.NET GC Internals

Concurrent Mark phase

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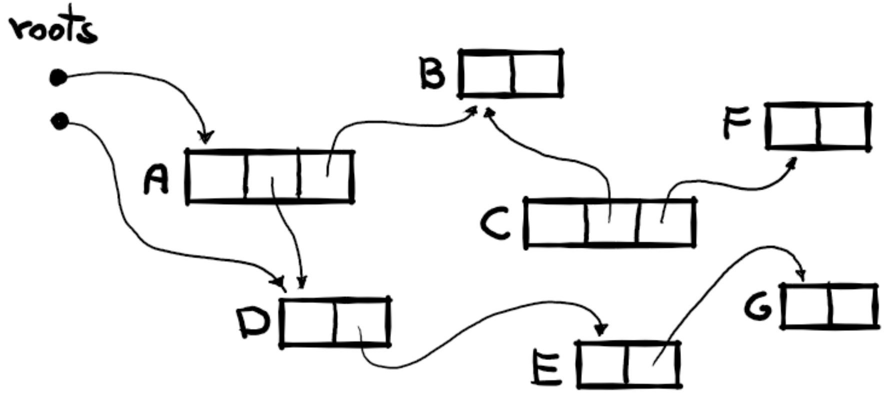
.NET GC Internals Agenda

- Introduction - roadmap and fundamentals, source code, ...
- **Mark** phase - roots, object graph traversal, *mark stack*, mark/pinned flag, *mark list*, ...
- **Concurrent Mark** phase - *mark array/mark word*, concurrent visiting, *floating garbage*, *write watch list*, ...
- **Plan** phase - *gap*, *plug*, *plug tree*, *brick table*, *pinned plug*, *pre/post plug*, ...
- **Sweep** phase - *free list threading*, concurrent sweep, ...
- **Compact** phase - *relocate* references, compact, ...
- **Generations** - physical organization, *card tables*, ...
- **Allocations** - *bump pointer allocator*, free list allocator, *allocation context*, ...
- **Roots internals** - stack roots, *GCInfo*, *partially/full interruptible methods*, statics, Thread-local Statics (TLS), ...
- **Q&A** - "but why can't I manually delete an object?", ...

Concurrent Mark phase



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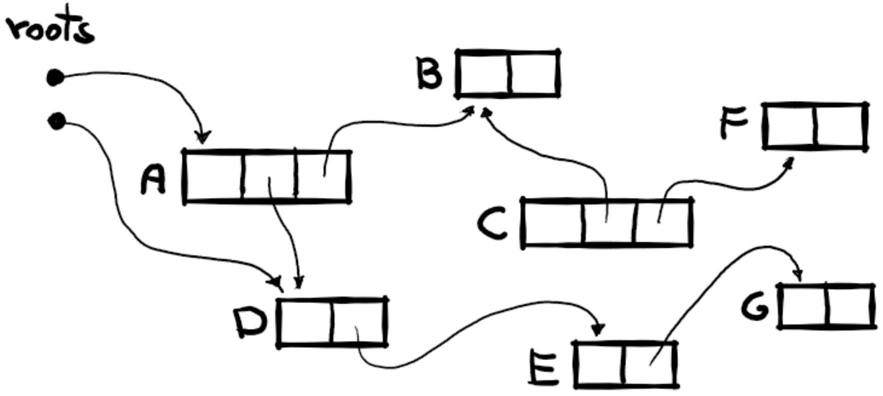

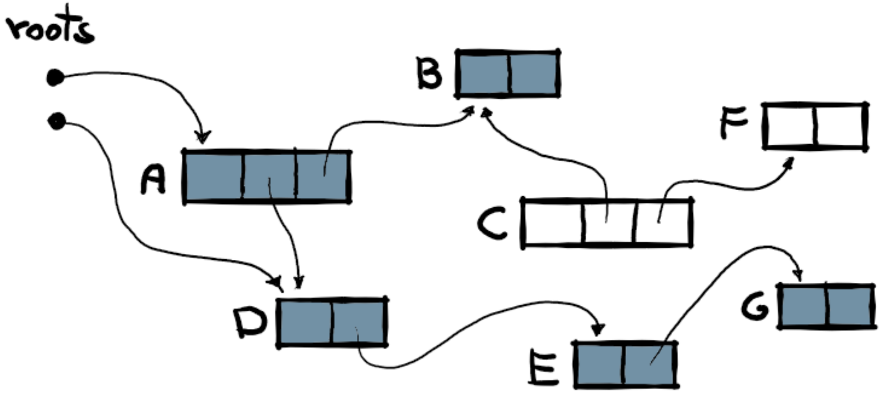

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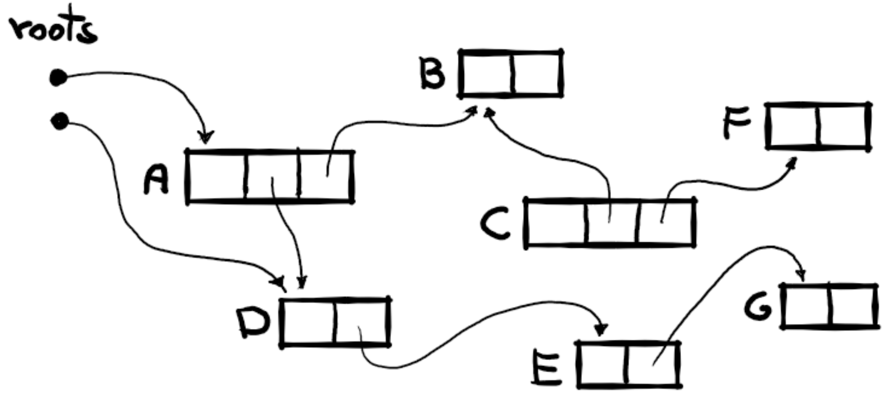

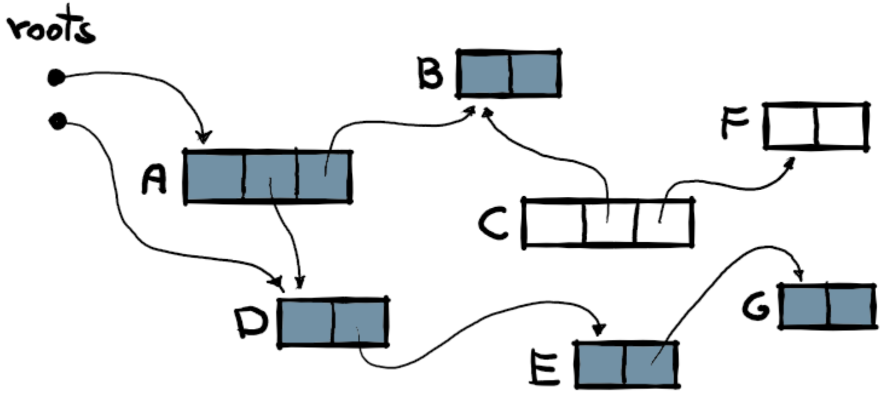

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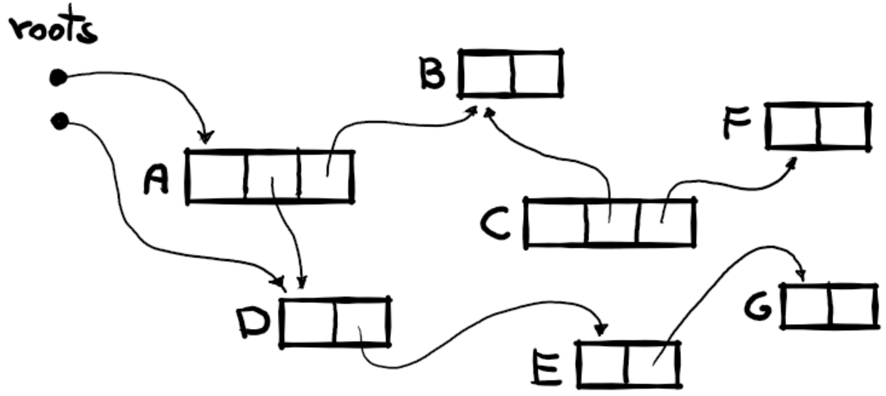

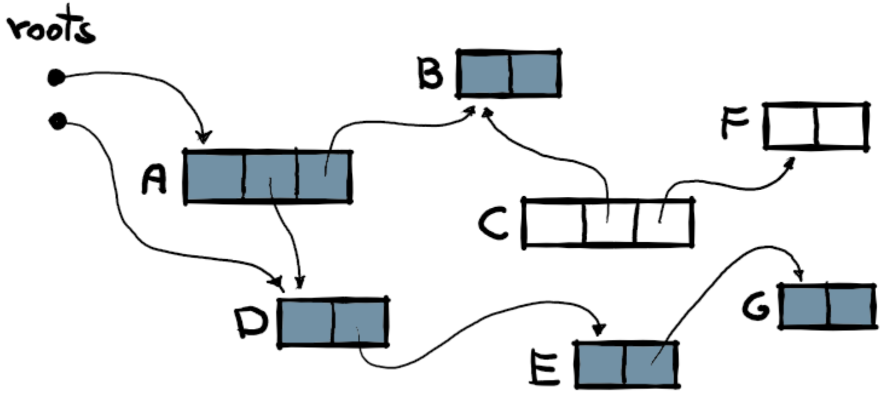

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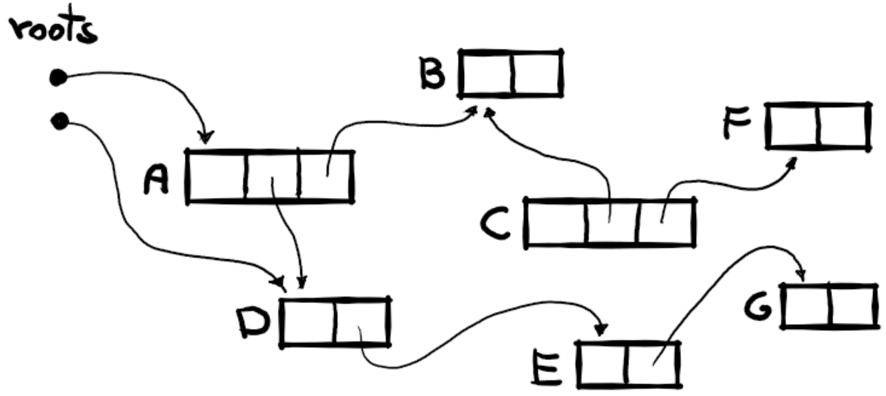

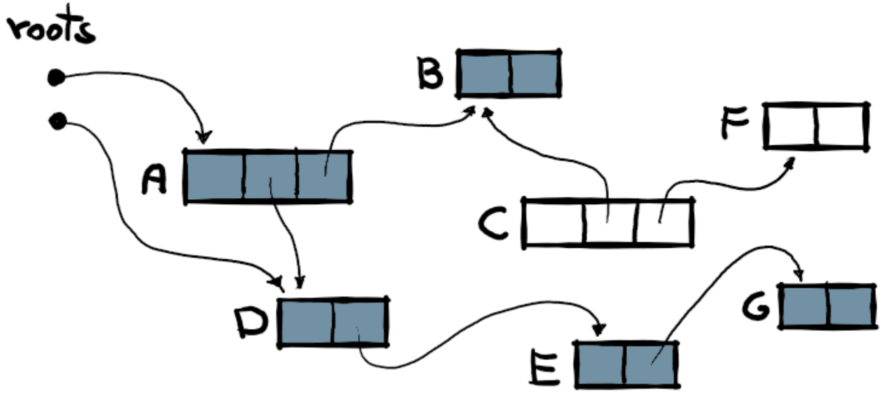

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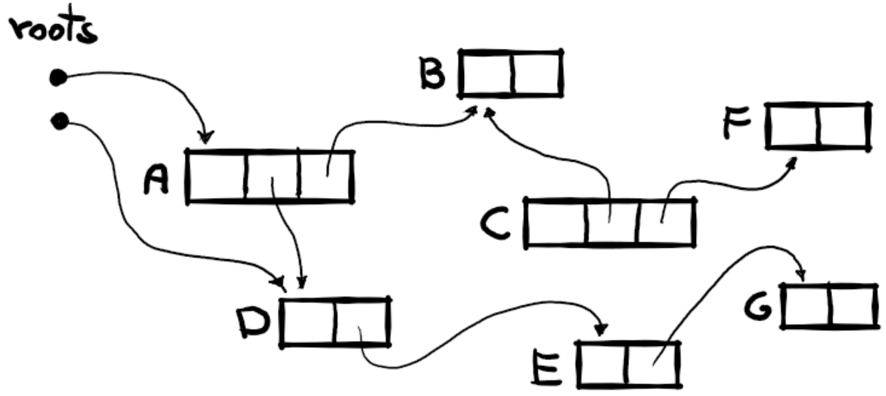

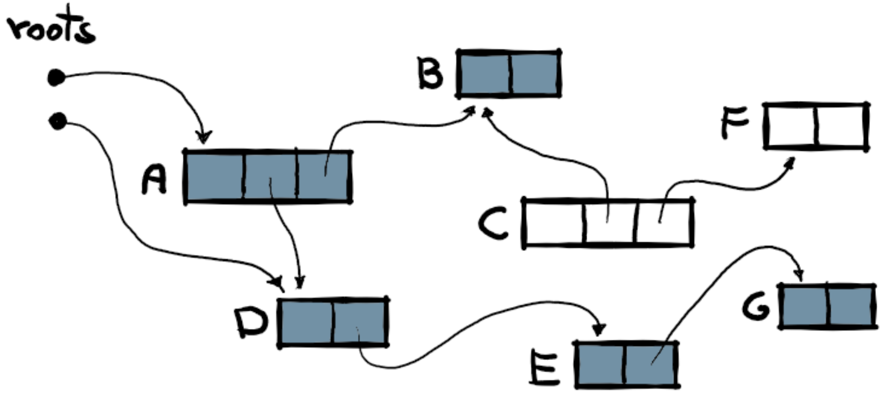

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  - #2 - how to get a consistent view while references are changing? - ups...

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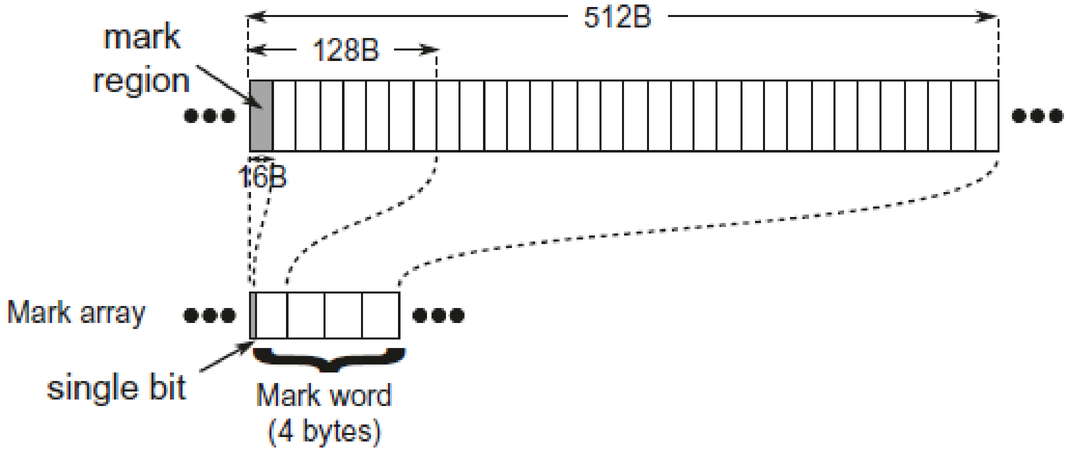

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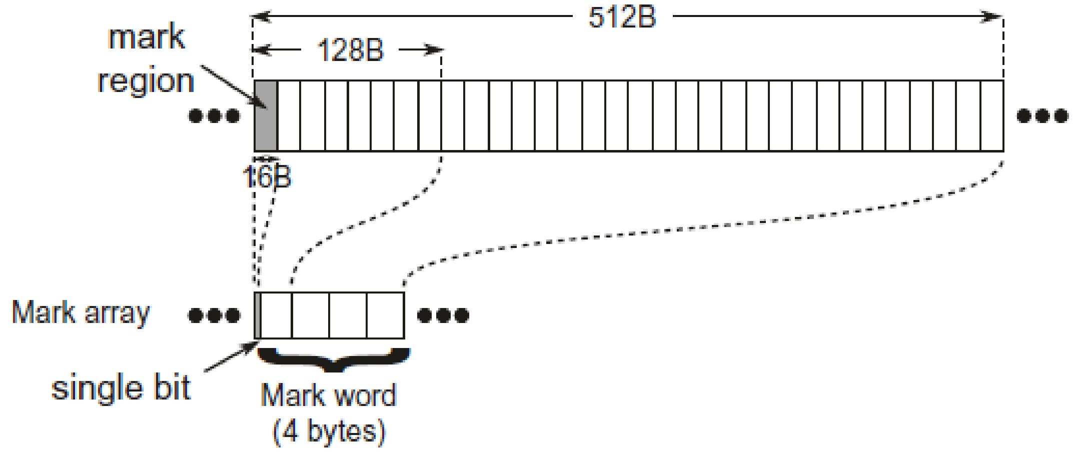

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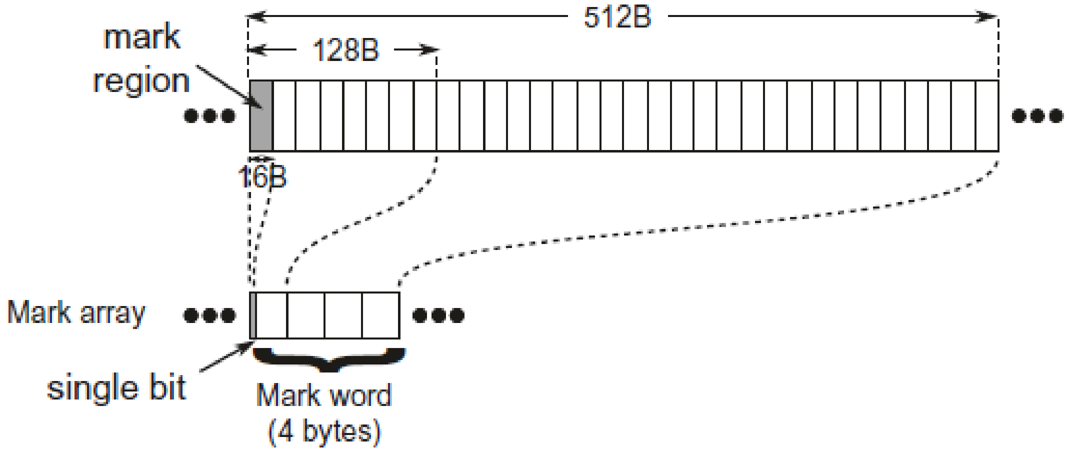

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- so, in case of 64-bit, we need 8MB of mark array per 1GB of data

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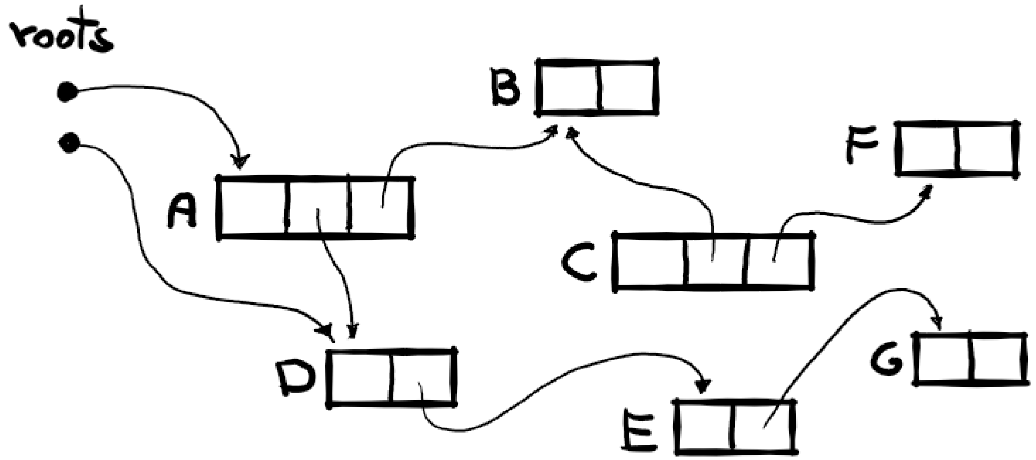
Using mark array during marking graph traversal:



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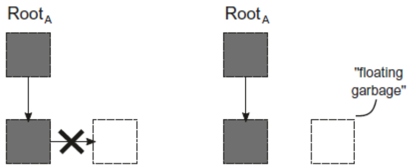

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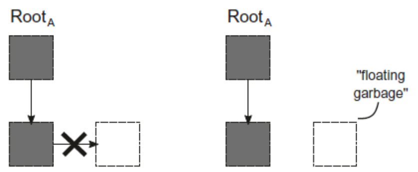

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  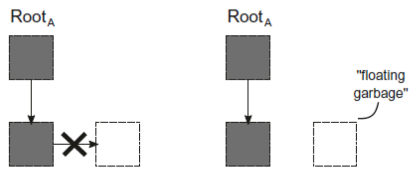

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  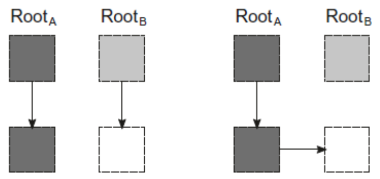

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  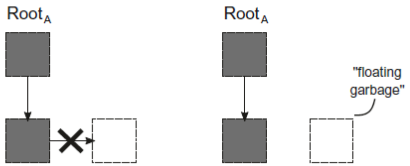

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  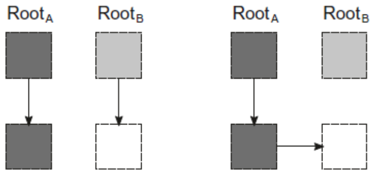

  well... this is **NOT fine**! *"The lost object"* problem - we will not visit it, and it will be GCed! 😲

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- so, yes - the more references modifications during Concurrent Mark, the bigger write watch list and then revisiting cost

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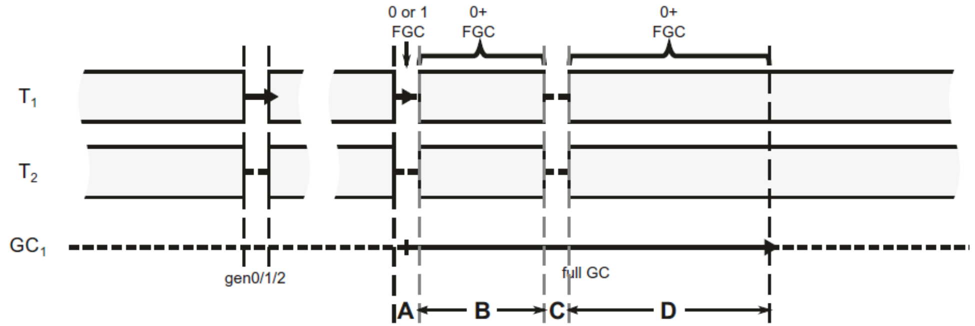

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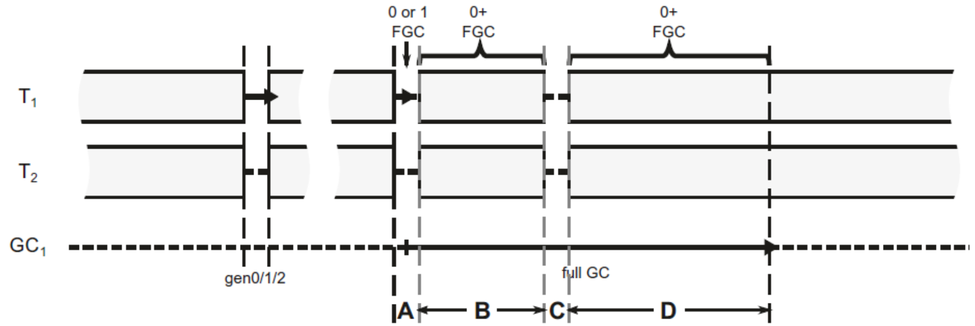

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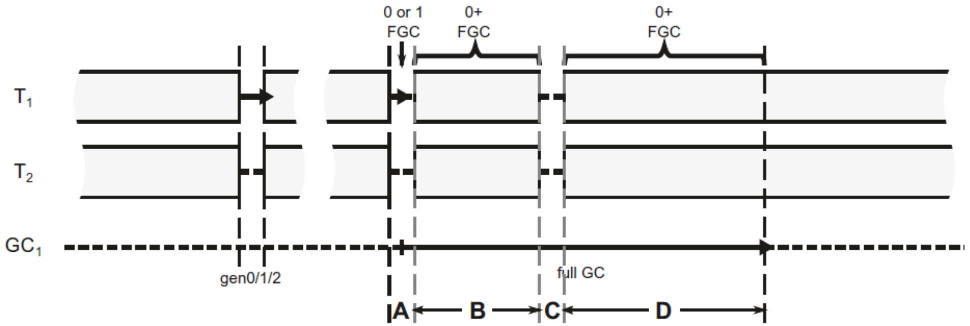

- `A` - initial "stop the world" phase - **initial work** list is being prepared from stack and finalization roots
- `B` - concurrent mark phase - the main work:
  - write barriers start to track modifications and store them in the **write watch list**
  - concurrent traversal happens - using "to visit list"
  - at the end, revisit objects from the write watch list

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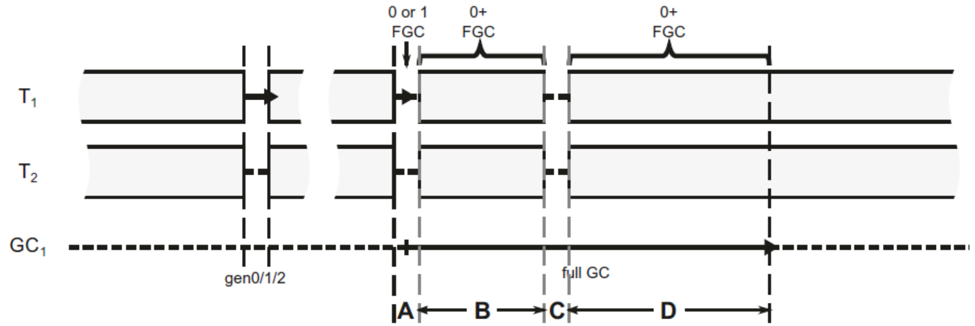

- `C` - final "stop the world" phase - to get "the final truth":
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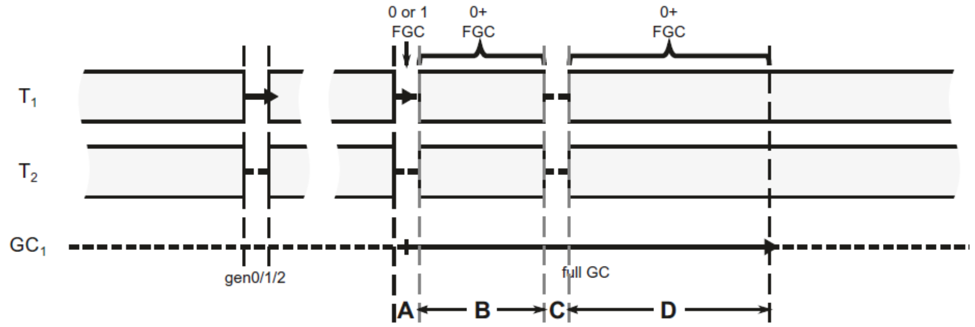

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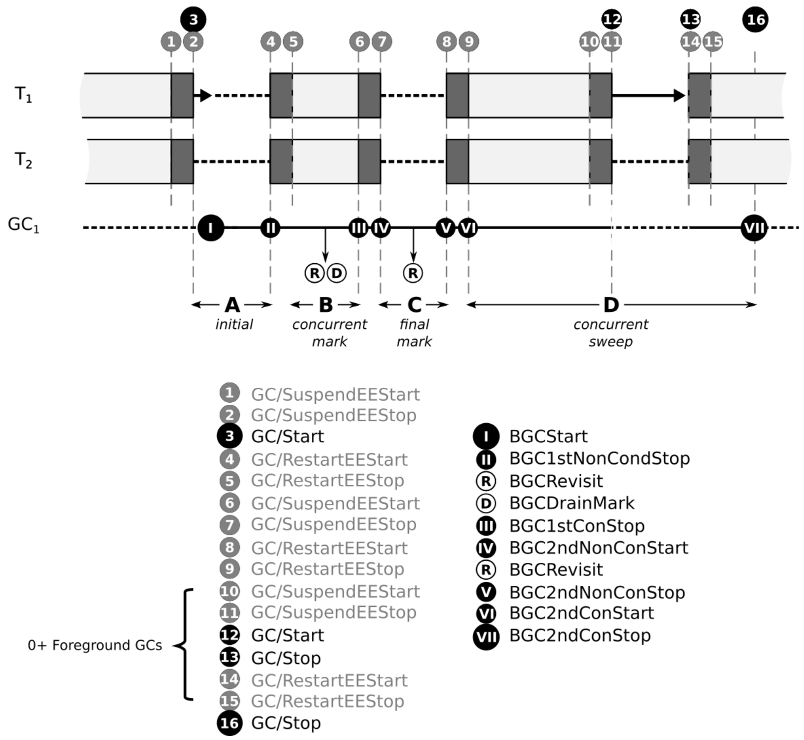
- `D` - "garbage collection"

Concurrent Mark - events



- **`BGCDrainMark`** - information about the number of objects in a "initial work list"
- **`BGCRevisit`** - how many pages were "dirty" and how many objects have been eventually marked because of that

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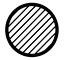
  - much more flexible - like it may have page-, large page-, "whatever-you-like"-granularity👍 However, it is still (current) page-size.

Concurrent Mark phase - inside code

In case of CoreCLR, the core code responsible for concurrent marking exists in `gc_heap::background_mark_phase` method. The three most important data structures are:

- `mark_array`, as we know it already,
- `background_mark_stack_array` for concurrent "to visit list" (aka "mark stack")
- `c_mark_list`, realizing "initial work list" populated at the initial phase

`c_mark_list` is populated with `gc_heap::background_promote_callback` method during stack and finalization queue scanning and then consumed by `gc_heap::background_drain_mark_list` method. This method calls `background_mark_object` [] for all objects in `c_mark_list` and fires a single `BGCDrainMark` event at the end (with the initial list size).

Concurrent Mark phase - inside code

As `FEATURE_USE_SOFTWARE_WRITE_WATCH_FOR_GC_HEAP` is defined, it enables the software write watch mechanism. You may see its usage in write barriers like `JIT_WriteBarrier_WriteWatch_PreGrow64`. The software write watch list is then consumed by `gc_heap::revisit_written_pages` method. It calls `revisit_written_page` (using the same `background_mark_object` [ ] on objects inside, one by one) on pages returned from `get_write_watch_for_gc_heap` method. At the end, a single `BGCRevisit` event is called with the "dirted" pages & marked objects counts.

`get_write_watch_for_gc_heap` uses 4kB-wide ("page") granularity and is tracked per byte of the table (to avoid multithreading issues) - see the `AddressToTableByteIndexShift` in `softwarewritewatch.h`.

Historically, the write watch list in case of Windows managed by the system itself and is consumed in the GC within `gc_heap::revisit_written_pages` method by calling `GCToOSInterface::GetWriteWatch`.

Concurrent Mark phase - inside code

All "regular" concurrent marking is done with the help of **`gc_heap::background_promote(obj,...)`** method that through **`background_mark_simple(obj)`** and **`background_mark_simple1(obj)`** (the one utilizing/consuming **`background_mark_stack_array`**) traverses the object's graph (marking corresponding bits in **`mark_array`** inside **`background_mark1(obj,...)`** method).