20.2 Memory Allocation

The Kernel can allocate memory using the following attributes passed to the Virtual Address Allocator. Some of these attributes can be combined while others must be specifically individualized.

Table 20.2.1: Memory Allocate Attribute

Value	Description
MALLOC_FLAGS_NONE	Any memory region and type may be returned
MALLOC_FLAGS_CLEAR	Clear memory region before returning to caller
MALLOC_FLAGS_LOW1MEG	Must be a region all below the 1 Meg mark
MALLOC_FLAGS_LOW16MEG	Must be a region all below the 16 Meg mark
MALLOC_FLAGS_LOW4GIG	Must be a region all below the 4 Gig mark
MALLOC_FLAGS_PHYSICAL	Must be a Physical Address memory region returned
MALLOC_FLAGS_ALIGNED	Must be aligned on a given boundary
MALLOC_HARDWARE32	MALLOC_FLAGS_LOW4GIG | MALLOC_FLAGS_PHYSICAL | MALLOC_FLAGS_CONTINUOUS
MALLOC_HARDWARE64	MALLOC_FLAGS_PHYSICAL | MALLOC_FLAGS_CONTINUOUS

20.2.1 None

This attribute, with the exception of the CLEAR attribute, is assumed to be the only attribute given and can be any memory region, contiguous or not, physically allocated or linear. This will be the most common type of memory allocated. Most allocation will use this type, so this must be the most efficiently coded allocation.

20.2.2 Clear

This attribute may be combined with any other attribute and simply instructs the Allocator to clear the memory region(s) to zero before returning to the caller. The act of clearing it does not have to be done at this point, just so long as the memory is clear. i.e.: A kernel task can be created to clear memory in the background, when idle, marking regions as clear, allowing the Allocator to simply return.

20.2.1 Low1Meg

This attribute may be combined with most other attributes and instructs the Allocator that all memory for this request must be below the `0x00000000_00100000` (1 Meg) memory mark.

20.2.2 Low16Meg

This attribute may be combined with most other attributes and instructs the Allocator that all memory for this request must be below the `0x00000000_01000000` (16 Meg) memory mark.

20.2.3 Low4Gig

This attribute may be combined with most other attributes and instructs the Allocator that all memory for this request must be below the `0x00000001_00000000` (4 Gig) memory mark.

20.2.4 Physical

This attribute may be combined with most other attributes and instructs the Allocator that all memory for this request must be physically allocated. i.e.: the memory must be physically present and use a physical address, not a linear address for returned memory region. All memory in this region will also be physically contiguous.

20.2.5 Aligned

This attribute may be combined with most other attributes and instructs the Allocator that the starting address for this request must be aligned on the given alignment.

20.2.7 Hardware32
This attribute is a combination of previous attributes indicating to the Allocator that all memory must be within the lower 4 Gig Address Space, all must be physically present, and must be continuous. This attribute is usually used by 32-bit only hardware.

20.2.8 Hardware64
This attribute is a combination of previous attributes indicating to the Allocator that all memory must be physically present, and must be continuous, though can be anywhere in the 64-bit addresses space. This attribute is usually used by 64-bit aware hardware.

20.3 The Virtual Heap
To make it easier on the kernel, a virtual memory heap is created. The heap is a number of blocks of memory available to the kernel. The heap is used as a simple way to allocate and free virtual memory without calling the underlining physical allocator for each and every memory request, making it much faster to allocate memory.

On Kernel start up, it calls the Virtual Memory Allocator to allocate a single linear block of memory, 64 Meg is suggested but not required, for this heap. The memory in the heap may or may not be physically contiguous. This heap is then further managed by a Heap Allocator. All requests for memory go through this Heap Allocator.

If a memory request can be satisfied from this initial block of memory, the Heap Allocator records the allocation within its catalog and returns a pointer to a region large enough to satisfy the request. No call to the Virtual Memory Allocator or Physical Memory Allocator is needed, drastically speeding up the memory request.

If the memory request cannot be satisfied, due to lack of remaining room in the current catalog, a special alignment request, a physical address request, or other situation, the Heap Allocator may then call upon the Virtual Memory Allocator to satisfy the request. The Virtual Memory Allocator may then call upon the Physical Memory Allocator to satisfy the request.

This Virtual Heap Allocator maintains a catalog of memory addresses from `0x00000000_00000000` to the size of the heap set by the Kernel. The Kernel's heap may set this limit to any amount. Any Heap created for a user task may set an initial limit, resizing as needed.

20.3.1 Heap Catalog
The Heap Catalog consists of Buckets and Pebbles within these buckets. Initially there is a single bucket of any size holding one to an arbitrary number of Pebbles within it. Each Pebble is marked used or free. If a Pebble is marked free, it may be used to satisfy a memory request. This Pebble can be split into two Pebbles so that the remaining part of the Pebble can then be used to satisfy another request.

If at any time there are not a Pebble within a Bucket to satisfy a memory request, a new Bucket may be allocated, placing free Pebbles within, to satisfy the request.

20.3.2 Buckets
A Bucket is allocated by the Virtual Memory Allocator, is of an arbitrary size, and is considered a contiguous number of virtually allocated bytes from start to end. The starting memory location and any contiguous byte to the end may or may not be physically contiguous, but must be virtually contiguous.

A Bucket is allocated and freed from the Virtual Memory Allocator using two functions, the first may be a function called `mmap()` and the second may be called `mmap_free()`. No other function is required as far as the Heap Allocator is concerned. All Virtual Memory allocated for a Bucket is cataloged by the Virtual Memory Allocator.

A Bucket maintains only the Pebbles within it and has no awareness of any other Pebbles within another Bucket.

A bucket may be resized at any time as long as the Pebbles within are maintained. If a Bucket has excess free Pebbles, or a single free Pebble with excess memory allocated for it, a Bucket may shrink to accommodate. If a Bucket doesn't have enough free space within, it may expand to create an addition number of Pebbles. However, any memory added to the Bucket must be contiguously added at the end of the currently allocated memory. i.e.: A Bucket may only increase in size if the added memory is Virtually consecutively added at the end and the new sized Bucket is still continuous.

A Bucket has the following format and must be stored in the first bytes of the allocated space returned from the Virtual Memory Allocator.

Table 20.3.2.1: Heap Bucket Format

Name	Size	Description
Magic	4	Signature identifying a valid Bucket
Local Flags	4	Flags for this Bucket
Size	8	Count of pages allocated for this Bucket
Largest	8	Size of largest free Pebble in this Bucket
Previous	8	Pointer to a previous Bucket
Next	8	Pointer to the next Bucket
First Pebble	8	Pointer to the first Pebble in this Bucket

20.3.2.1 Magic
This field is a signature of `0x4255434B`, (`'BUCK'` in little-endian format) indicating that this is actually a Bucket.

20.3.2.2 Local Flags
This field is used to indicate a few attributes about the Pebbles within this Bucket.

Table 20.3.2.2.1: Local Flags

Value	Description
Bit 0	If set, use best method fit. If clear, use first fit.
other	Not used and is in error if found

Any flag given is for this Bucket only. No field, flags or other, are used in any other Bucket.

20.3.2.2.1 Method Used
Bit 0 is used to indicate which allocation method to use for this Bucket.

If set, the allocator is to use the Best Fit method when allocating a free Pebble within this Bucket. This is to use the smallest free Pebble that will satisfy the request.

If clear, the allocator must use the first free Pebble it finds in this Bucket. This is to speed up the process.

20.3.2.3 Size
This field is used to store the number of pages allocated for this Bucket. This value is used for the free function of the Virtual Memory Allocator, so it knows how many pages to free.

20.3.2.4 Largest
This field holds the largest free block within this Bucket. The Heap Allocator code can compare this field with the request to see if there is a Pebble large enough to satisfy the request. This is so the Heap Allocator does not have to parse any of the Pebbles to see if one is large enough, and can move on to another Bucket if there is none. This field must be maintained after a Pebble in this Bucket is modified.

20.3.2.5 Previous/Next
These two fields create a linked list of Buckets. If a field is non-zero, there is a Bucket in that direction. At least one Bucket must always exist and its previous field must be NULL.

20.3.2.6 First Pebble
This field points to the first Pebble in this Bucket. A Bucket must always have at least one Pebble, even if it is a free for use Pebble. After a call to free a Pebble, if this happens to create a single Pebble within a Bucket and this Pebble is free for use, it is up to the Heap Allocator if it would like to free this Bucket from the Heap's list.

The First Pebble, the Bucket's First pointer value, must not be assumed to be just after the Bucket. The First Pebble field may point to any Pebble within the Bucket. An advantage of this is to update the Bucket's first Pebble field to point to the newly freed Pebble, so that when allocation is to take place, the first Pebble found is a free Pebble. However, this creates more work when finding a used Pebble. Also, see Sections 20.3.3.8 and 20.3.5.

20.3.3 Pebbles
Pebbles are stored within a bucket. A Bucket must have at least one Pebble. A Pebble is used to satisfy a memory allocation request.

A Pebble has the following format.

Table 20.3.3.1: Heap Pebble Format

Name	Size	Description
Magic	4	Signature identifying a valid Bucket
Local Flags	4	Flags for this Pebble
Sent Flags	4	Flags from the Sender
Padding	4	Reserved/Used to align next field
Size	8	Number of available bytes in this Pebble
Name	32	name/comment/signature for this Pebble
Parent	8	Pointer to the parent Bucket of this Pebble
Previous	8	Pointer to a previous Pebble in this Bucket
Next	8	Pointer to the next Pebble in this Bucket

20.3.3.1 Magic
This field is a signature of `0x524F434B`, (`'ROCK'` in little-endian format) indicating that this is actually a Pebble.

20.3.3.2 Local Flags
This field is used to indicate a few attributes about this Pebble.

Table 20.3.3.2.1: Local Flags

Value	Description
Bit 0	If set, is used. If clear, is free for use.
other	Not used and is in error if found

Any flag given is for this Pebble only. No field, flags or other, are used in any other Pebble.

20.3.3.3 Sent Flags
This field is used to indicate the initial flags. For example, if you allocate memory with an alignment value, what happens when you use `realloc()` requesting a larger size? This is so your `realloc()` function can fail if it finds that you originally allocated with an alignment attribute and you are asking for a larger size. See Section 20.3.7 for more information on this field.

20.3.3.4 Padding
This field is reserved for future use and currently is only to pad to the next field.

20.3.3.5 Size
This field is the number of bytes within this Pebble assigned for use. This size must be at least 64 and must be a count of 64 bytes in size. i.e.: It must be at least 64, 128, 192, 256, 320, etc. This field may not actually represent the exact number of bytes requested, but must be at a 64-byte count at or above the amount requested. This is to align the next Pebble on a 64-byte count from the end of the previous pebble. This alignment is not to be relied upon, nor assumed. See Section 20.3.6 for reasons why.

20.3.3.6 Name
This field is an optional field and may contain anything the Kernel wishes to place here. This could simply be a character string of the function or filename that called the allocator. It can also be a signature associated with a driver who has requested it. It is purely optional and used for debugging purposes. Your Heap Allocator must ignore this field other than maintaining this field throughout its life. Your Heap Allocator must work as expected if this field is removed from Table 2.3.3.1 above. i.e.: No field within that table may rely upon its offset, nor can you assume the size of the table.

20.3.3.7 Parent
This field points to the Parent Bucket this Pebble resides in. All Pebbles, free or not, must maintain this pointer.

20.3.3.8 Previous/Next
These two fields create a linked list of Pebbles. If a field is non-zero, there is a Pebble in that direction. The first listed Pebble must have a Previous field of NULL and the last listed Pebble must have a Next field of NULL.

All Pebbles must remain within the allocated memory of the Bucket. i.e.: When adding a Pebble, it must be within an address that is contained within the memory allocated for the Bucket. No Pebble may be allocated outside of its intended Bucket and no Pebble may point to another Bucket's Pebble.

20.3.4 Splitting Pebbles
When Splitting a Pebble to allocate a portion of the memory allocated to it, you must add at least one Pebble in either direction, updating the two surrounding Pebbles to point to this newly added Pebble. You may only split a Pebble when there is enough room to satisfy the current allocation request *and* a new Pebble will have at least the 64-byte minimum free space allotted for it. If splitting a Pebble does not leave enough room for a new Pebble and this 64-byte space, the Pebble is not to be spit and the allocated size must remain as is.

20.3.5 Merging Pebbles
When two consecutive Pebbles are free, your Heap Allocator should merge these Pebbles to create a single Pebble. To do this, the first Pebble needs to consume the second Pebble so that the first Pebble. All linked-list pointers must be updated for any surrounding Pebbles. The Size field in the first Pebble is now increased to the size of both Pebbles including the deleted Pebble's block (currently 80 bytes).

Be sure to watch that if you delete a Pebble by doing this, the Bucket's First Pebble pointer is still valid. i.e.: by deleting this Pebble, first make sure the Bucket wasn't pointing to this pebble, and adjust if needed.

20.3.6 Aligned Requests
When the caller is requesting a memory address that is aligned on a supplied boundary requirement, it is up to your Heap Allocator to satisfy this request. The manner in which you do is not specified here. However, here are a few examples.

1) Your Heap Allocator may adjust a Pebble's location so that the byte just after the Pebble satisfies the alignment request. To do this, you forgo the 64-byte alignment request specified in section 20.3.3.5 and place a Pebble so that it is just before the aligned location. To do this, you must have an original free Pebble large enough to split and place a new Pebble within the allocated space so that this new Pebble's memory region is now aligned.
2) You may insert a new Bucket into the Heap, so that the newly created first Pebble is now aligned on the requested alignment. However, this makes it so that your code cannot assume the first Pebble is

just after the memory used for the Bucket. This means that there may be unused space between the memory used to store the Bucket data and the first Pebble. However, this is an easy way to allocate aligned and/or physically aligned memory. See the next section for more on this use.

20.3.7 Physical Requests

Physical contiguous memory requests must also be satisfied by the Heap Allocator. However, being the nature of the request, a new Bucket is usually created, then option 2) in Section 20.3.6 is performed. The Heap Allocator passes a flag to the Virtual Memory Allocator to return memory that is Physically and Contiguous allocated. The Heap Allocator requests the Virtual Memory Allocator to make sure and allocate Physical Memory addresses that are contiguous, prefixing an extra page, which may or may not be Physically allocated, to store the Bucket data as well as the Pebble just before the first Physically allocated memory page.

This is where the Sent Flags field may be used within the Pebble. This way when the Heap Allocator calls upon the Virtual Memory Allocator to free the space, it can indicate that it was physically allocated memory, if needed.

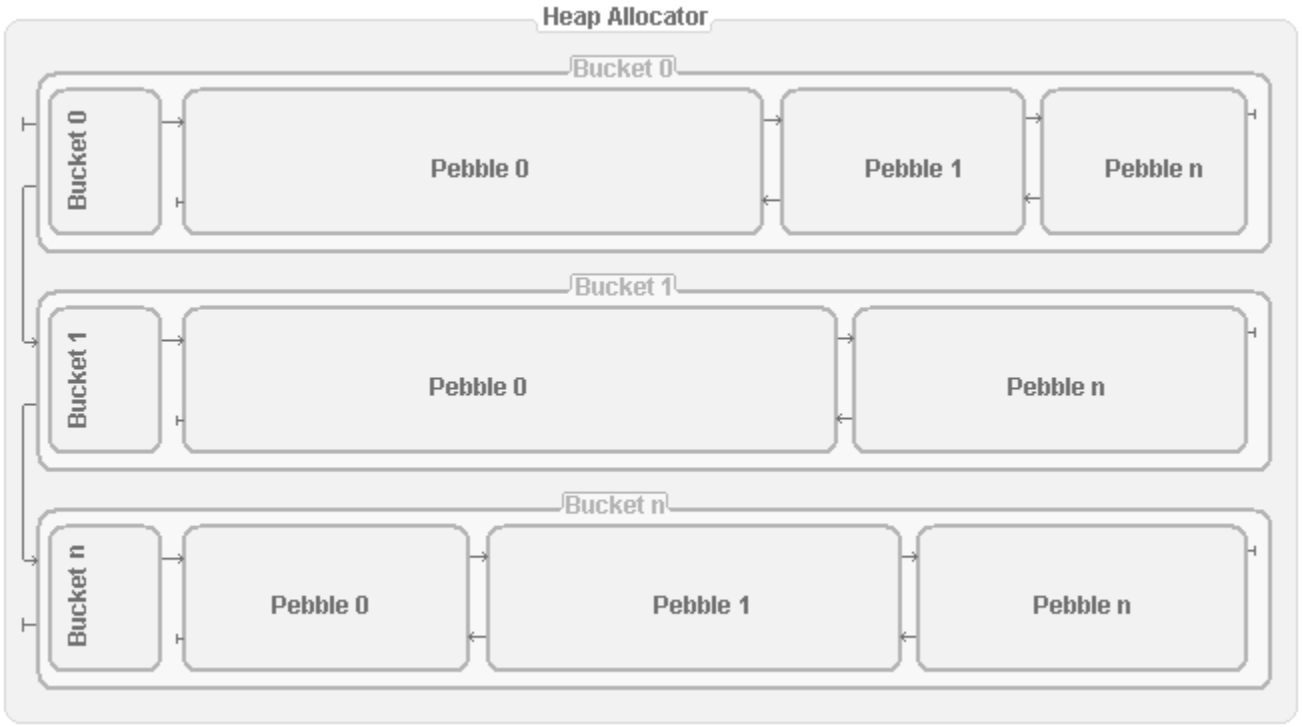
20.3.8 Multithreading/Multitasking

If your Heap Allocator will be used on a multi-process platform, a locking mechanism is strongly suggested. A simple Spinlock will suffice. Lock any code that modifies a Bucket or a Pebble within that Bucket, remembering to unlock when finished.

20.3.9 Example Layout

The following is an example layout of the memory allocated by a Heal Allocator. This example has three Buckets with each Bucket having an arbitrary number of Pebbles.

Figure 20.3.9.1: Example Layout



In this example, there are three Buckets, each having more than one Pebble. The example shows that each Bucket is the same size. This usually is the case, but doesn't have to be. Each bucket can be a different size due to different allocation strategies.

In a Bucket, there are usually no connecting Unused Pebbles. i.e.: If two connecting Pebbles are marked Free, the Heap Allocator should merge them.

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