How we measure and optimize for RAIL in V8's GC

mlippautz@, ulan@

BlinkOn 6, Munich

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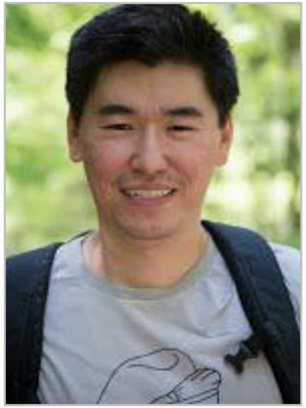
Who We Are - V8 GC Team Munich

Hannes
Payer

Jochen
Eisinger

Marcel
Hlopko

Michael
Lippautz



Ulan
Degenbaev

V8 GC and RAIL

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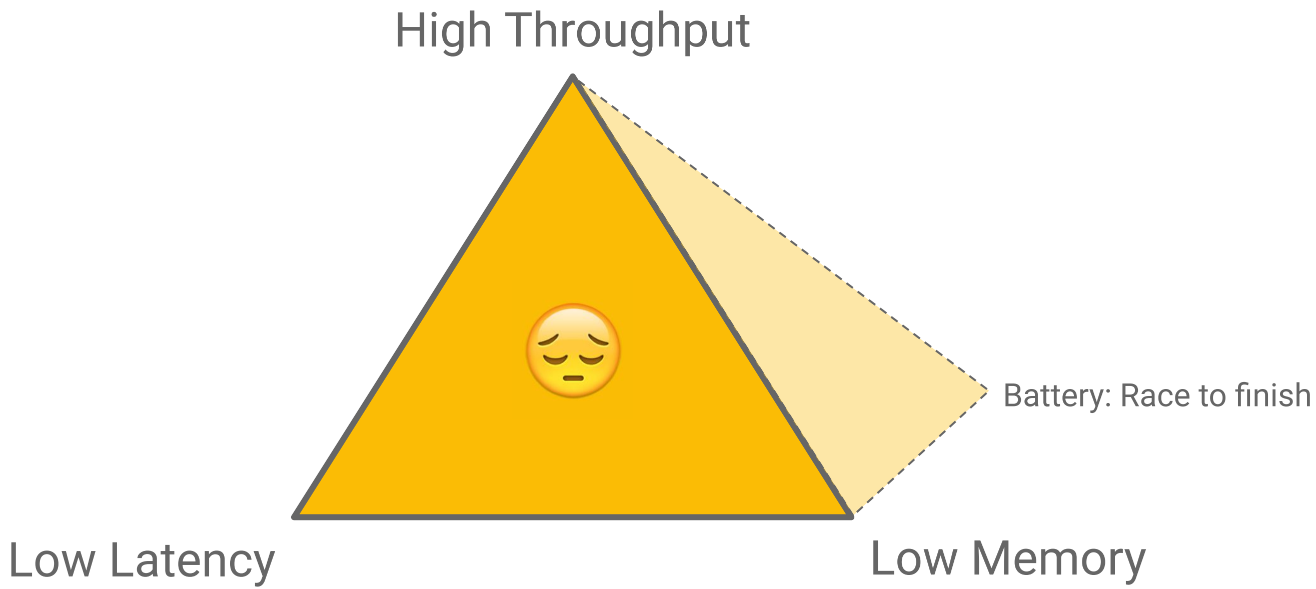
The Impossible Garbage Collection Triad



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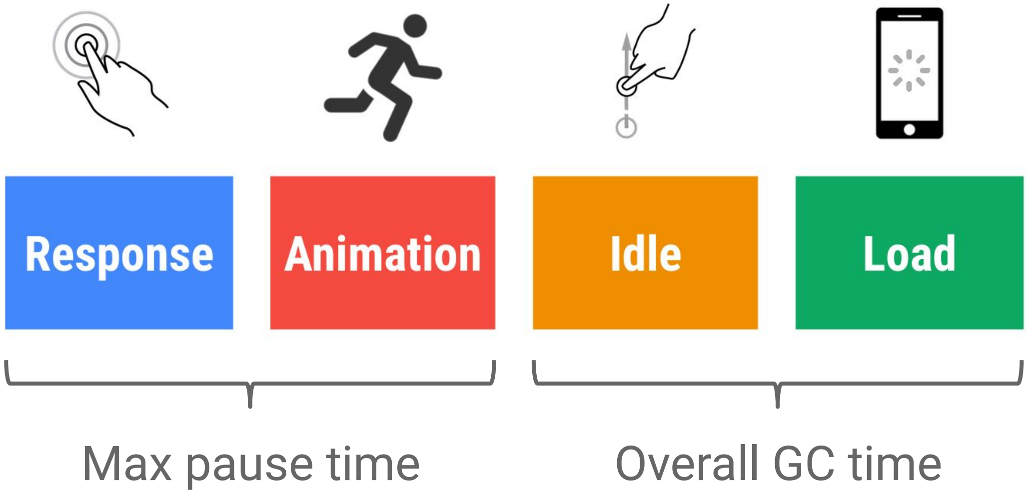
RAIL and GC Metrics

- Ideally: No GC… ever
- In practice: Prioritize

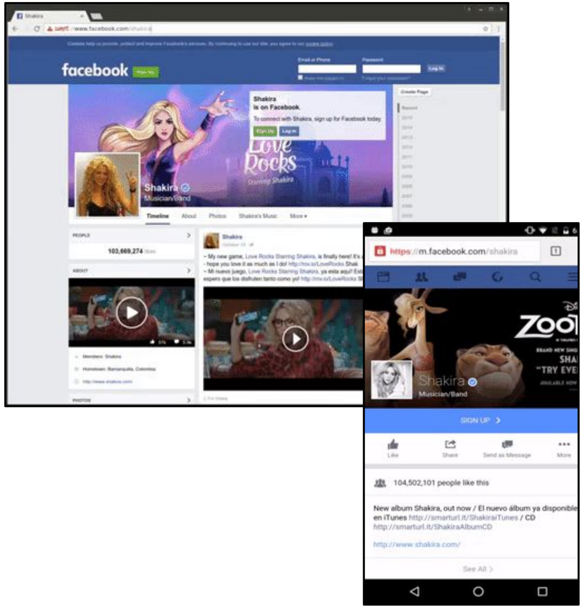


Fine print

Without consuming too much memory 😊

Real World Benchmarking

- Catapult (Telemetry)
- Record/replay for real-world websites
- Mobile and desktop



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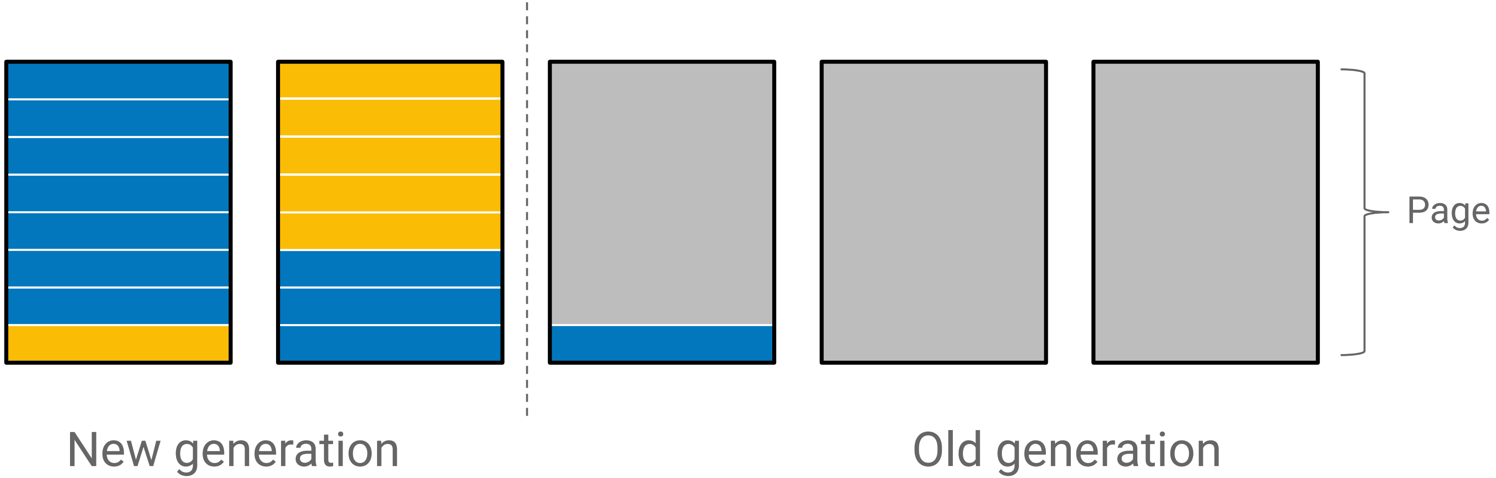
V8's Generational Garbage Collector

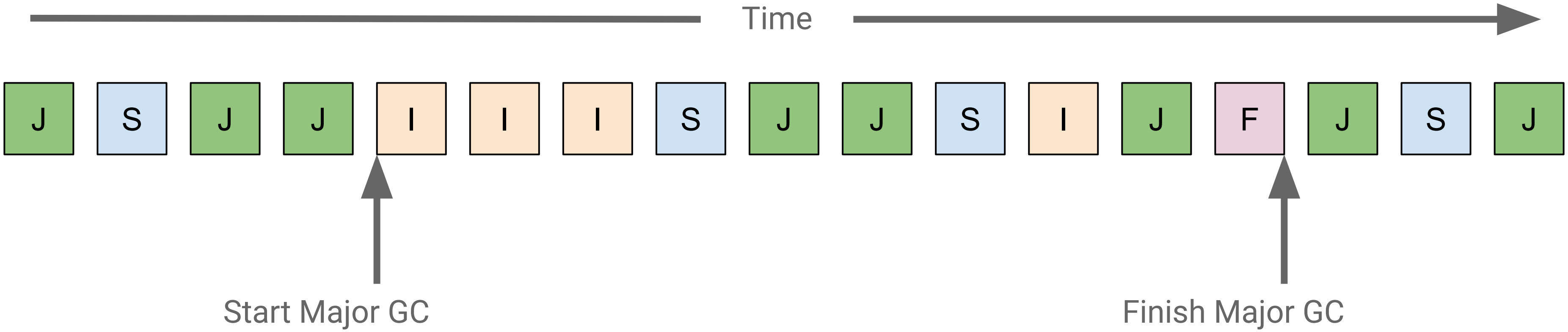
Generational hypothesis: "Most objects die shortly after their allocation"

- New generation: Semi-space Scavenger (Cheney)
- Old generation: Mark-Compact (and Sweep)



GC Events

- **J** JavaScript code
- **S** Minor GC: Scavenger (~0-10 ms)
- **I** Major GC: Incremental Marking (~0.01-*CONFIGURABLE* ms)
- **F** Major GC: Final Mark-Compact Collection (~4-20 ms)



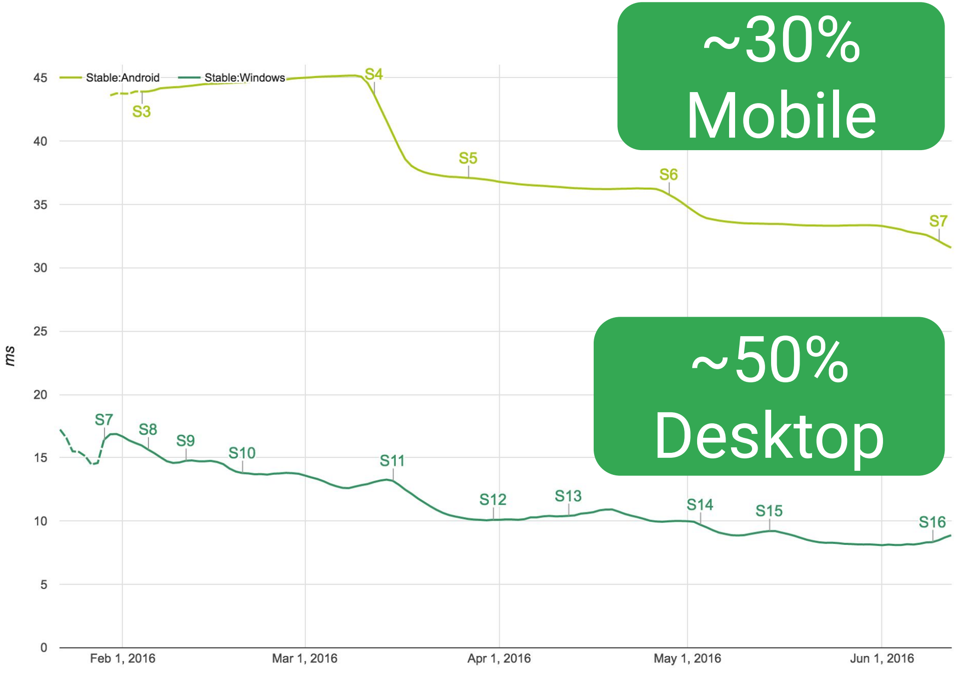
V8 GC Update

Focusing on A

Orinoco

Mostly parallel and concurrent GC
without strict generational boundaries
to
reduce jank and memory consumption
while providing high throughput

... landing incrementally



UMA: Major GC final pause **F** (50 %-ile)

Evacuation

- *Copy* objects within semi space of new generation
- *Move* objects from new to old generation
- *Copy* objects within the old generation
- Re-*write* remembered set pointers

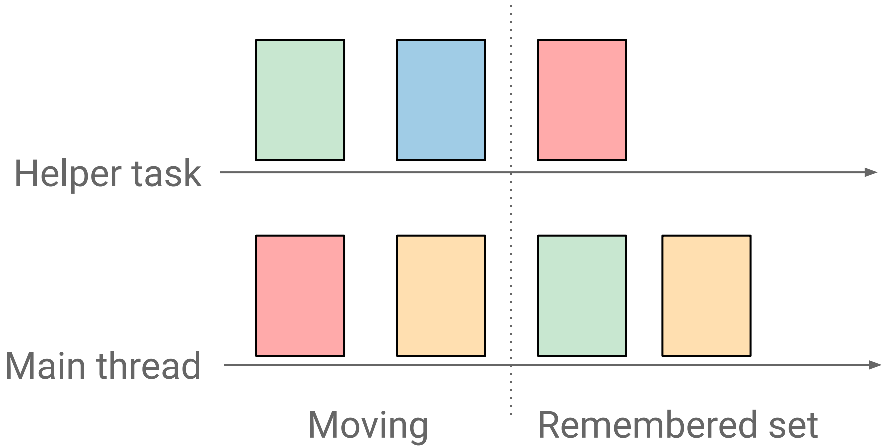
Writing memory is expensive

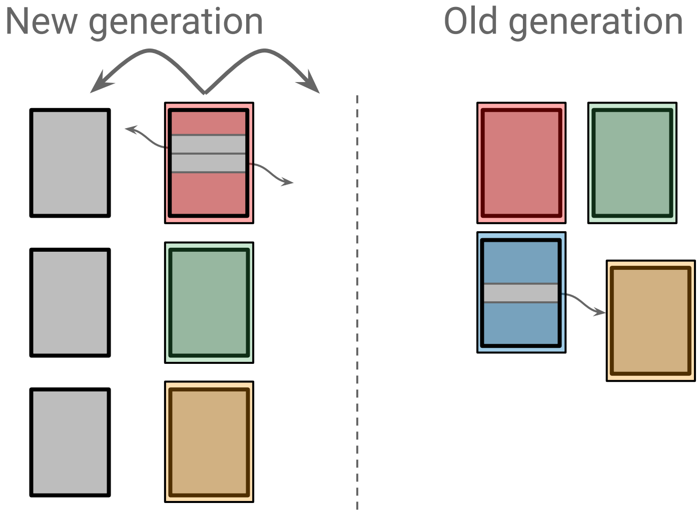
Orinoco

Design GC to utilize available resources

Parallel Evacuation during Major GC

- Lock-step
  - Parallelize moving of memory based on pages
  - Parallelize processing remembered set pointers





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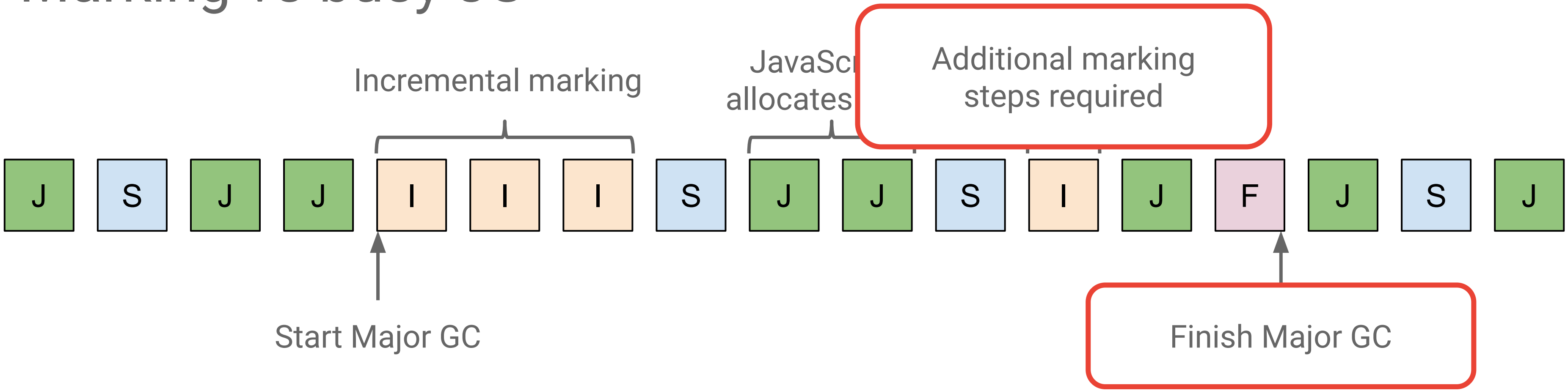
Marking vs busy JS



Live heap gets bigger

More marking steps, longer finalization pause

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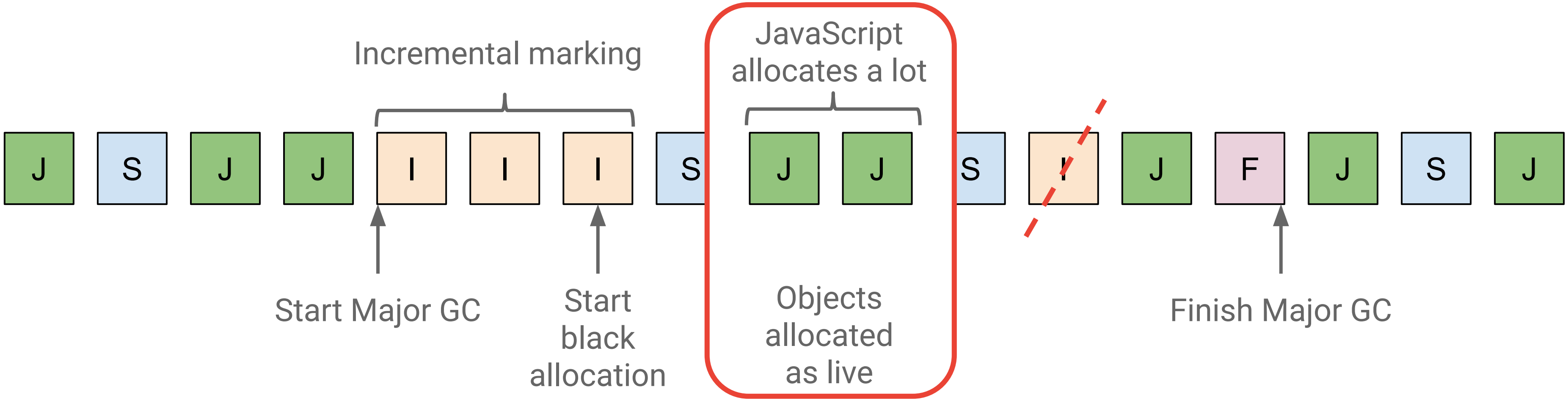
🤘 Black Allocation

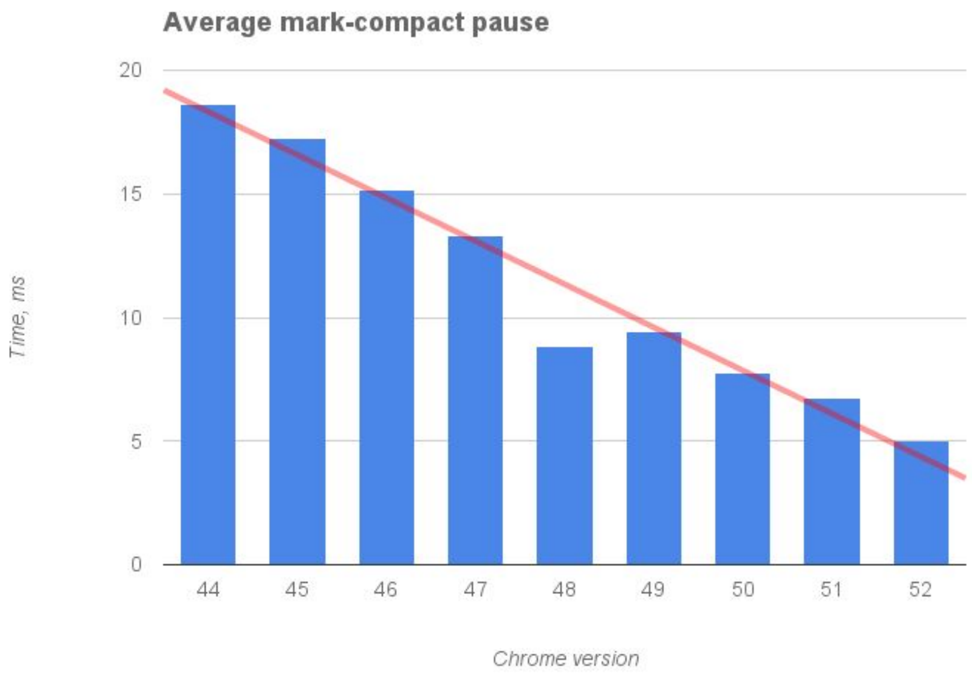


Assumption: Objects allocated during marking will survive the following GC

Objects are allocated as live (already marked)

Some Results: Facebook during A

Some Results: Facebook during A



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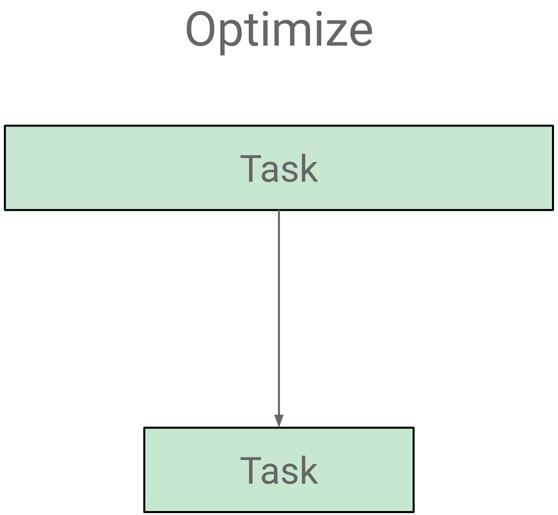
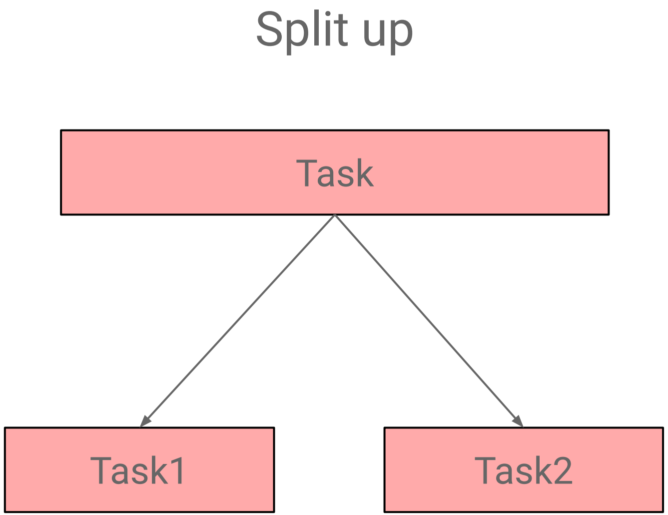
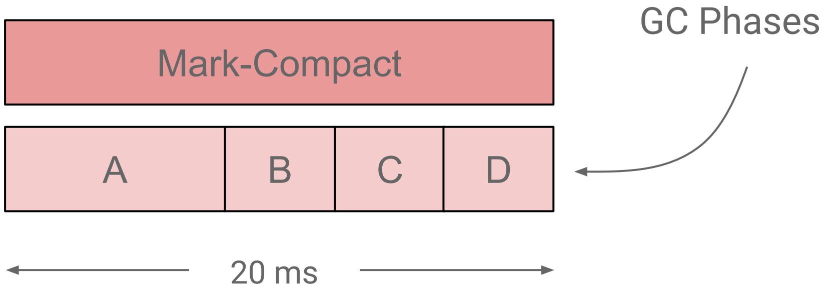
Reflection and Future

Two ways to reduce latency





Making GC more incremental



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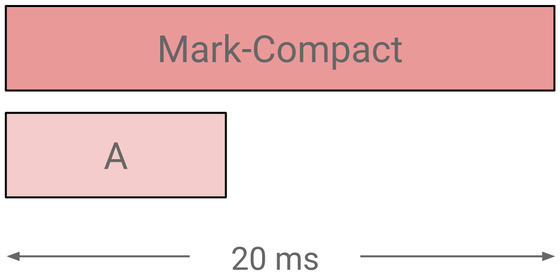
Making GC more incremental

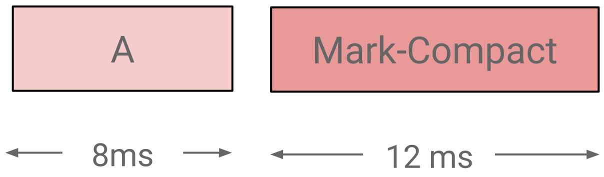
Before:

max-pause = 20ms



After:

max-pause = 12ms



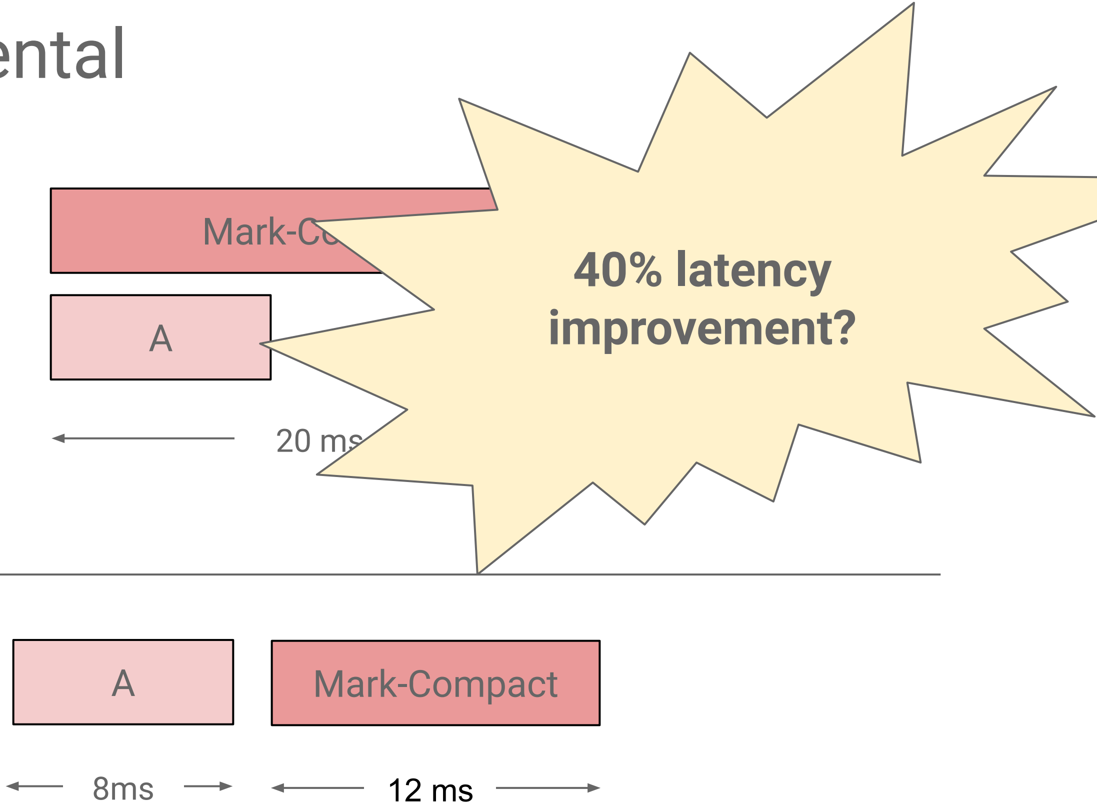
Making GC more incremental

Before:

max-pause = 20ms

After:

max-pause = 12ms



Making GC more incremental

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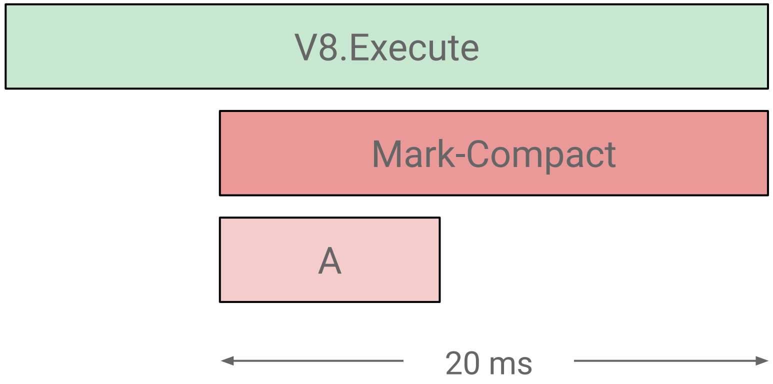
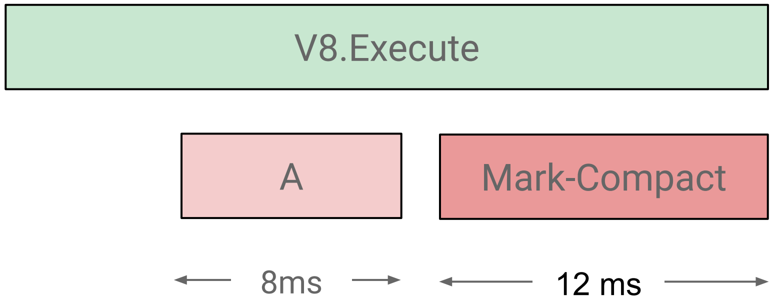


After:

max-pause = 12ms



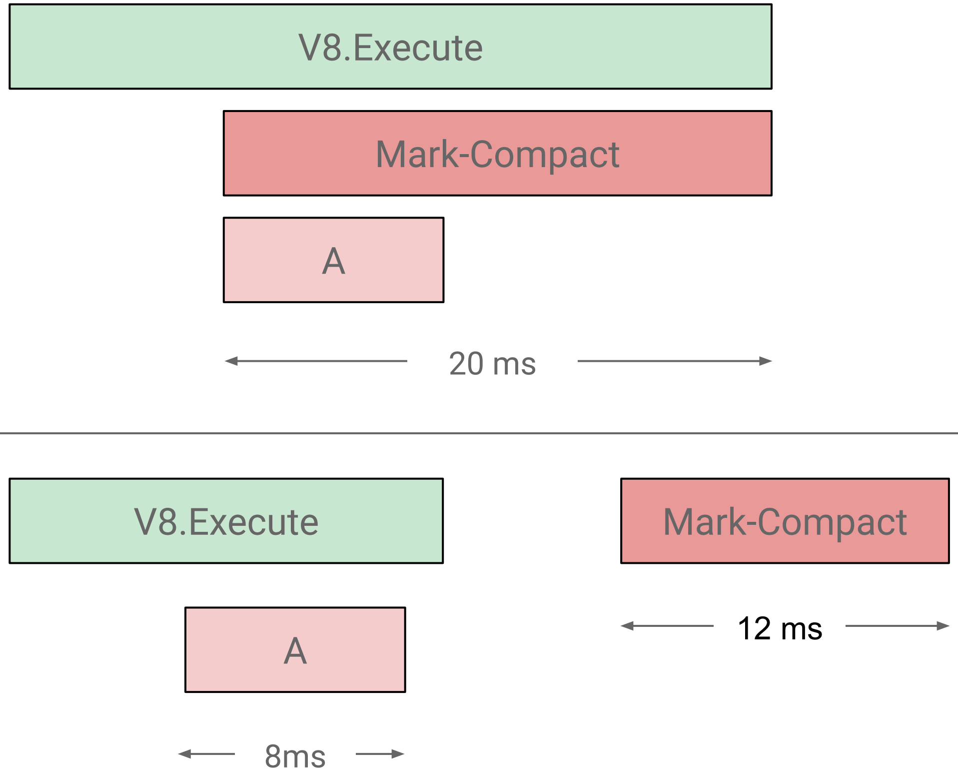
Making GC more incremental

Before:

max-pause = 20ms

After:

max-pause = 12ms



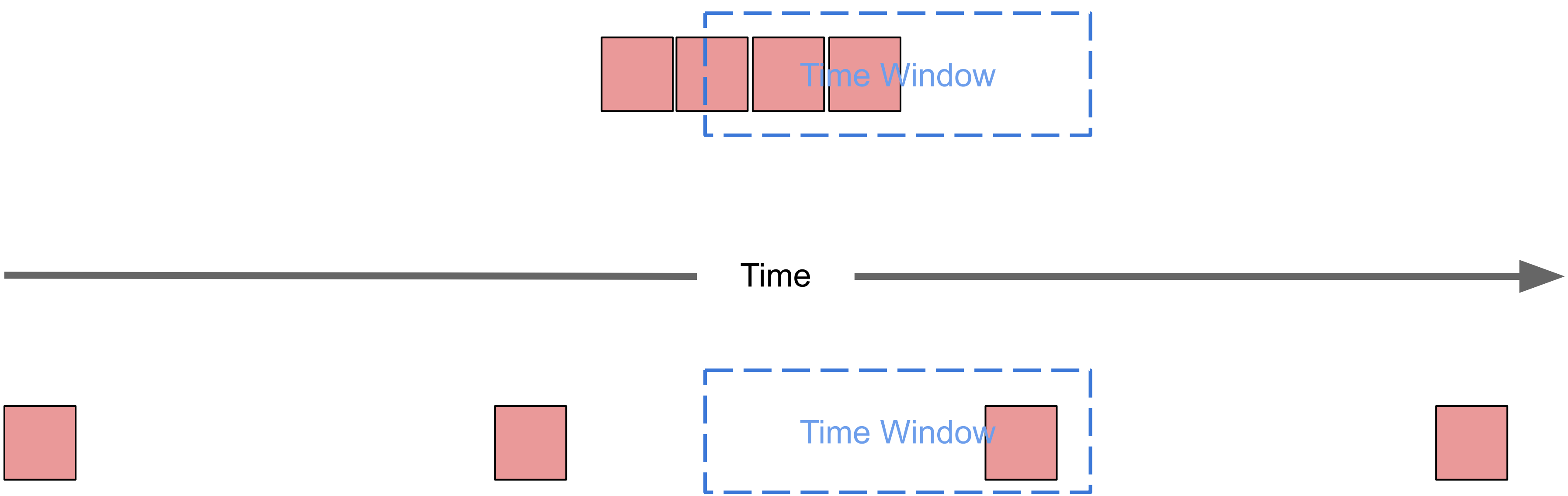
User facing metrics from PWM and system health

- Response: response latency
  - minimize GC work in critical time window
- Animation: animation latency
  - minimize GC work in critical time window
- Idle: responsiveness risk a.k.a responsiveness hazard
  - minimize GC work in tasks longer than 50ms
- Load: time until load finishes
  - minimize GC work during page load

Overfitting: delay GC in RAL, post many 49ms tasks in I

Simpler model: consider only RA, critical time window position is arbitrary

Uniform incremental steps



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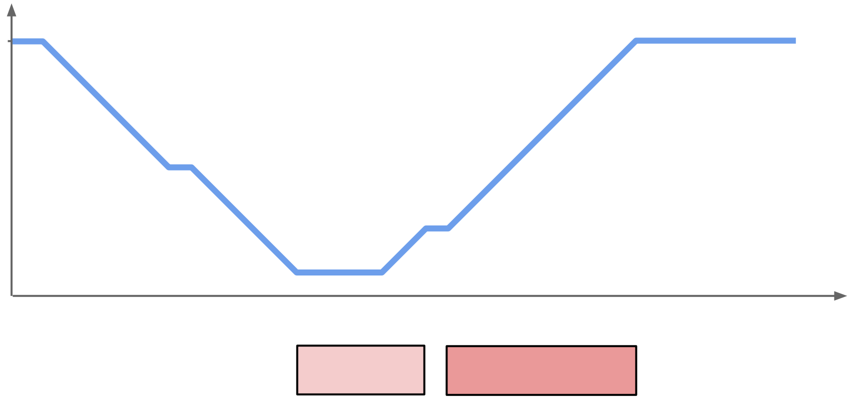
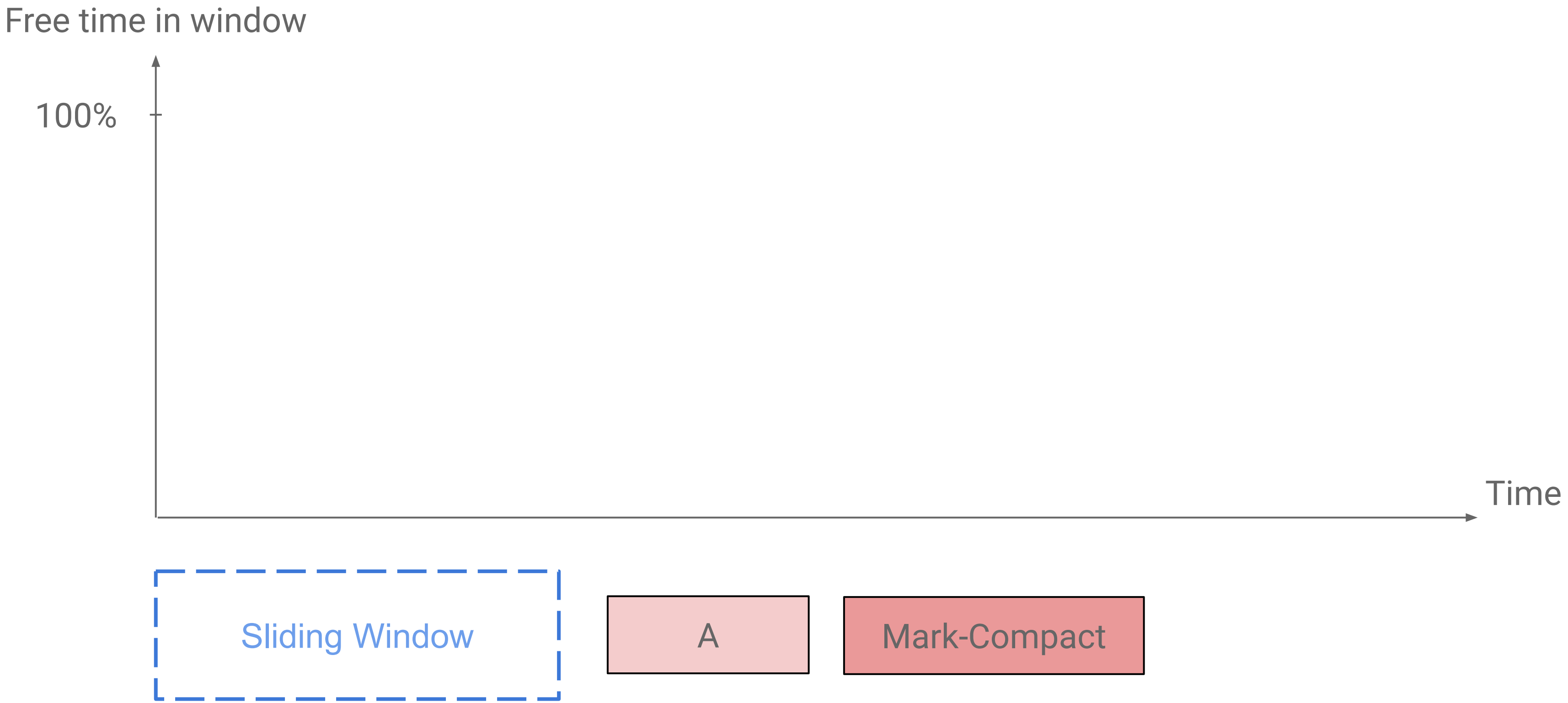
Mutator Utilization

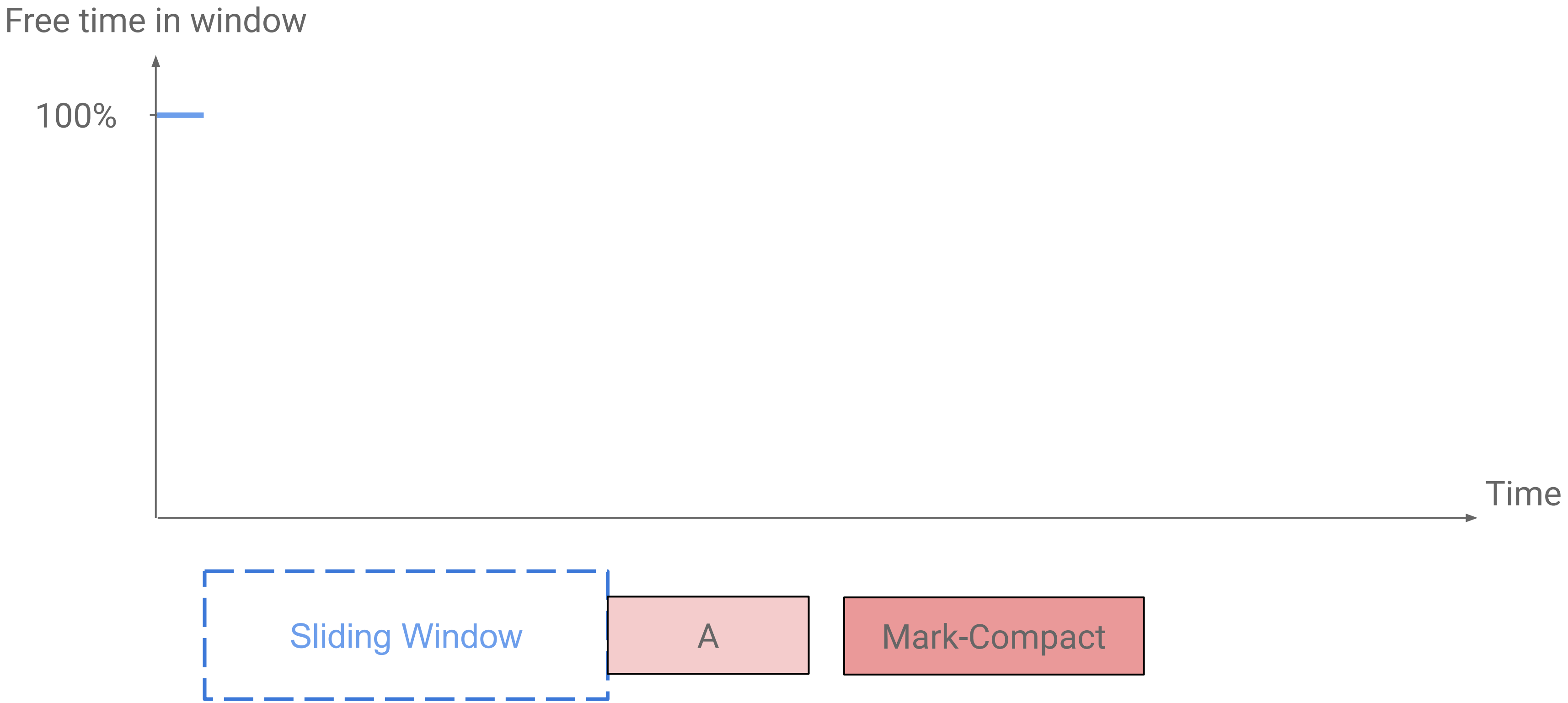


- Introduced by Cheng and Blelloch in 2001 for real-time GC.
- Called ***mutator utilization*** - application *mutates* reachability graph from GC POV
- Can be generalized to other tasks in Chrome

Utilization function



Utilization function



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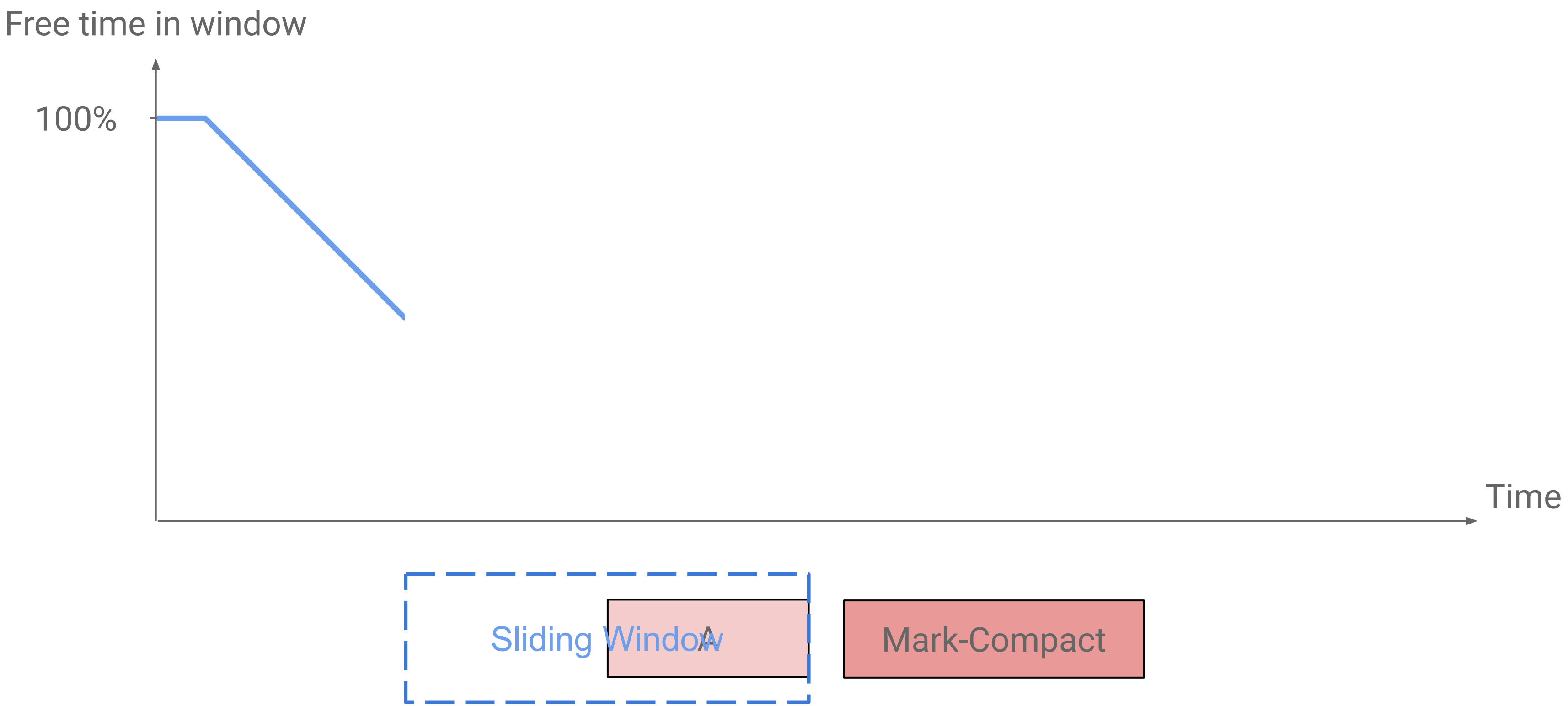
Utilization function



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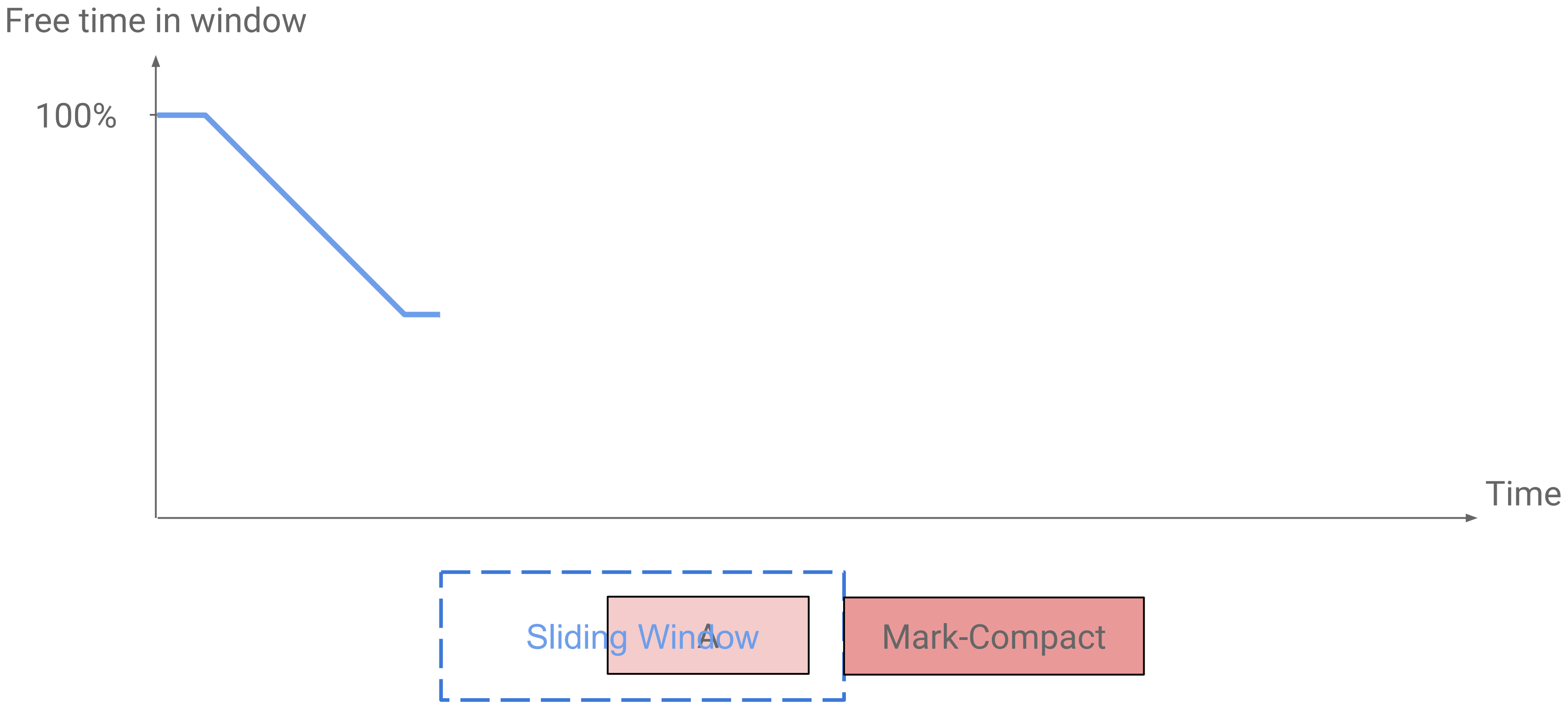
Utilization function



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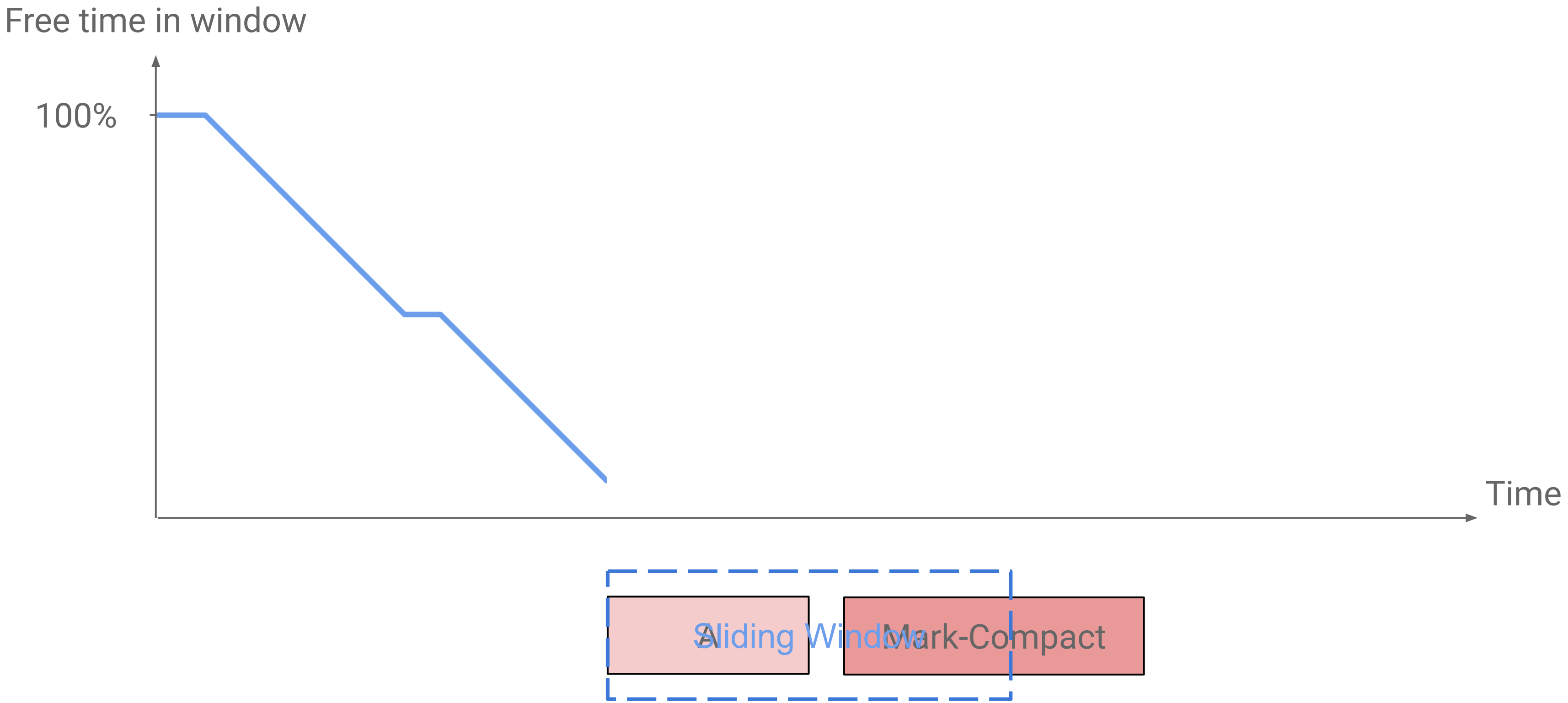
Utilization function



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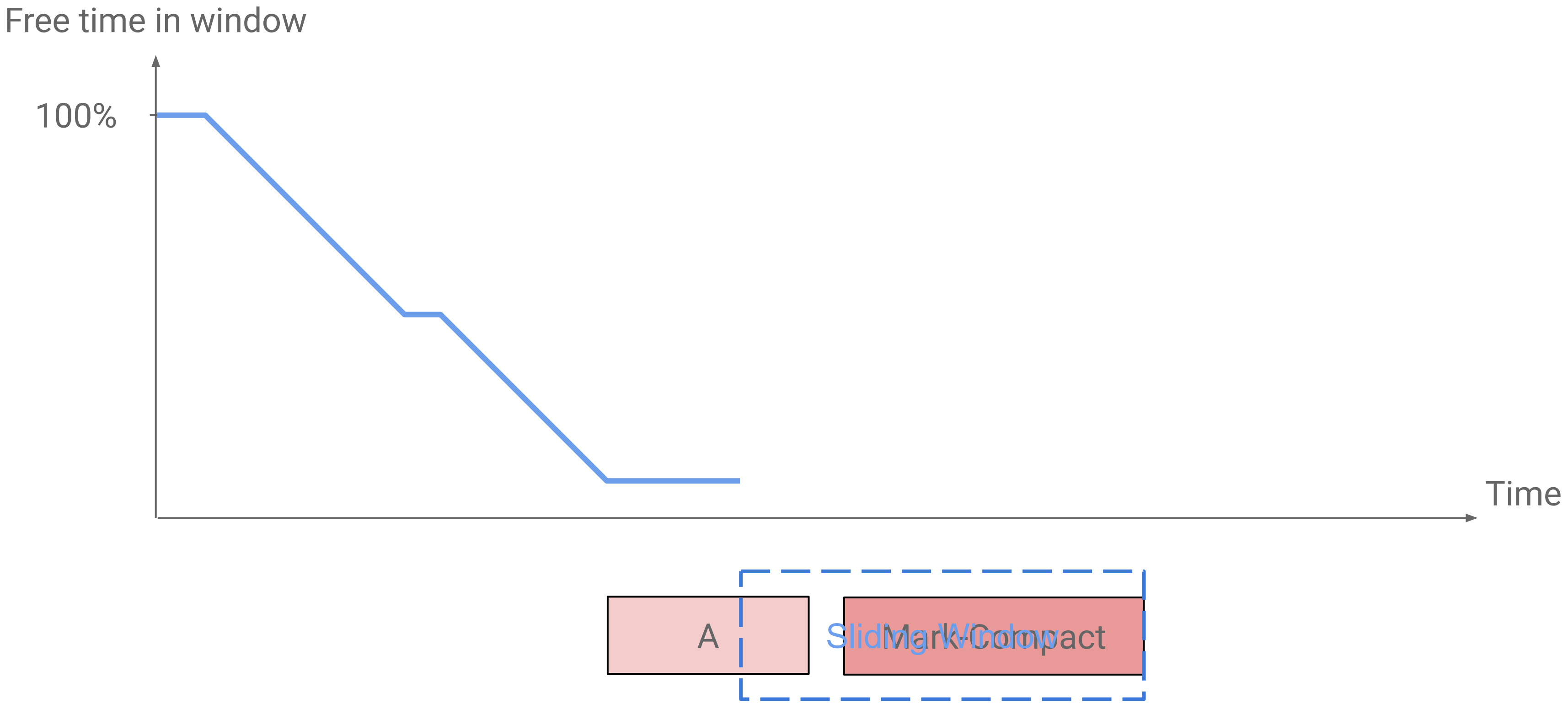
Utilization function



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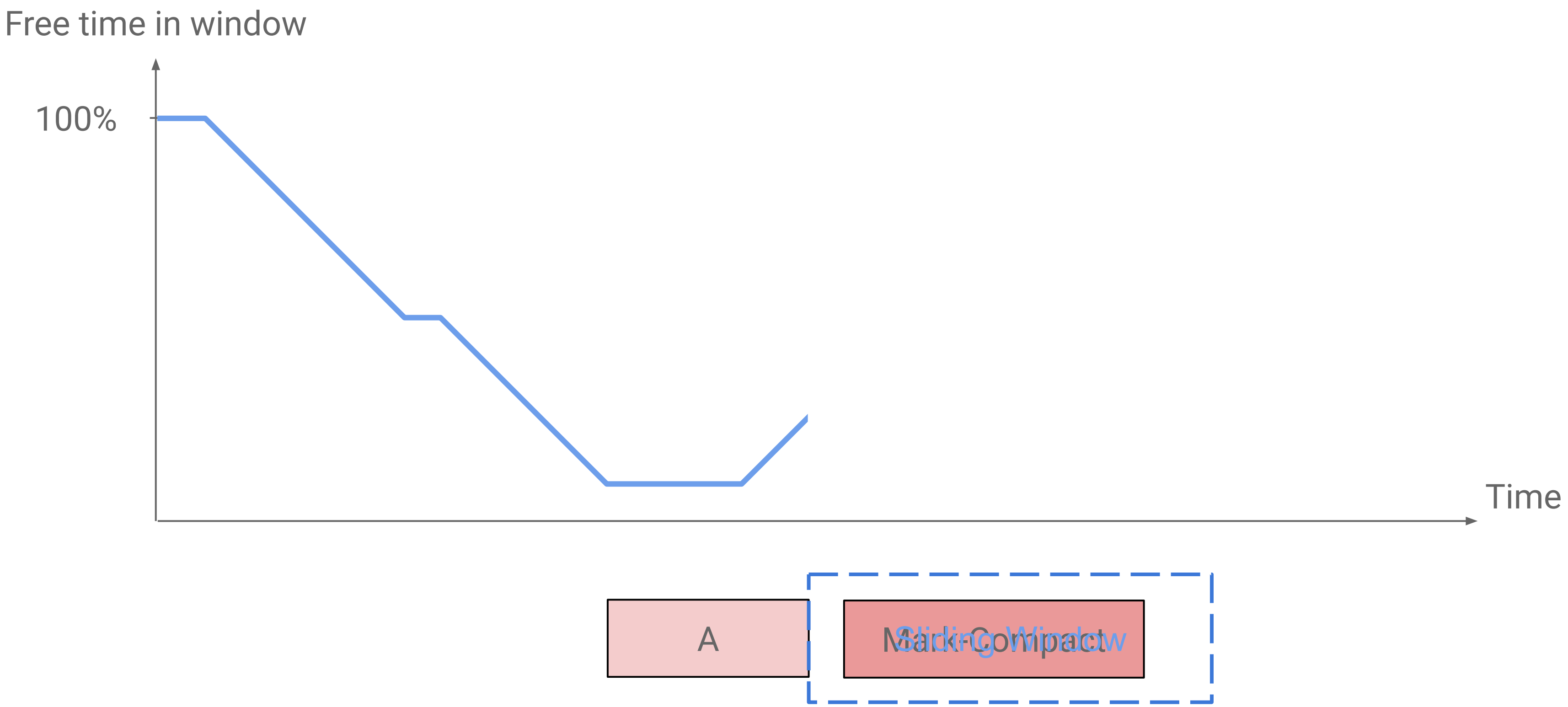

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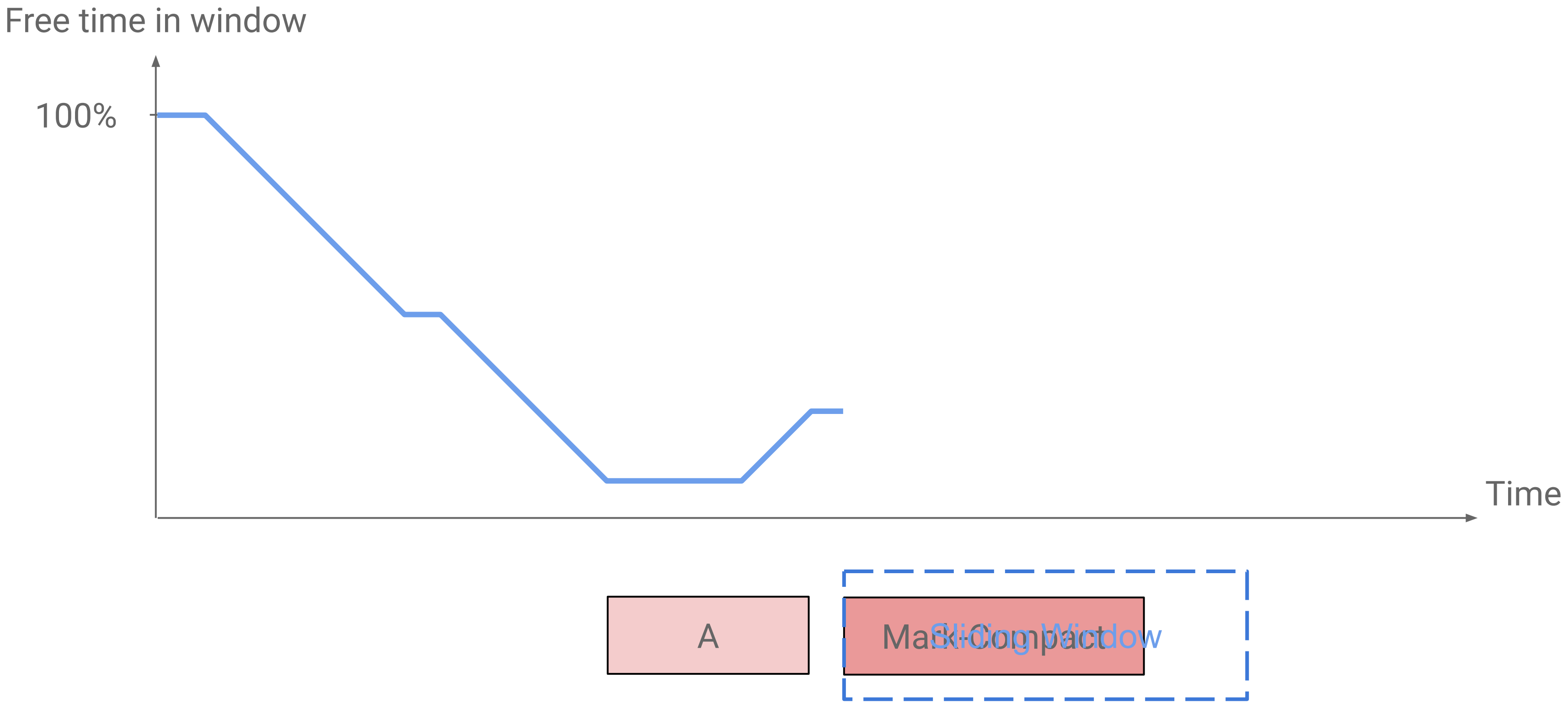

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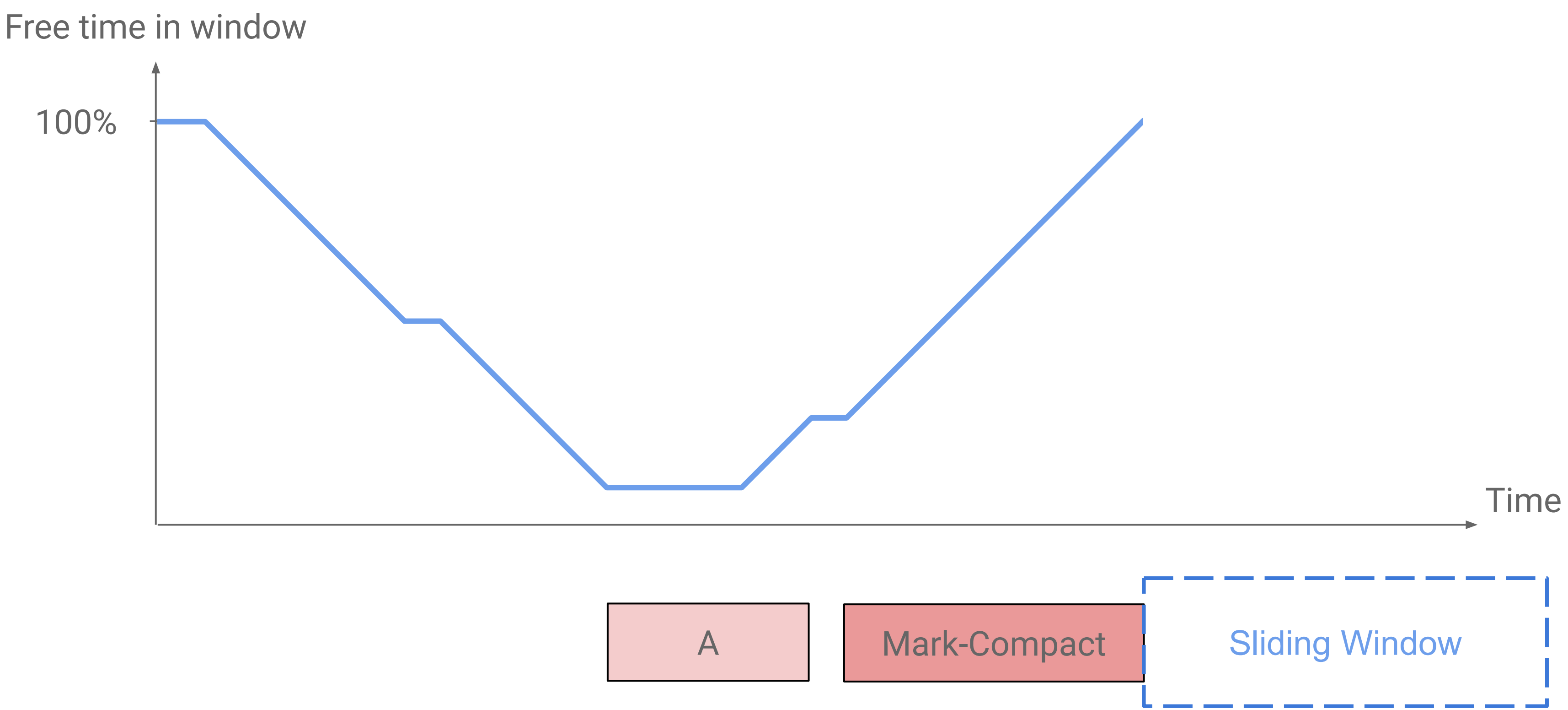

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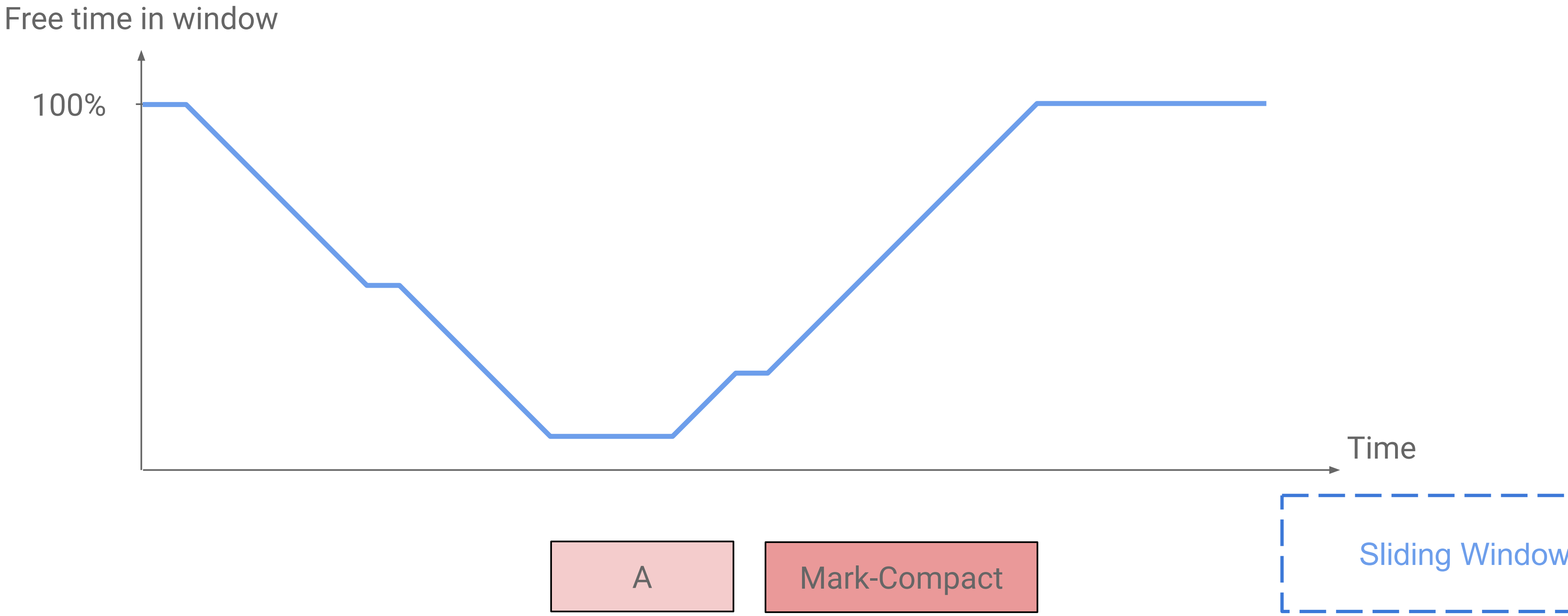
Utilization function



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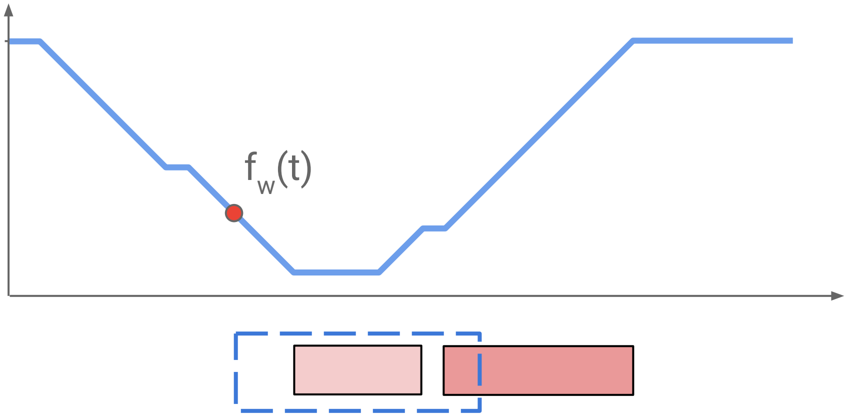
Interpretations



- $f_w(t)$ = fraction of time GC leaves to application in the time window [t, t+w).
- $f_w(t)$ = probability that a high priority task arriving at any moment in [t, t+w) is not queued

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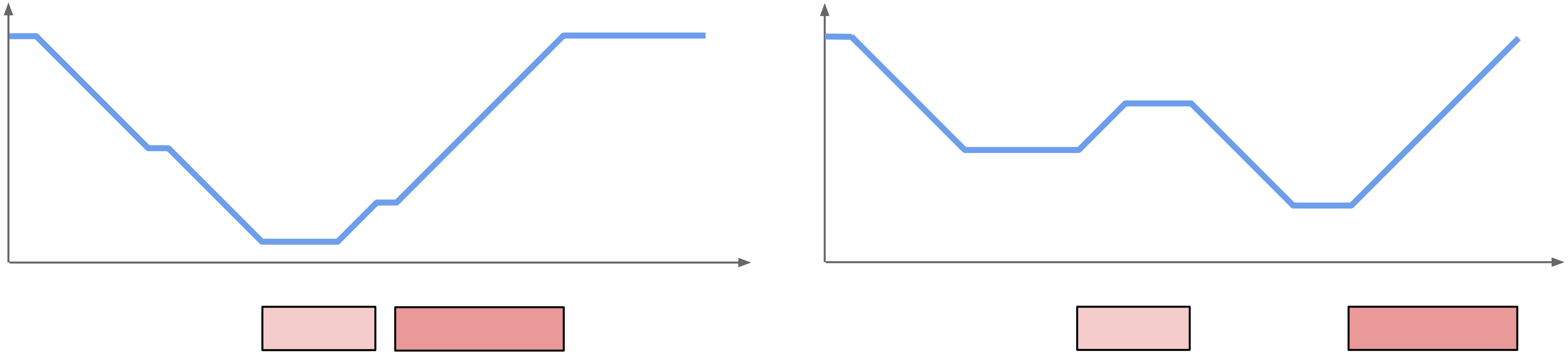
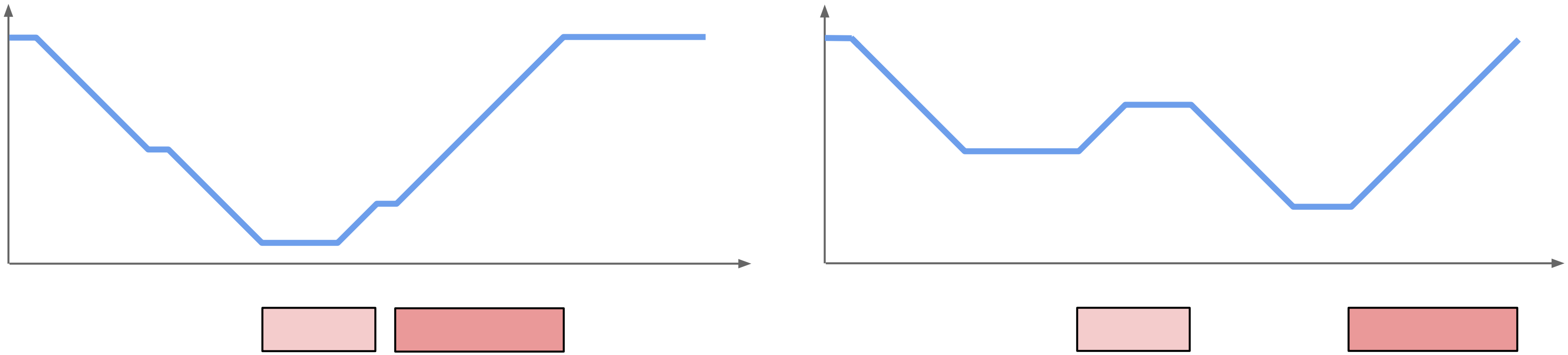
Utilization function

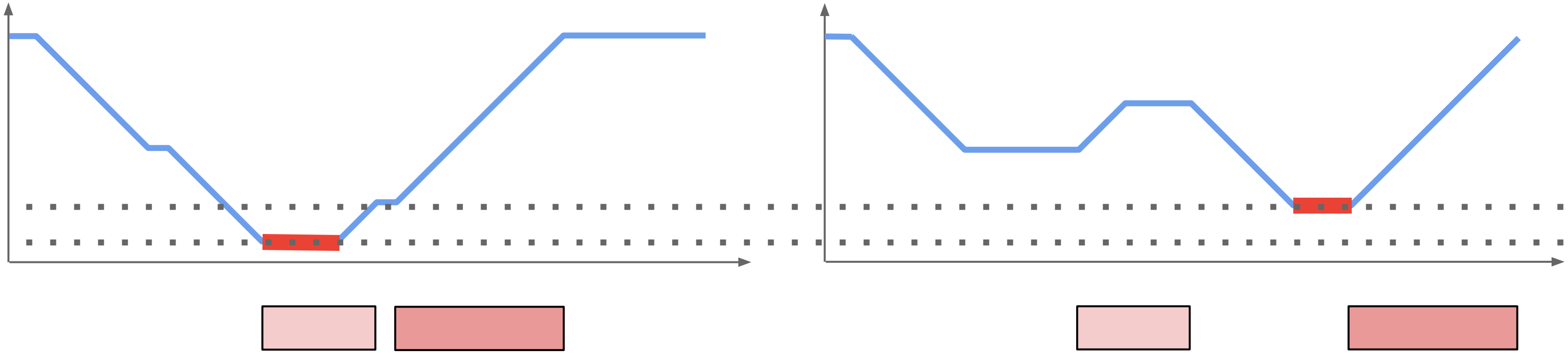


Utilization function



How to compare?

Minimum mutator utilization



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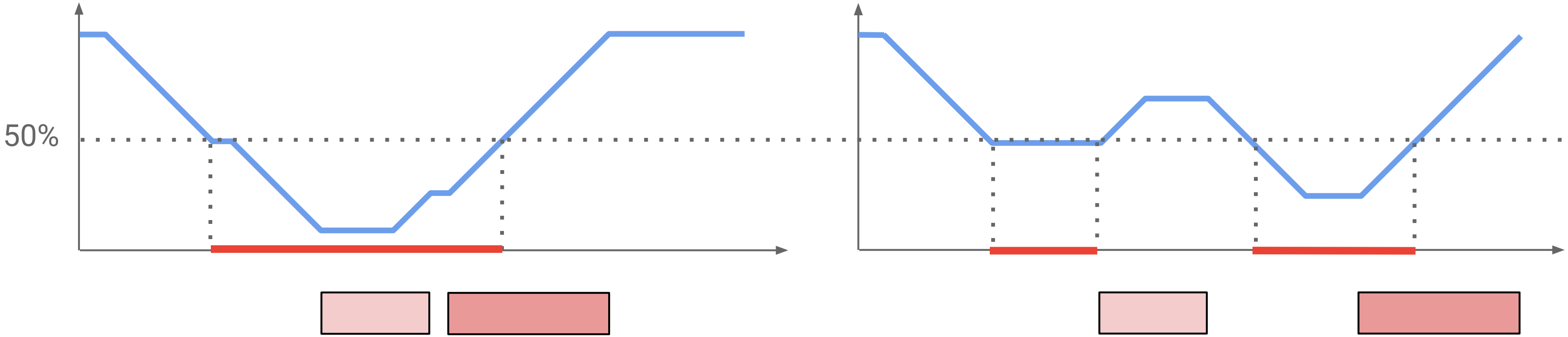
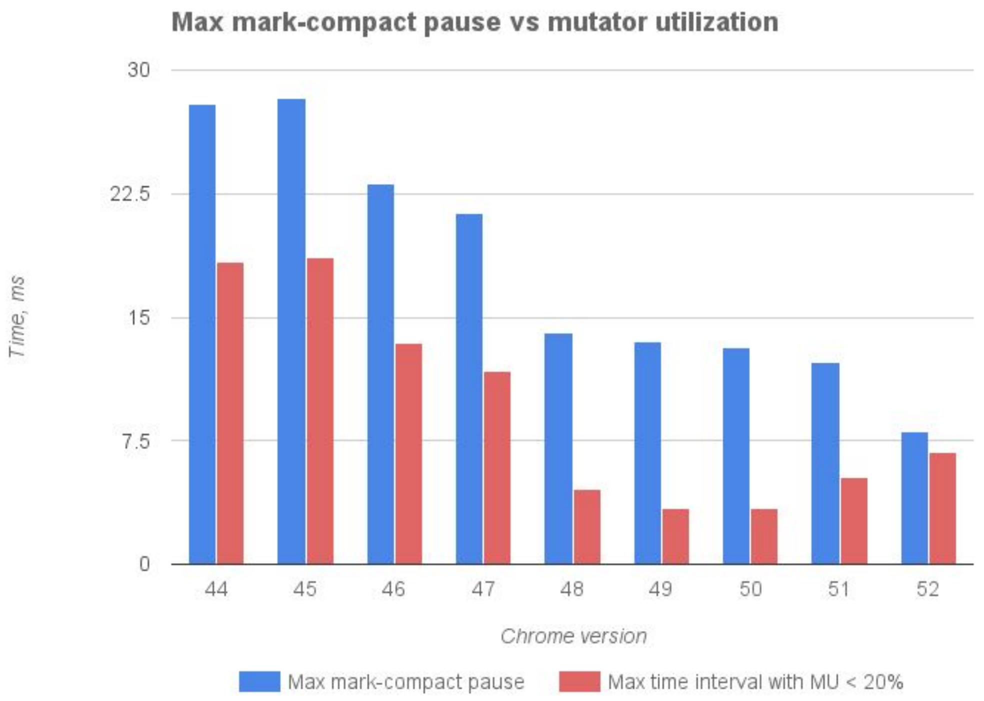
Intervals with low mutator utilization



The largest interval where f(x) ≤ 50% for all points in the interval.

Evaluation



Max mark-compact pause vs mutator utilization
30
22.5
15
7.5
0
Time, ms
44
45
46
47
48
49
50
51
52
Chrome version
Max mark-compact pause
Max time interval with MU < 20%

What we learned

- Incremental development of Orinoco - good idea!
  - Stability feedback via Canary channel
  - Performance feedback via UMA and telemetry
- Pause time distribution is not the whole performance story
  - Density of GC events on the timeline is also important
  - Mutator utilization can be good indicator of latency impact

Thanks!

Google

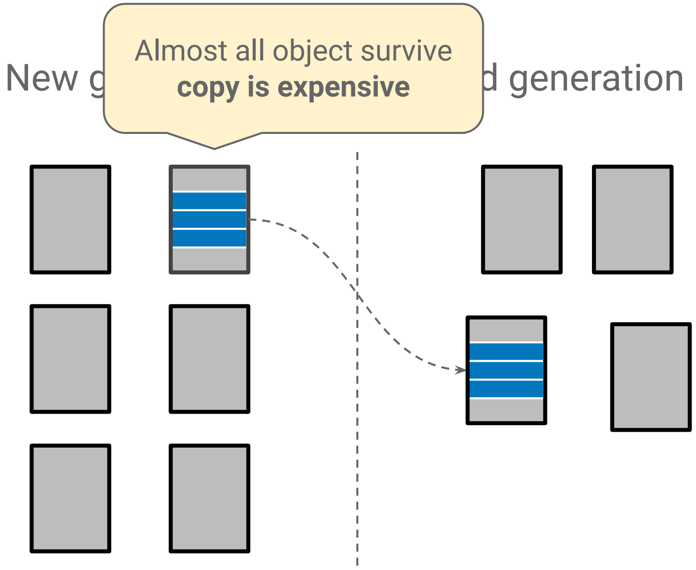
Changes on the way

Experimental

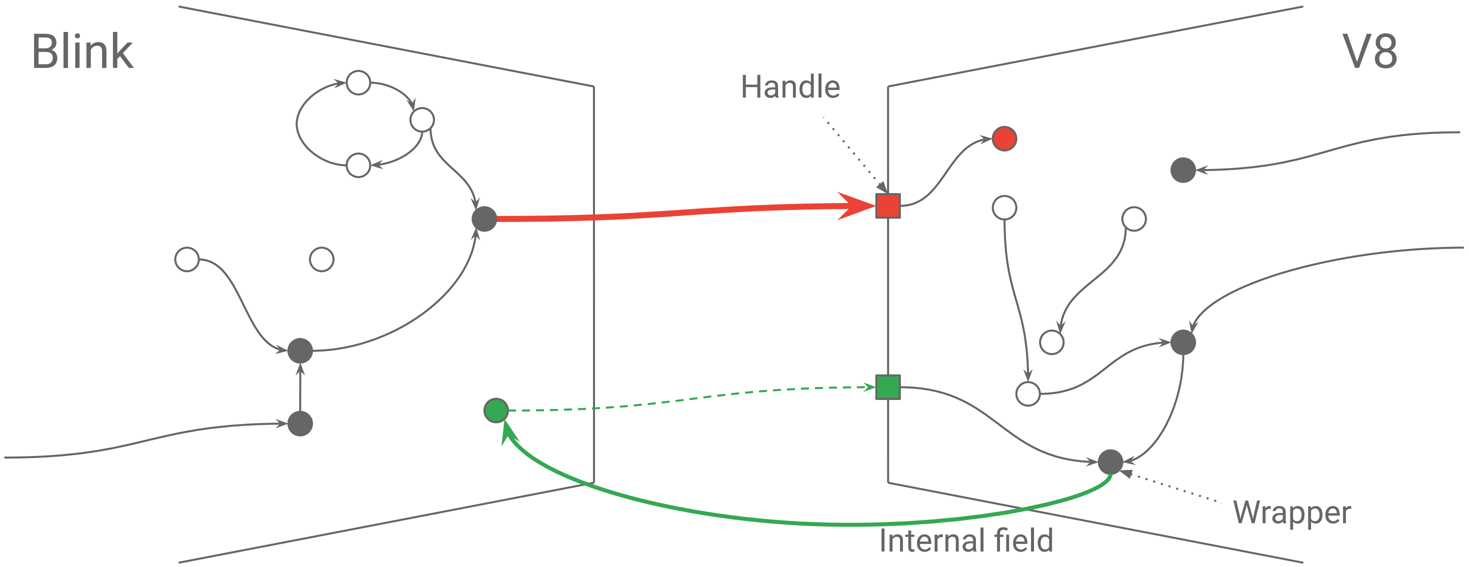
(behind flags)

Unified Heap

- Allow pages to move from young to old generation without copying



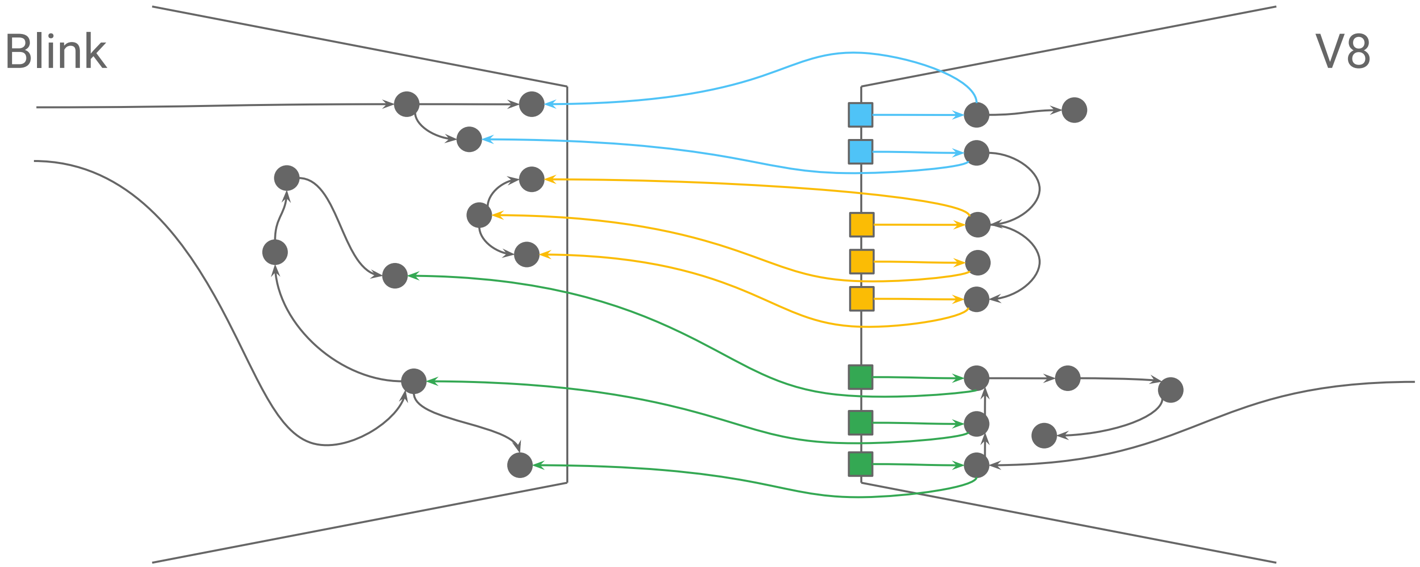
Blink ⇔ V8 - Connecting the Worlds



Handles keep V8 objects alive

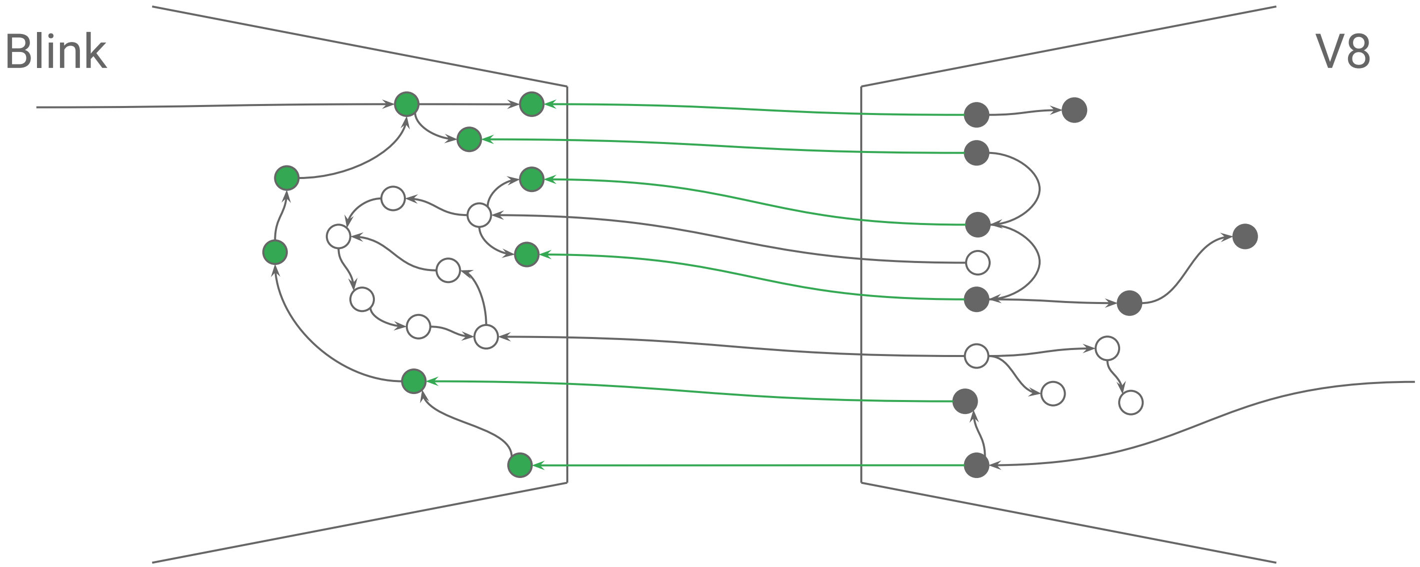
Wrapper keep Blink objects alive

Current Approach: Object Grouping



- Handles know which group they belong too (rule-based)
- Groups keep objects alive

Becoming friends with Blink: Tracing of wrappers



- Tracing through the Blink tree
- No need for handles

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