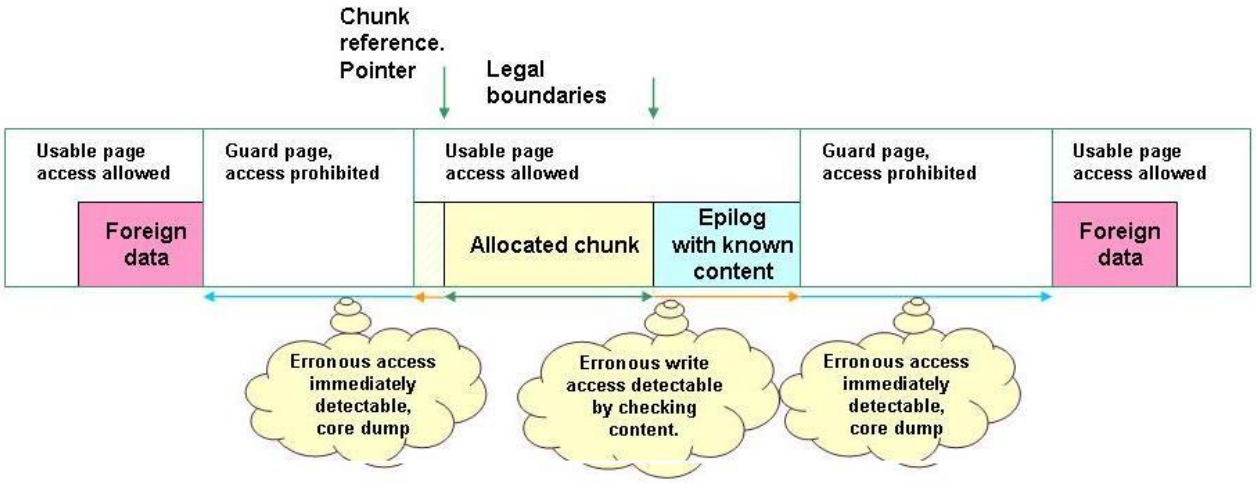
Heapchecker can frame each allocated chunk with

- eye catcher byte sequence or
- guard pages.

In the log example above the eye catcher damage was determined in a chunk of size 100 Byte at address 0x6608d90. Heapchecker can also dump the content of this memory chunk for analysis.

Guard pages technique is even more powerful than eye catchers. Every allocation will be placed between two guard pages protected by OS.

Eye catchers and guard pages techniques can be combined. The following picture points this up.



Conclusion

Heapchecker is a component of *SAP liballoc* library which allows to replace an origin (libc) memory management with another one developed at SAP.

Heapchecker is applicable in analysis of memory heap runtime issues. It can be used if analysis with higher level tools like e.g. ABAP Memory Analyzer was not possible or not successful.

Related Content

Reference - Memory Management in ABAP AS

Reference - TREX MemWatch

Reference - dynamic linker and LD_PRELOAD

For more information, visit the Performance homepage.

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