

.NET Garbage Collection

Fundamentals of .NET Garbage Collection

Writing High-Performamnce .NET Code

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In .NET, you need to think of memory performance at least as much as CPU performance. It is so fundamental to smooth .NET operation, that the most significant chunk of this book's content is dedicated to just this topic. - Ben Watson, Writing High-Performamnce .NET Code



Heaps

Heap = Process memory reserved for allocation of data.

A managed process has 2 kinds of heaps:

- **Native Heap:**
used by Windows & CLR for unmanaged memory, e.g.
Windows API, OS data structures, the CLR itself
- **Managed Heap** (*GC Heap*):
used by the CLR to allocate objects subjected to garbage collection

The Managed Heap

The Managed Heap is divided in 2 sections.

- **Small Object Heap (SOH)**
for objects < 85000 bytes, most of all objects
- **Large Object Heap (LOH)**
for objects \geq 85000 bytes, mostly arrays and strings

Size of an empty object: 16 bytes (32bit), 32 bytes (64bit).

Actually its 12 bytes and 24 bytes but the memory manager can't handle that very well.

The Small Object Heap

The Small Object Heap is divided in 3 generations.

- **Gen 0** the 1st generation
- **Gen 1** the 2nd generation (serves as cache for Gen 2)
- **Gen 2** the 3rd and last generation

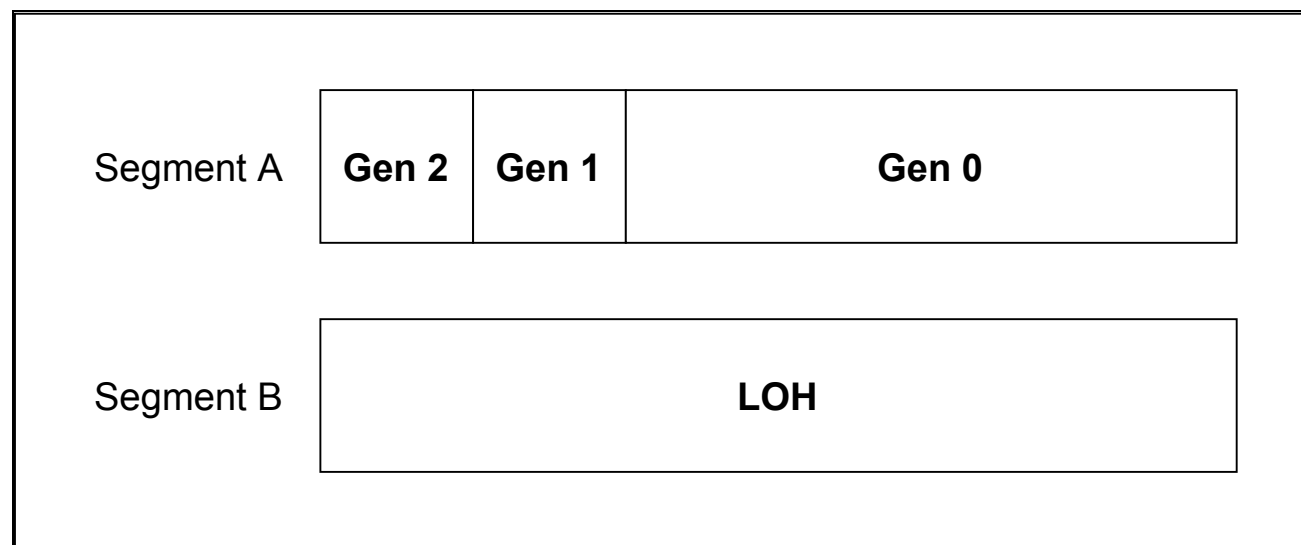
Once in Gen 2, objects stay here till they *die*.

Objects are *alive* as long as they are referenced by a **GC root**, e.g. static variables, managed threads or pinned handles.

Segments

Segments = Fixed sized parts of physical memory owned by SOH or LOH.

- LOH & Gen 2 can span multiple segments
- Gen 0 & Gen 1 always reside in the same segment



Allocation

The CLR tries to allocate new objects 3 times:

Fast Allocation

1. Try to allocate at the end of Gen 0

Slow Allocation (if Fast Allocation fails)

2. Try to allocate anywhere within Gen 0
3. Or try to expand Gen 0 and allocate at the new end

If expansion exceeds segment size a *Garbage Collection* is triggered!

Garbage Collection

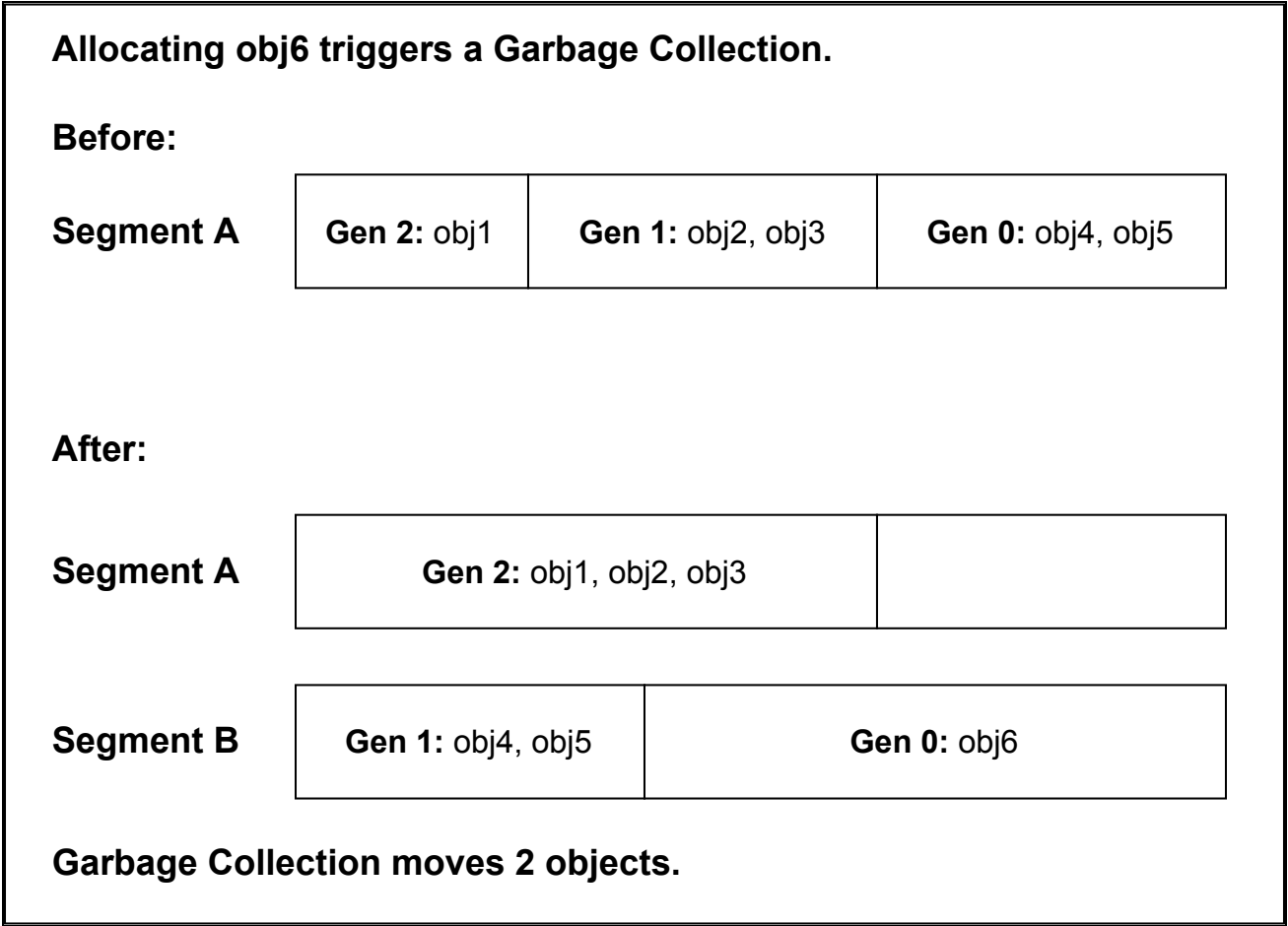
Garbage Collection consists of 4 phases:

1. **Suspension:** Suspend all managed threads
2. **Mark:** Mark all objects referenced by any GC root as *seen/alive*
3. **Compact:** Relocate and promote seen objects to reduce memory fragmentation
4. **Resume:** Resume all suspended threads

Garbage Collection happens only for the triggering generation and lower generations. Gen 2 collection also collects Gen 1 and Gen 0. Gen 1 collection also collects Gen 0.

All non-*seen* objects die of here!

Example



Example

- We try to allocate obj6 which triggers a garbage collection
- Fast Allocation fails and Gen 0 expansion exceeds segment size
- A Gen0 Garbage Collection is triggered:
 - Gen 1 objects are not moved and promoted to Gen 2 (see Gen 1 as cache for Gen 2)
 - Gen 0 objects are moved to a new segment and promoted to Gen 1
 - A new Gen 0 is reserved and obj6 is allocated there

Example

- **Gen 2 and Gen 1 are not garbage collected!**

Gen 2 and Gen 1 collections may not be triggered by allocations but due to other internal GC metrics and thresholds, e.g. available memory on a machine.

The Most Important Rule

■ [...] the garbage collector was explicitly designed with this idea in mind: **Collect objects in Gen 0 or not at all.** - Ben Watson, Writing High-Performance .NET Code

- Garbage Collections tend to get more expensive for higher generations
- Gen 1 objects need to be moved **physically** when SOH requires a new segment

Ideally, most objects die in Gen 0 and few live in Gen 2 for the lifetime of the application.

**Time spend in garbage collection
is time not spend in the rest of
the program!**