From Global to Local Quiescence: Wait-Free Code Patching of Multi-Threaded Processes

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Apply updates during the run time

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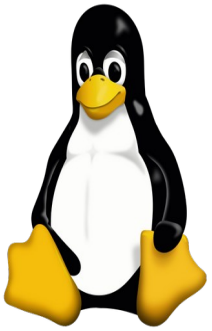

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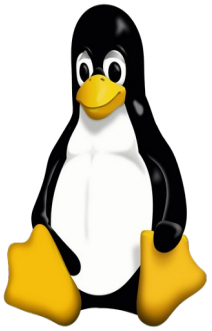
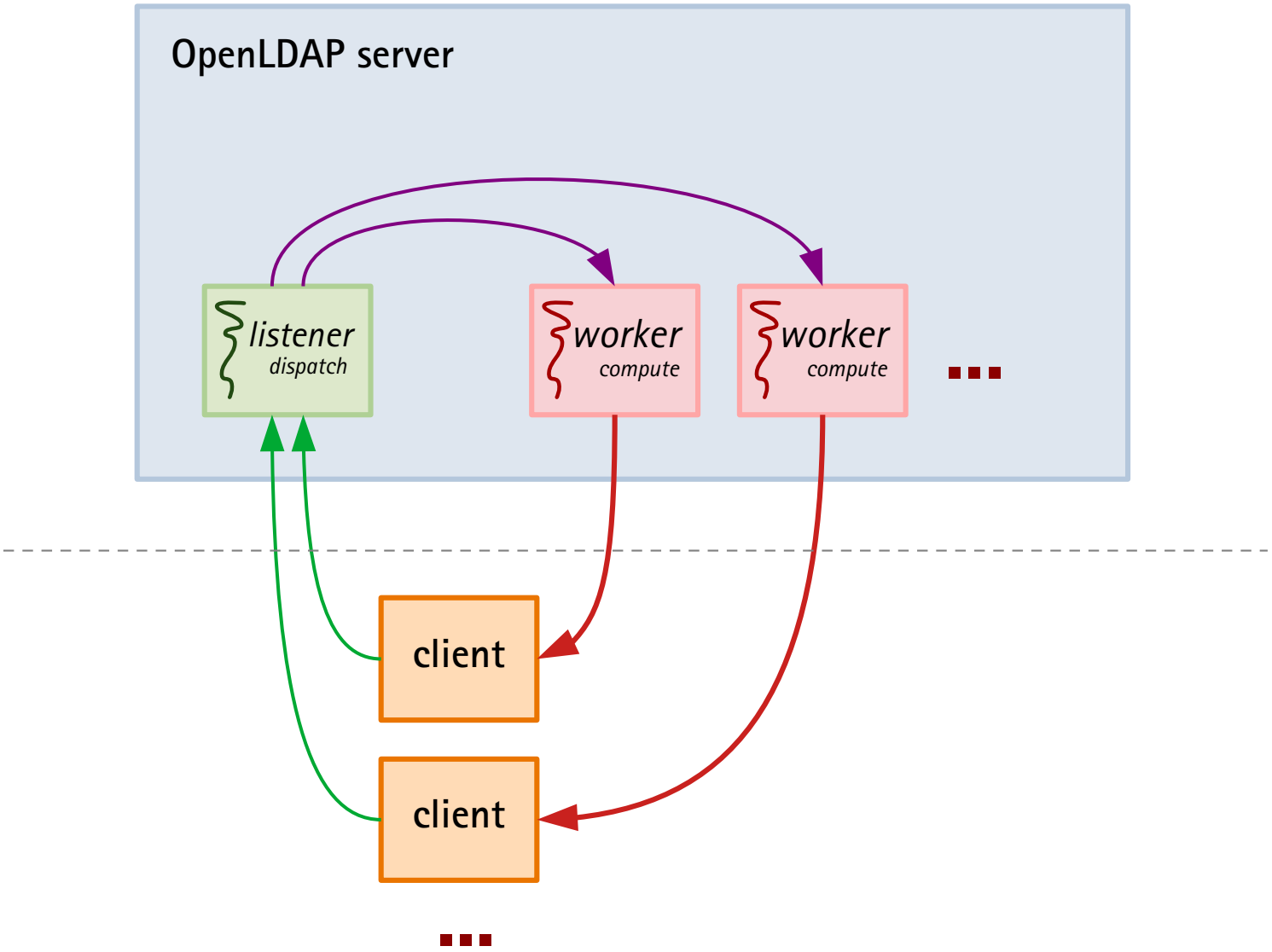


Userspace Applications?

→ DSU rarely used in practice

Example: OpenLDAP



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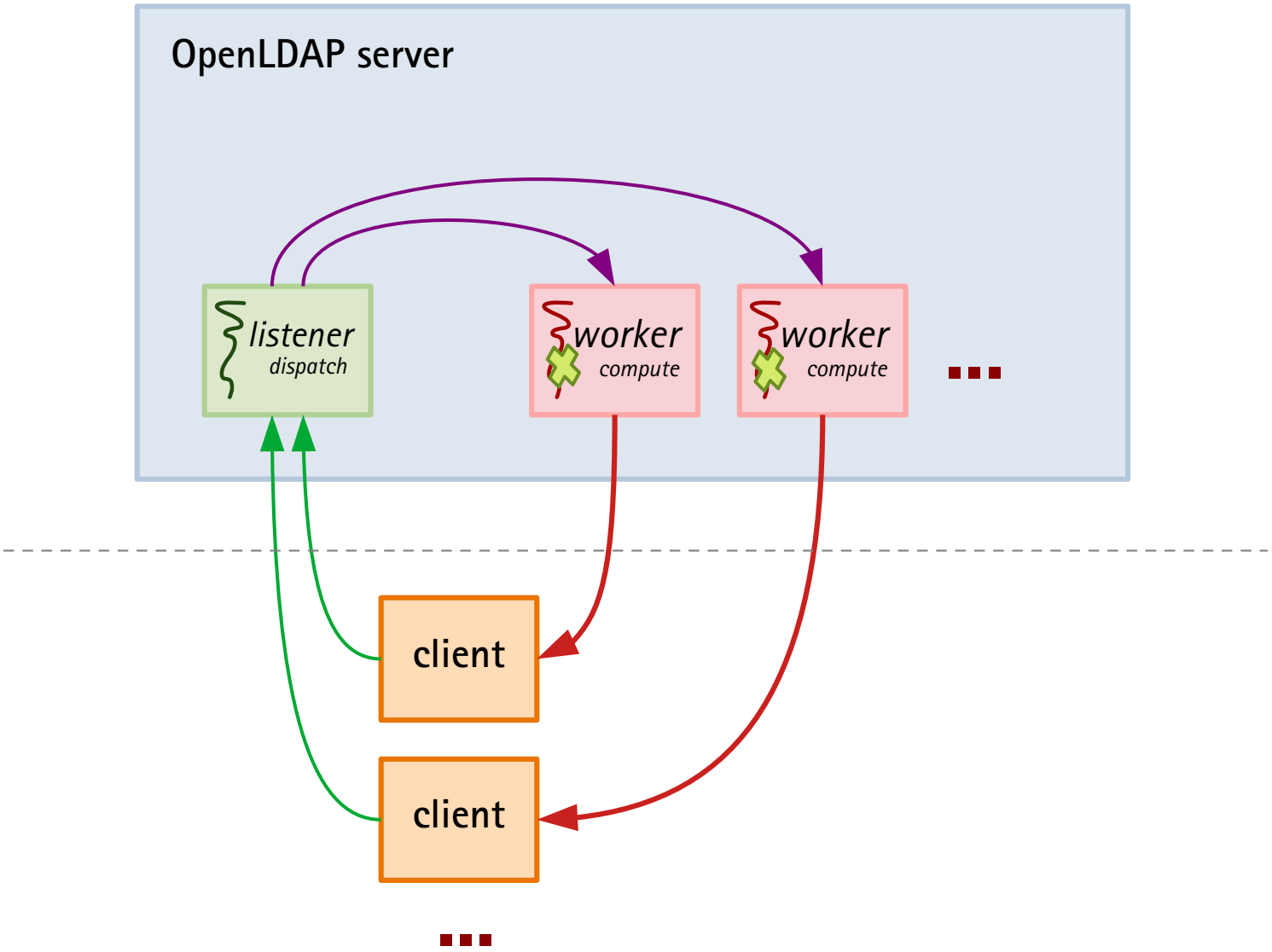

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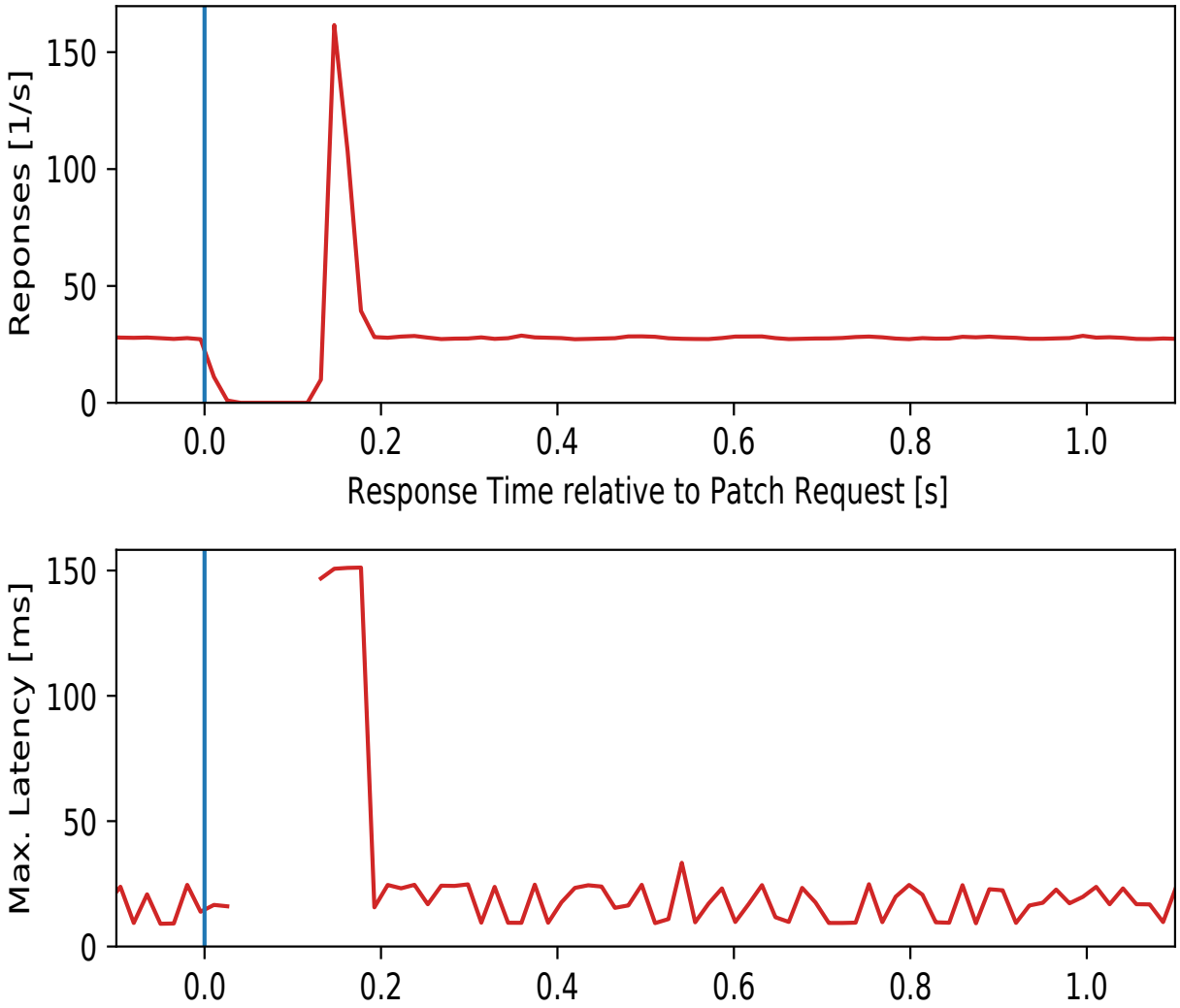
Global Quiescence:
All workers must be in the barrier before patching

Global Quiescence

The to-be-patched code is not active in any thread



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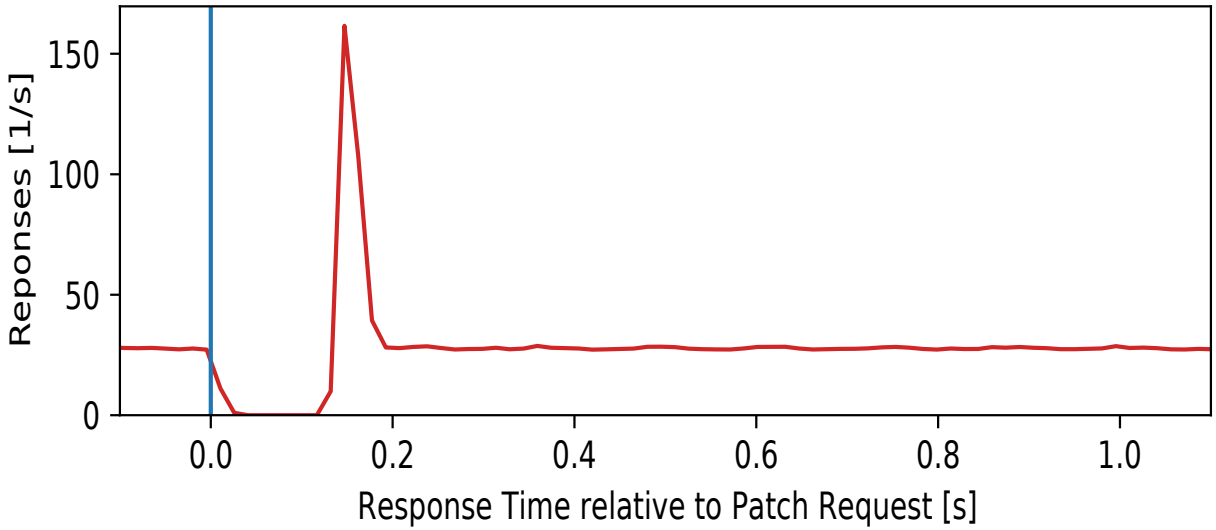

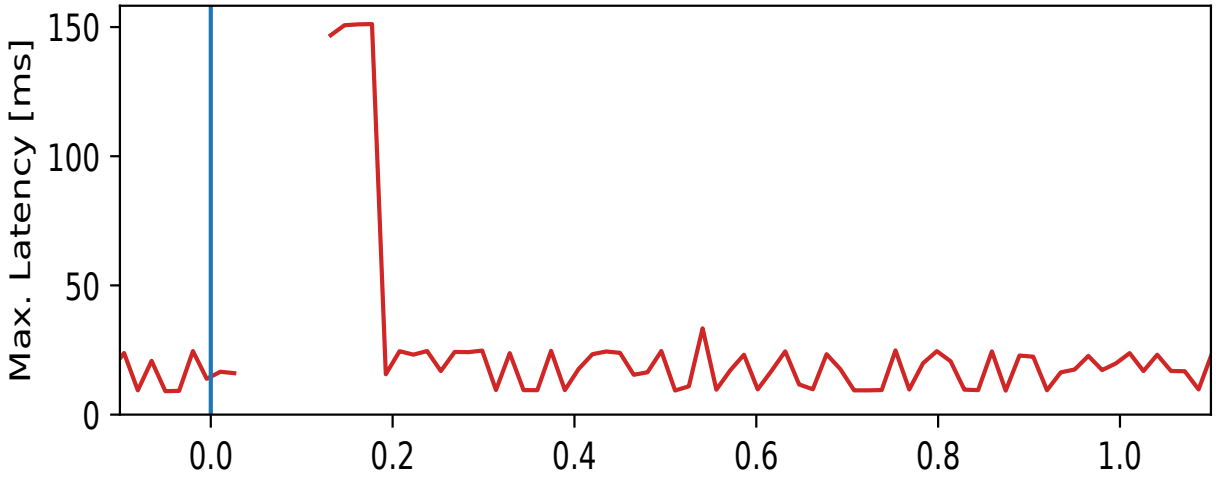

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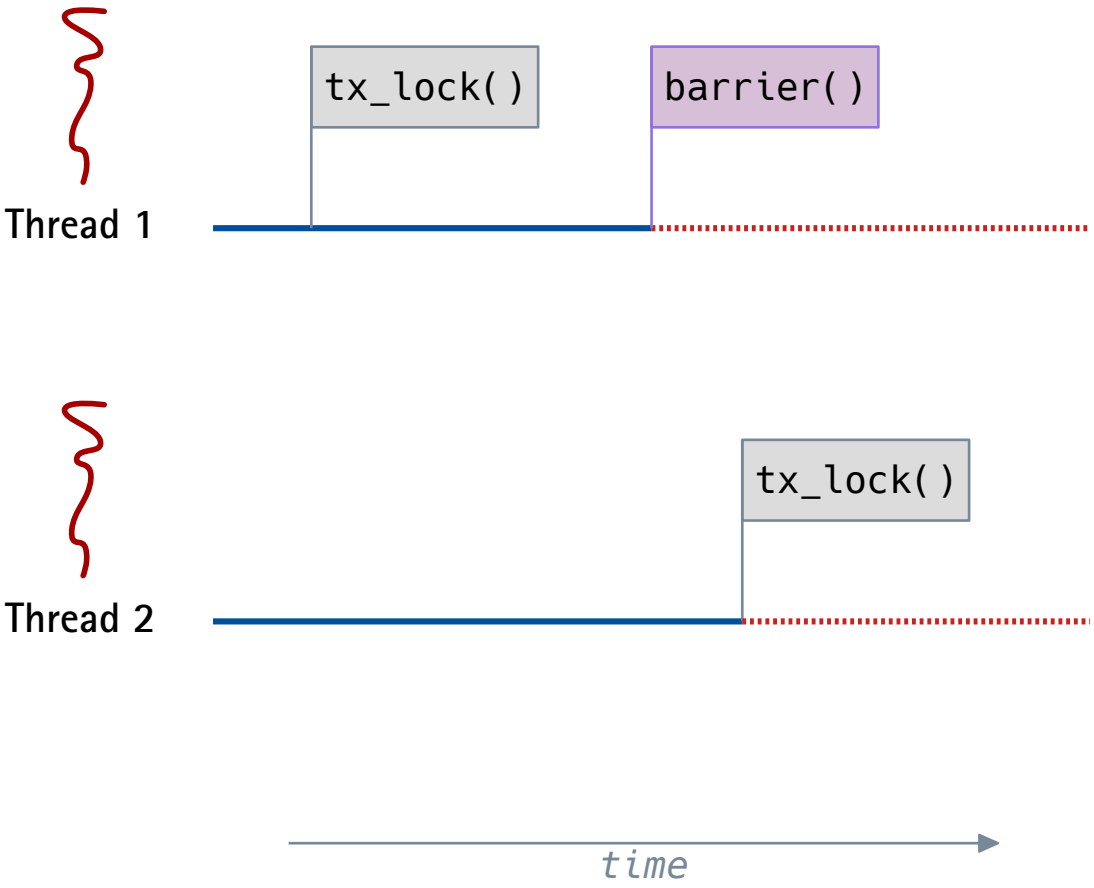
#2: I/O Operations

#3: Inter-Thread Dependencies

Global Quiescence

→ MariaDB: Transaction Locks



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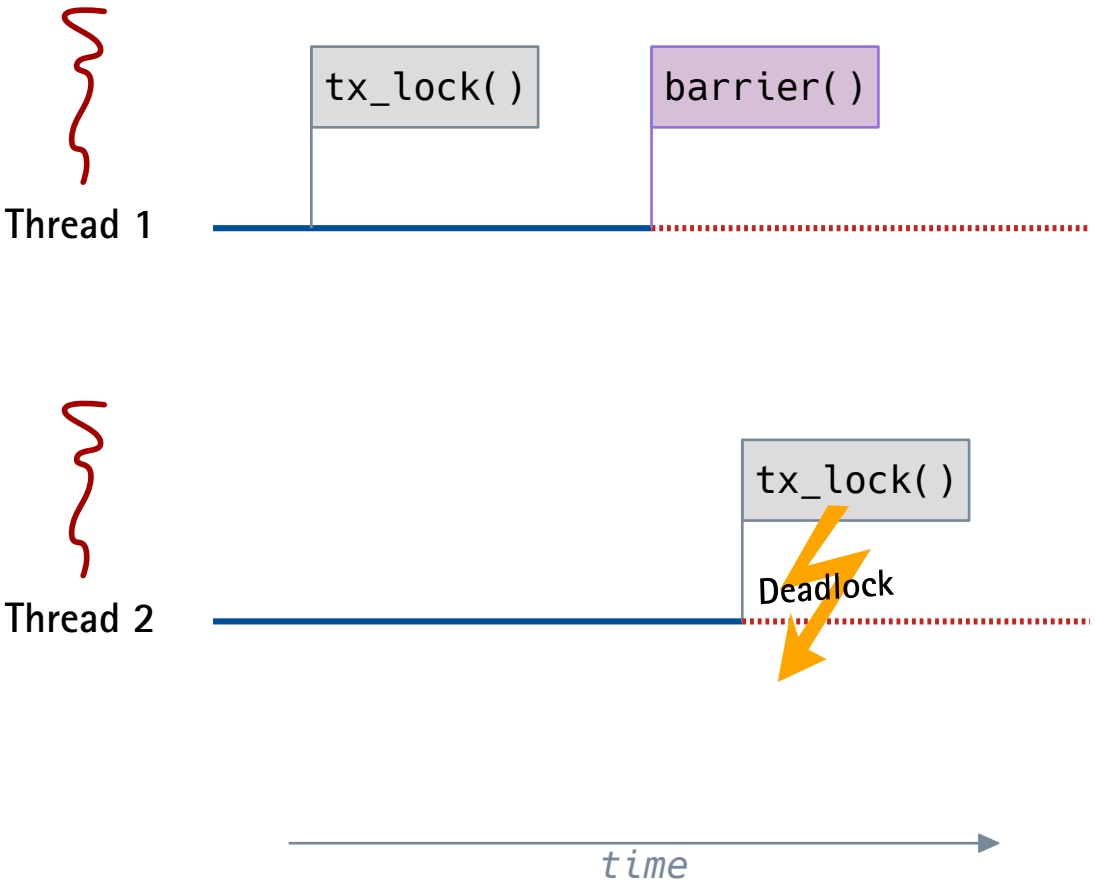

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  → Problems: kernel-specific, performance penalty

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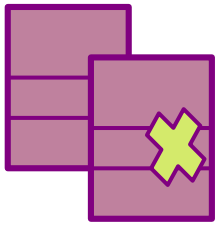


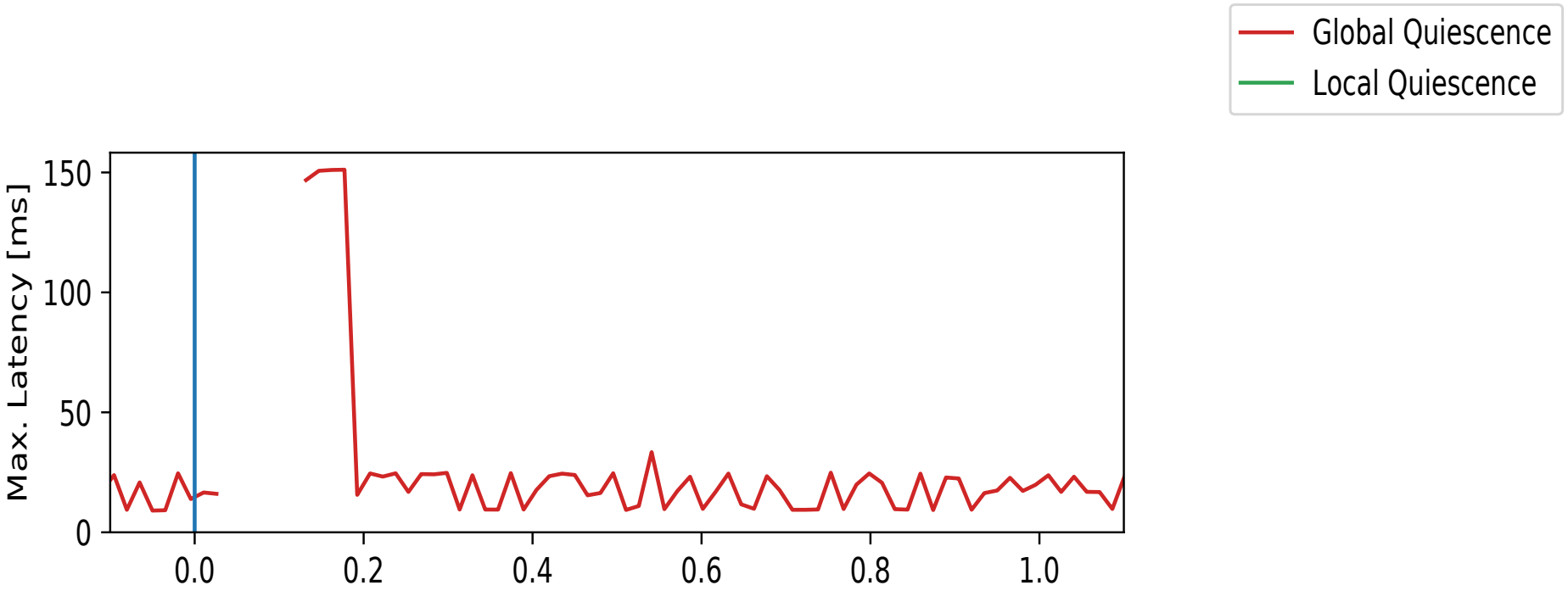
Wait-Free Code Patching
via Address-Space Generations

OS extension for run-time modification in multi-threaded processes

- AS generations: Multiple views of an address-space
- Thread-local quiescence
- Thread-by-thread migration between AS generations

→ Implementation in the Linux Kernel

Local Quiescence



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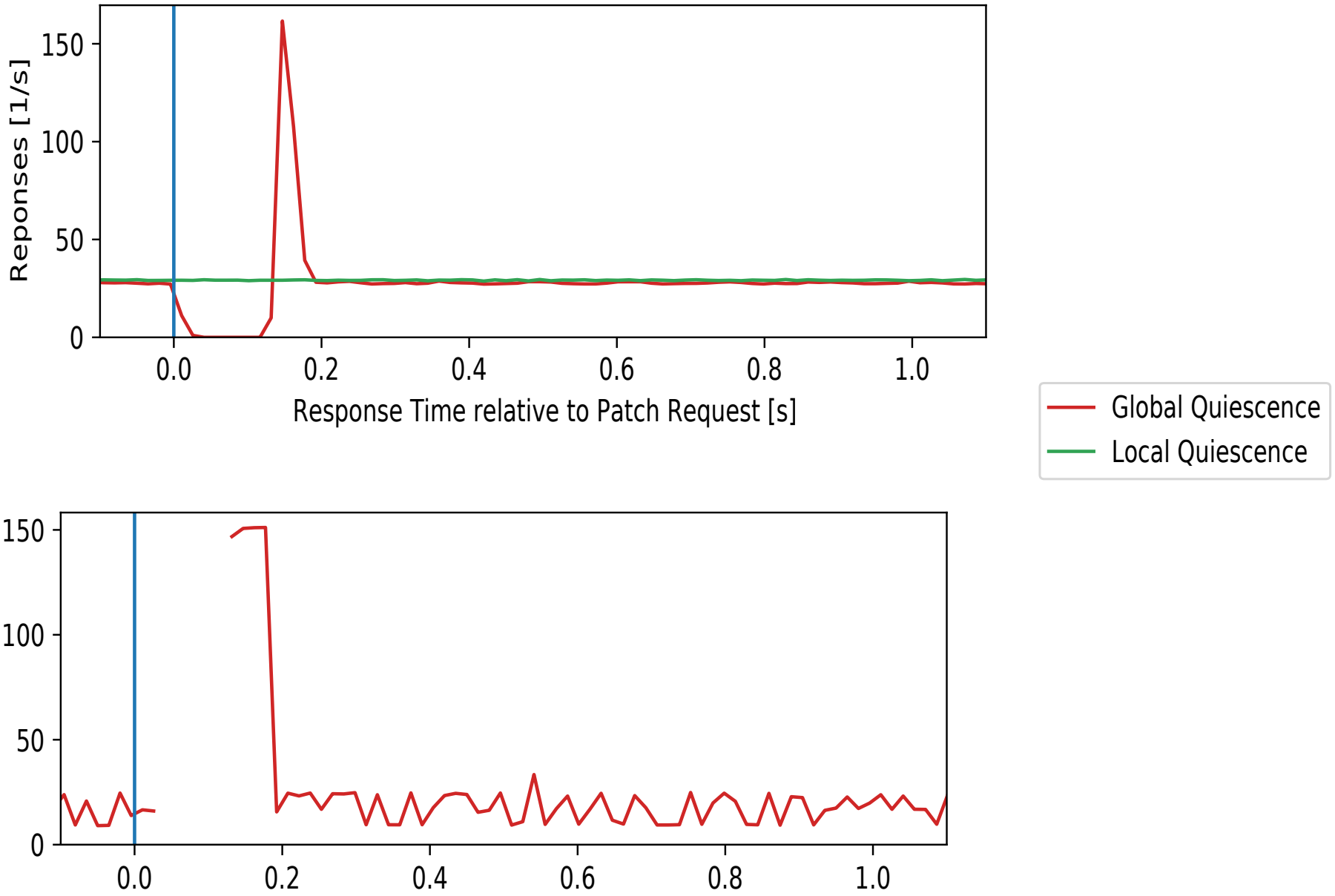

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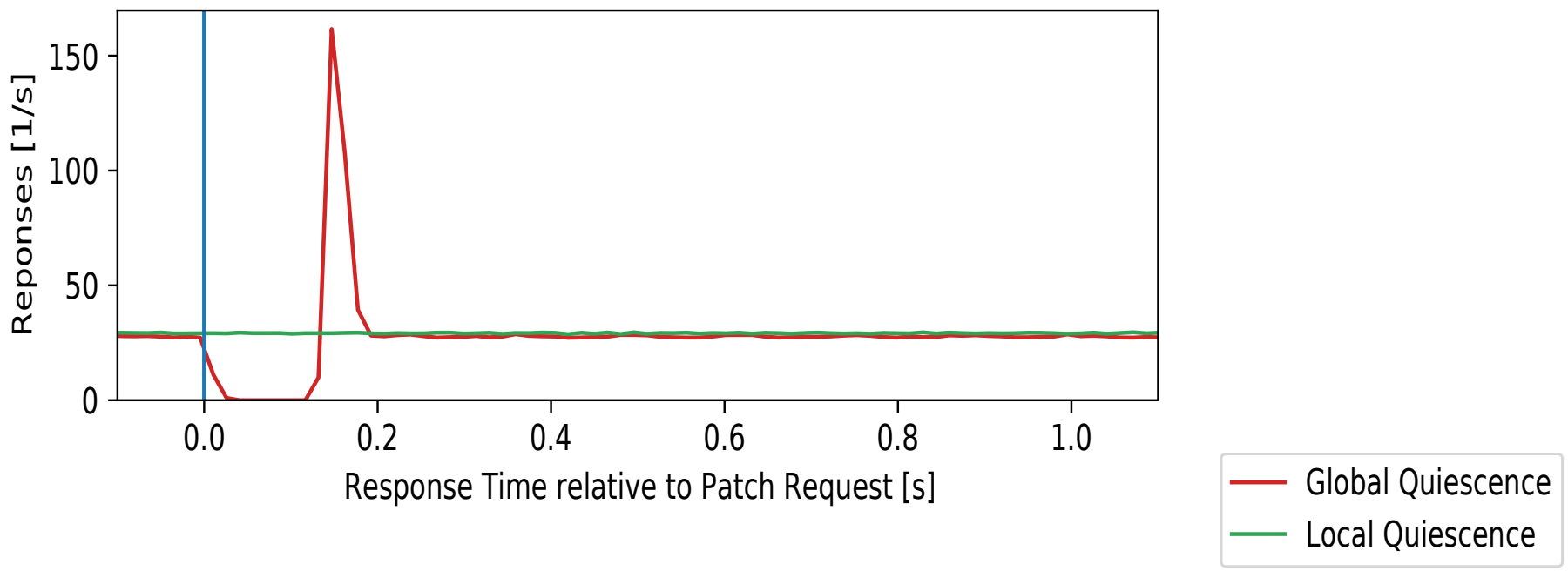

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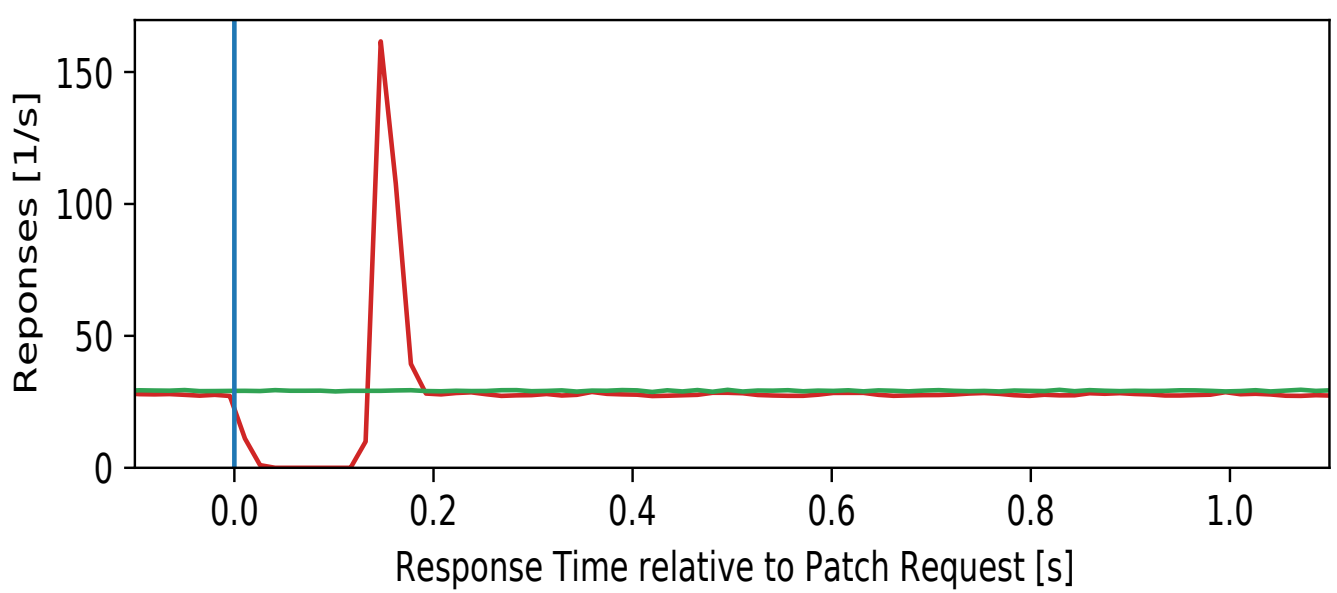

Inter-Thread Dependencies
→ No more deadlocks!

Global Quiescence
Local Quiescence

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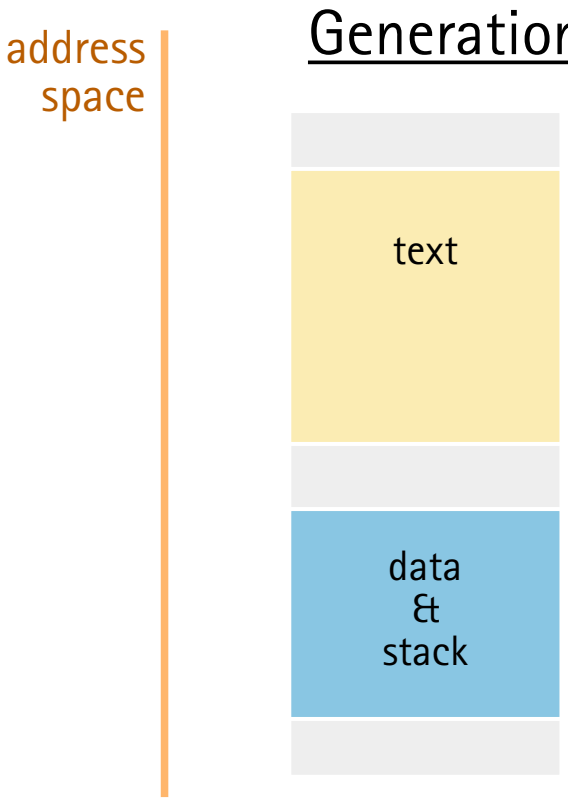

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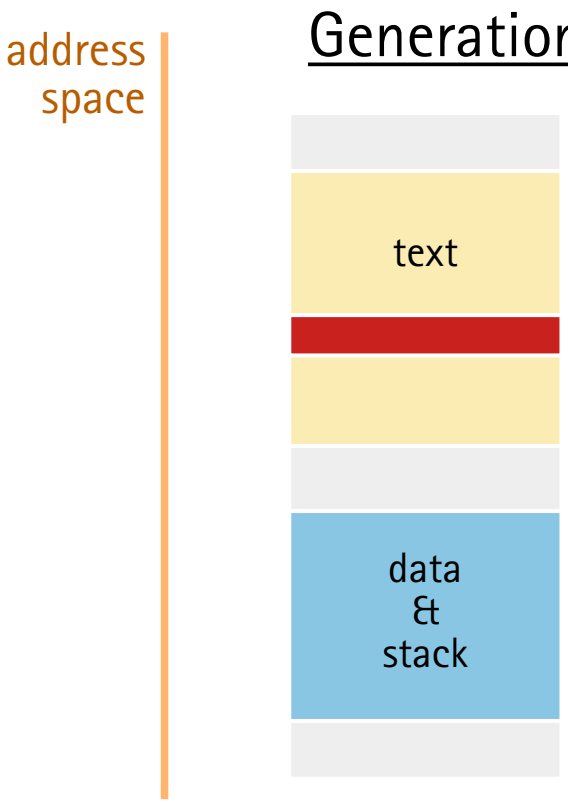

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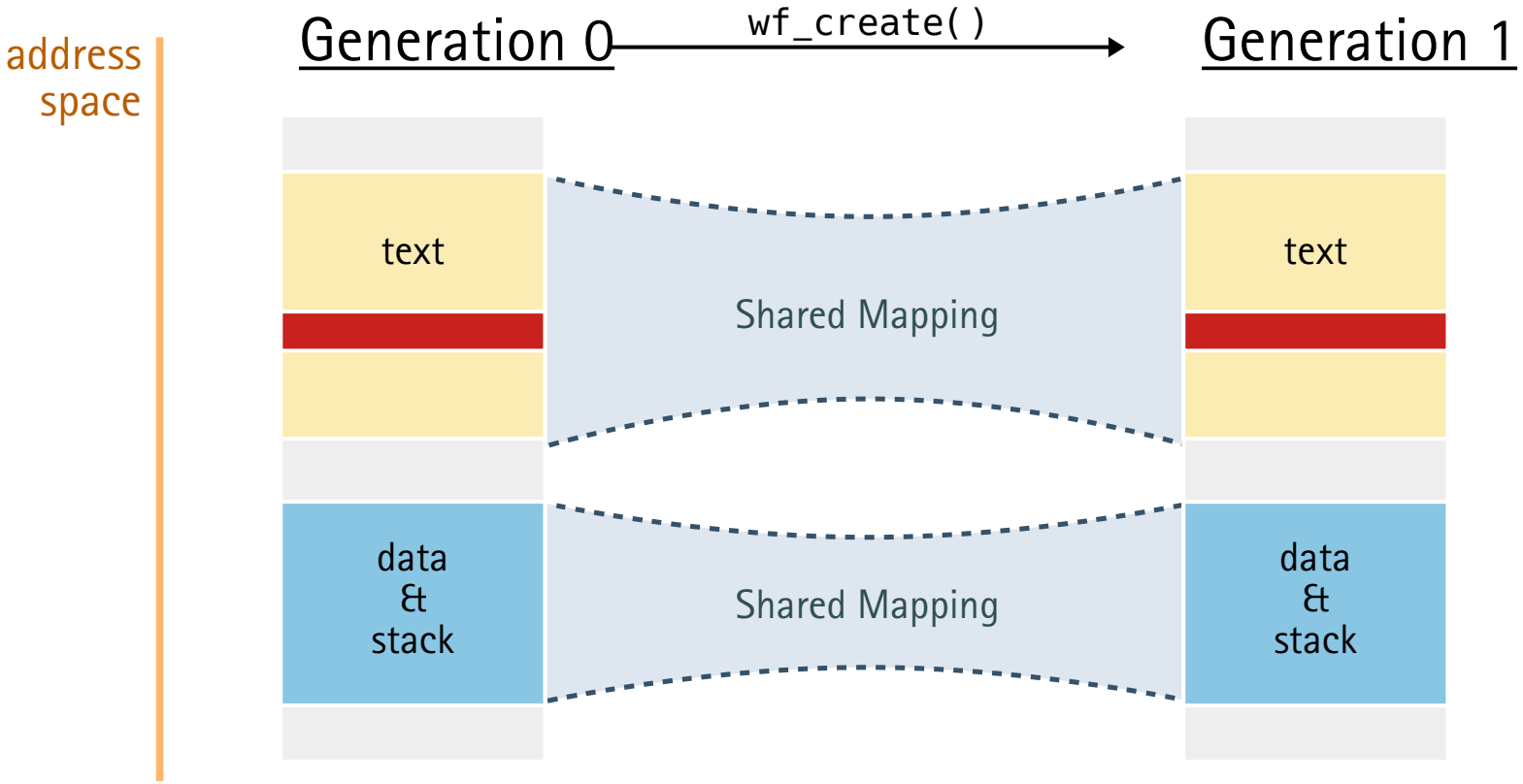

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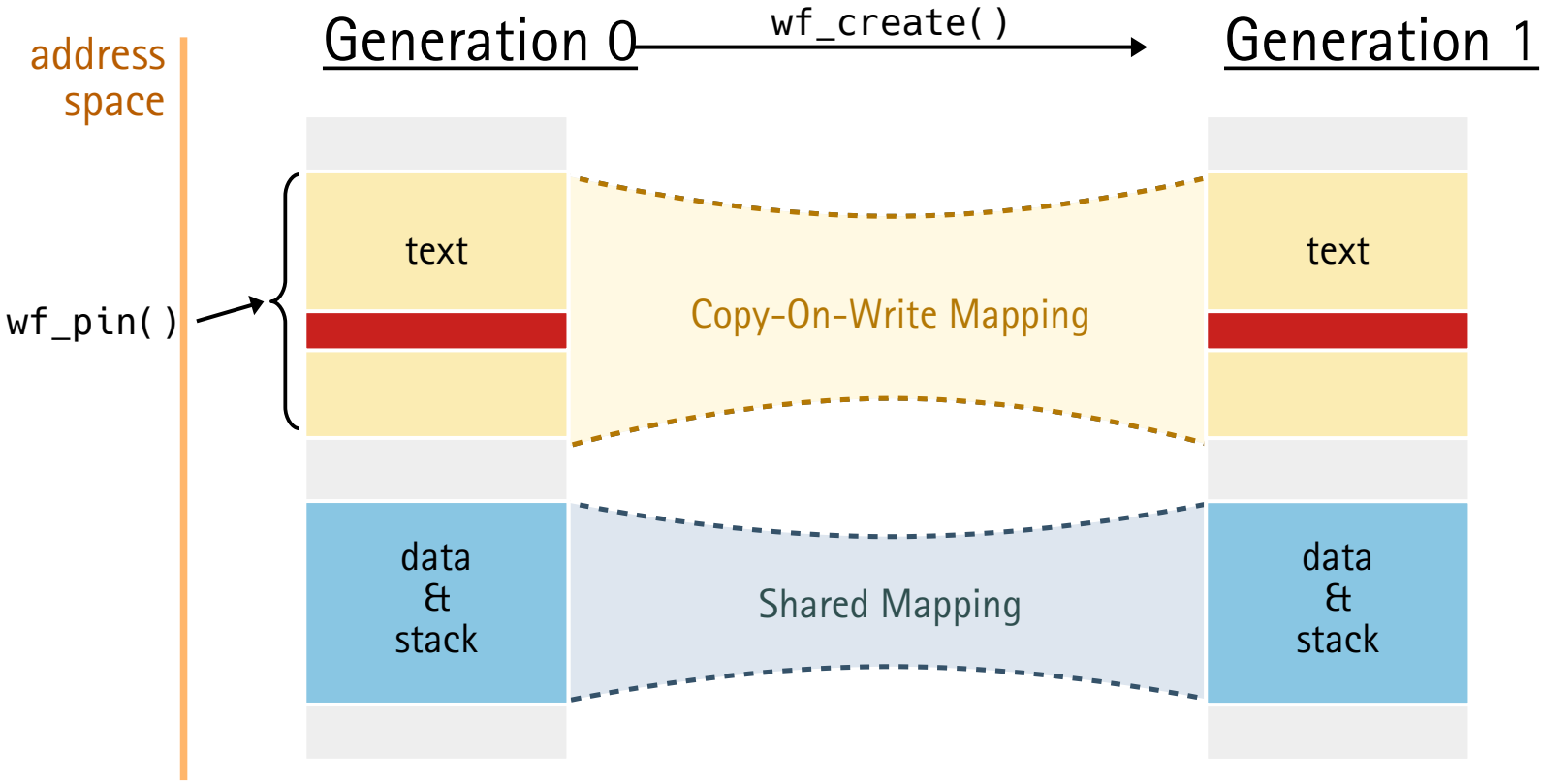

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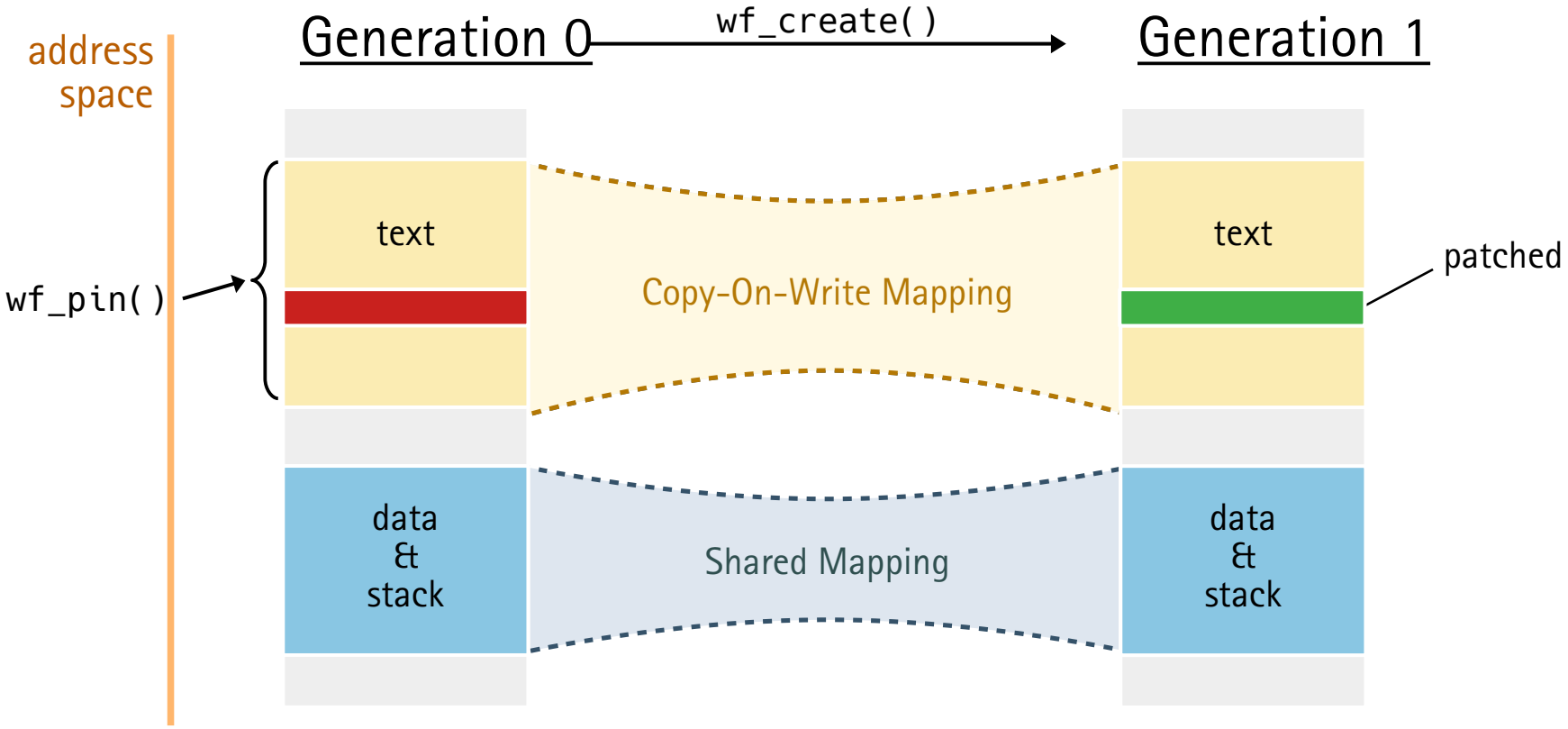

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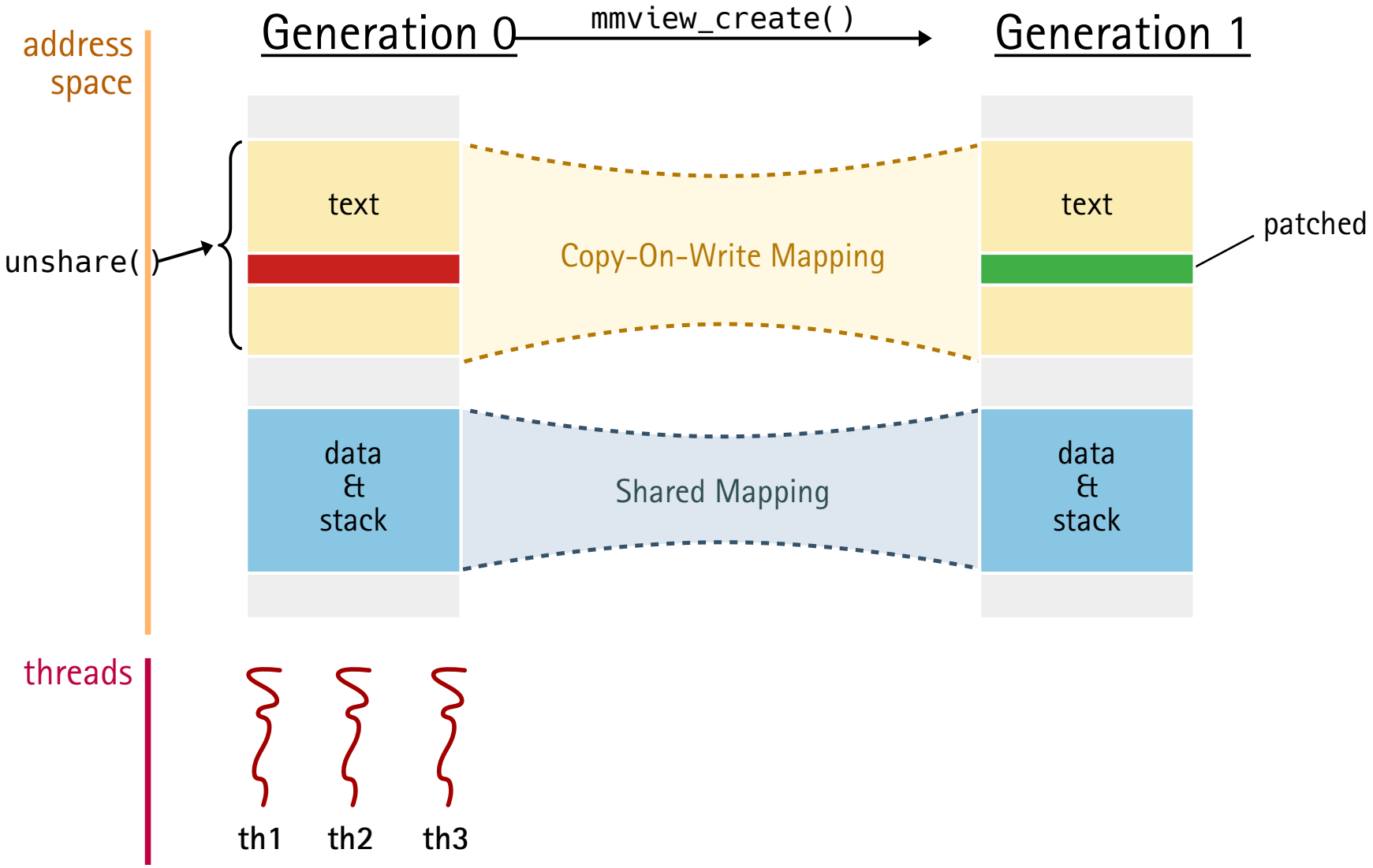

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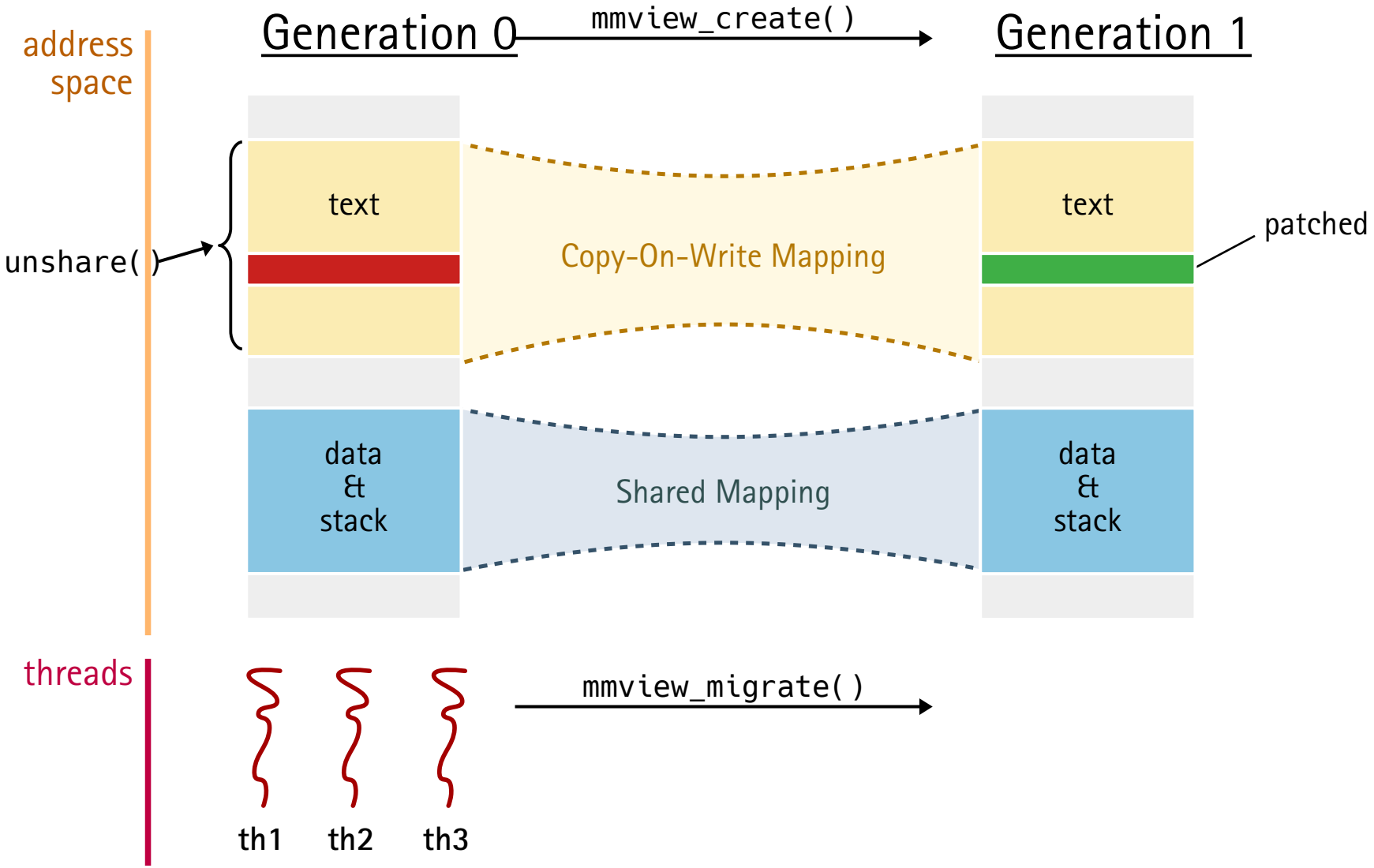

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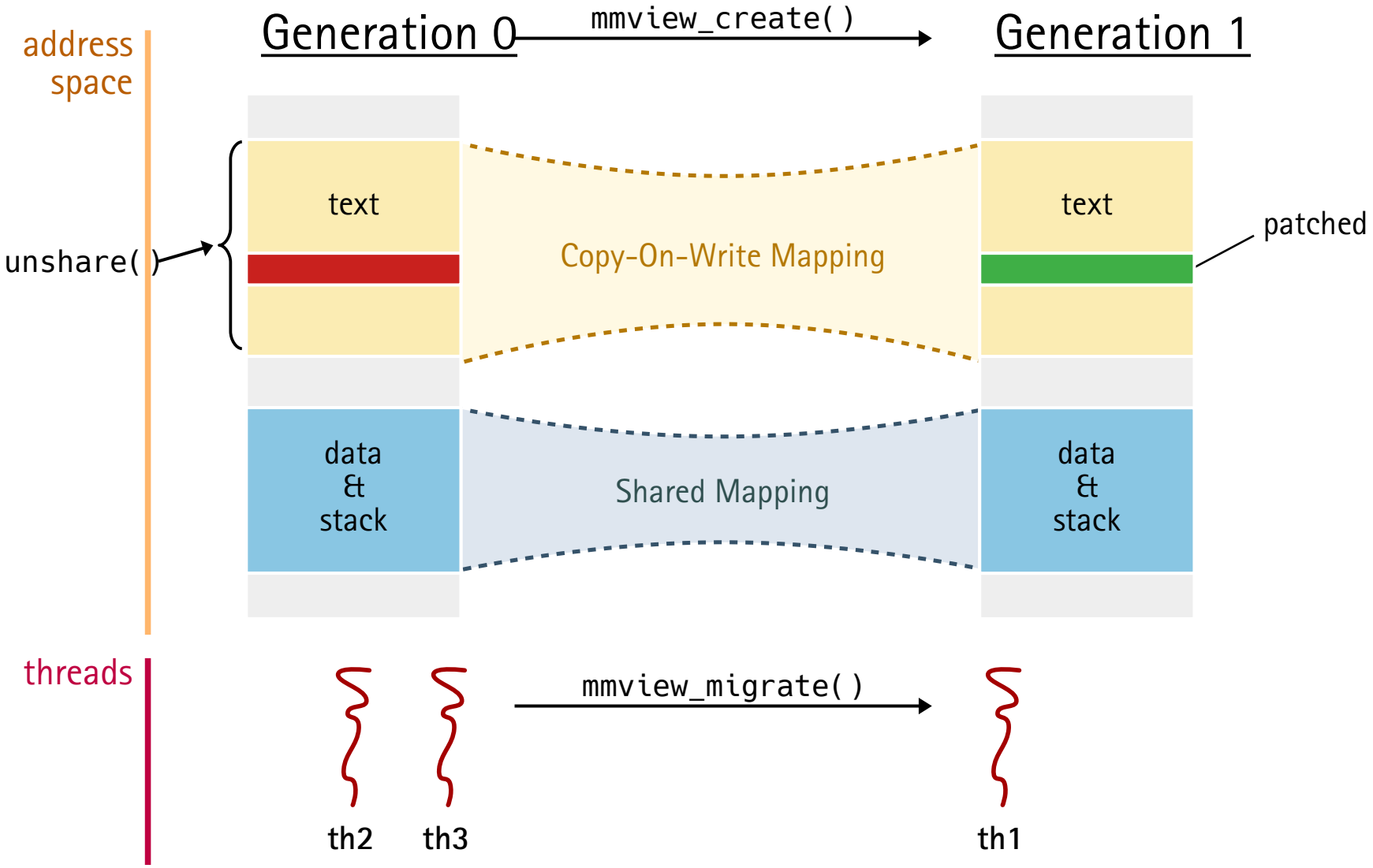

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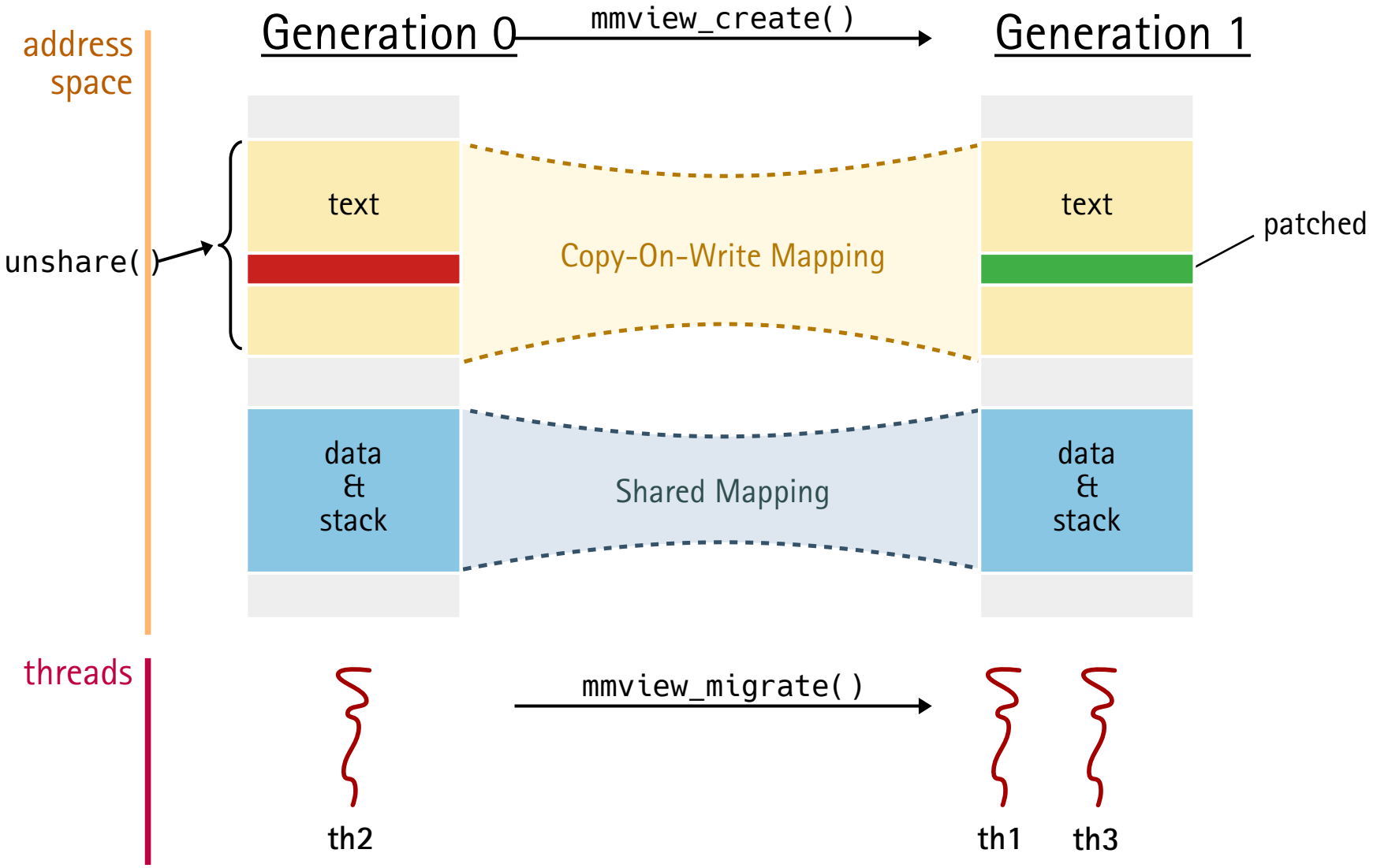

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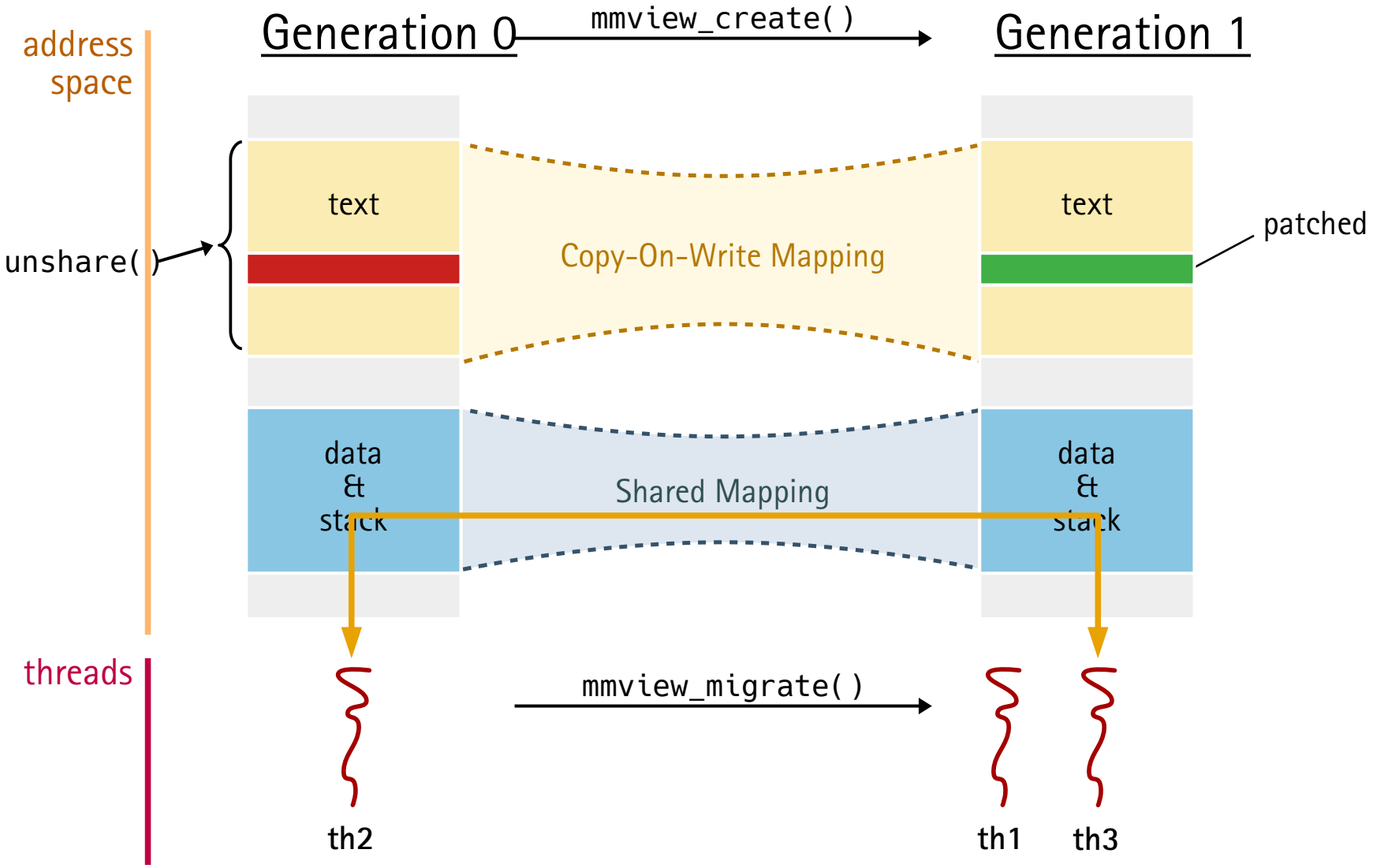

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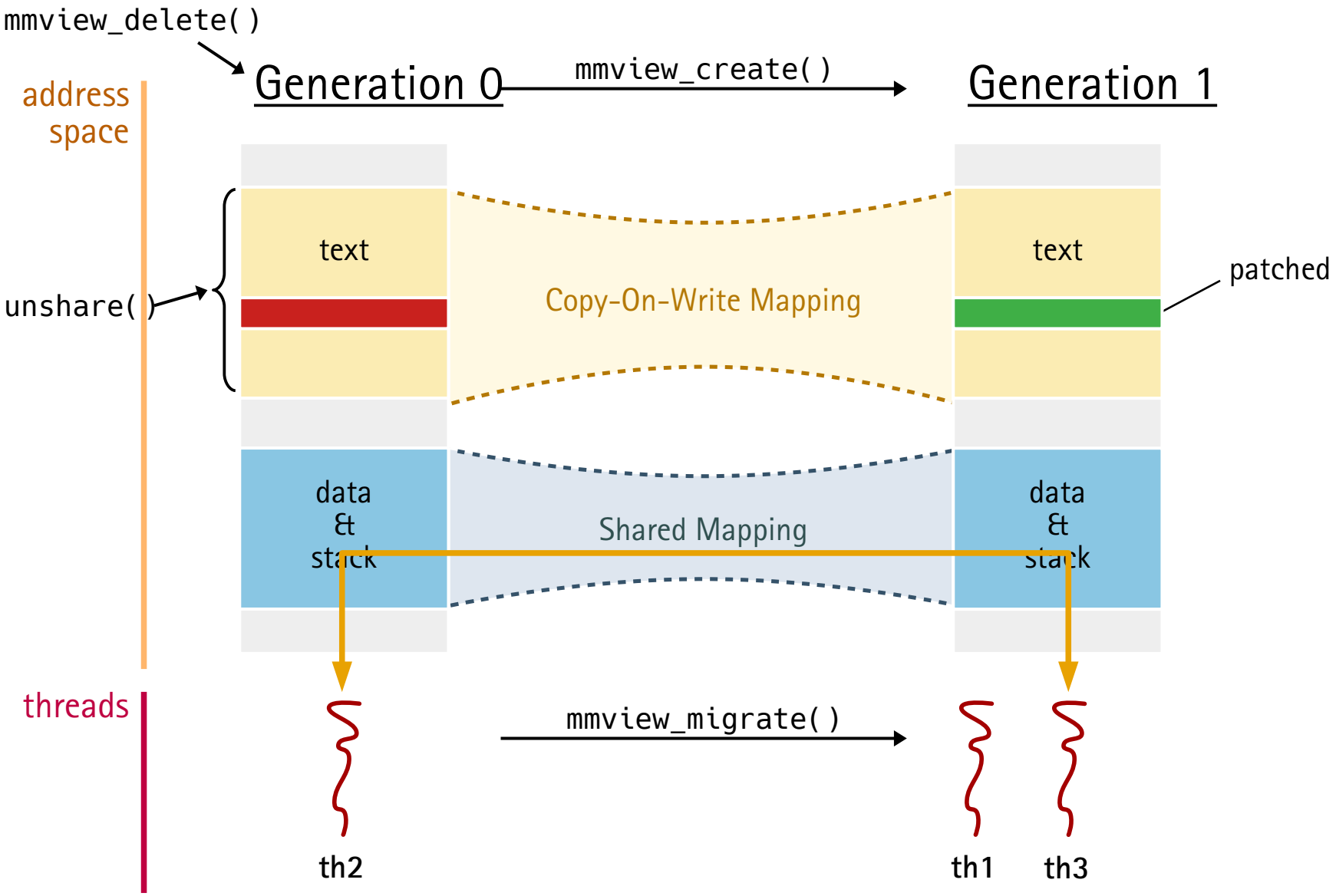

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void worker_thread() {
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  if (migration_pending()) {
    wf_migrate();
  }

 }
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void patcher_thread() {
 while (1) {
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  wf_create();
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  apply_patch();
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  if ( op->ors_filter != ros->ors_filter ) {
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    op->o_tmpfree( op->ors_filterstr.bv_val, op->o_tmpmemctx );
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```

patched

Example: OpenLDAP

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void worker_thread() {
 while (1) {
  wait_for_work();
  do_work();

  // quiescence point
  if (migration_pending()) {
    wf_migrate();
  }

 }
}
```

```
void patcher_thread() {
 while (1) {
  wait_for_patch_request();
  wf_create();
  wf_migrate();
  apply_patch();
  set_migration_pending();
 }
}
```

do_work()

```
void rwm_op_rollback( Operation *op, SlapReply *rs, rwm_op_state *ros ) {
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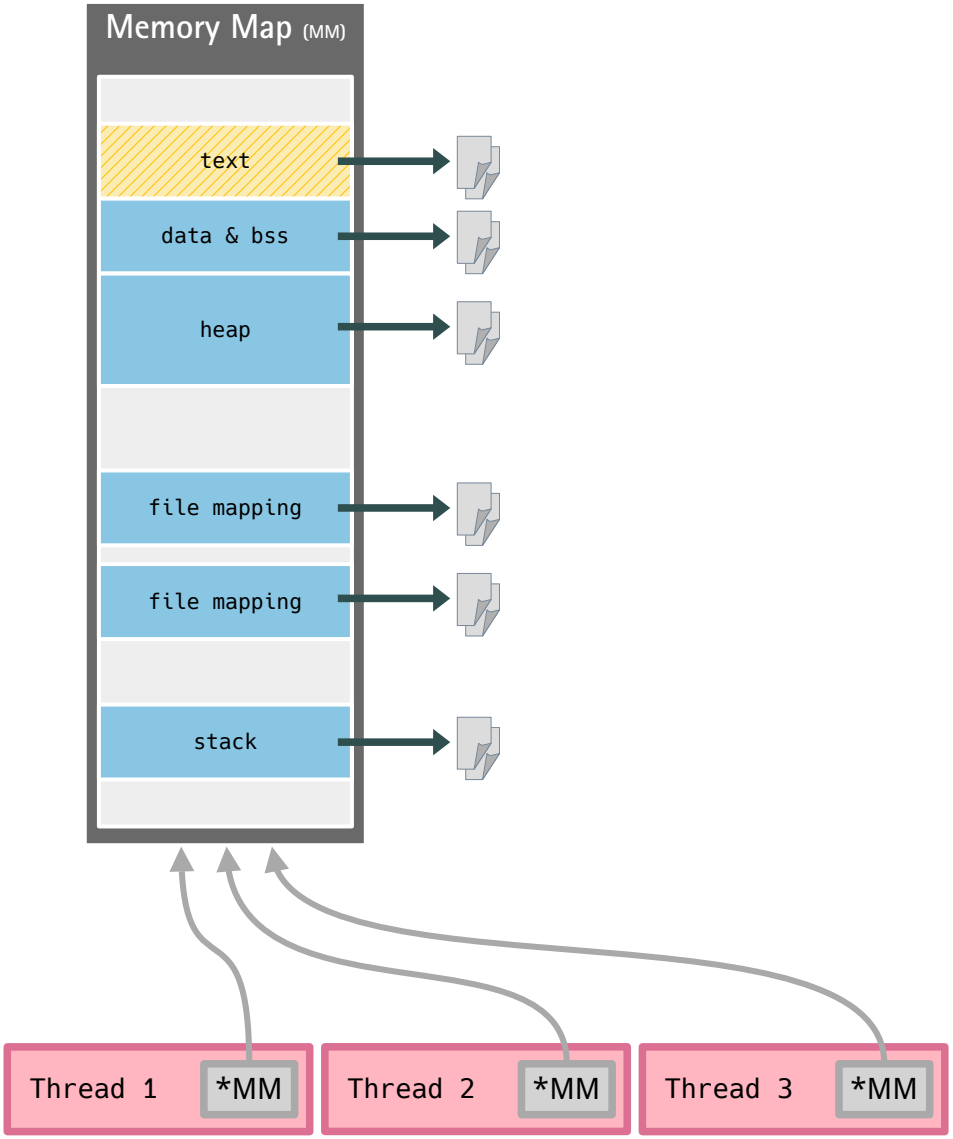

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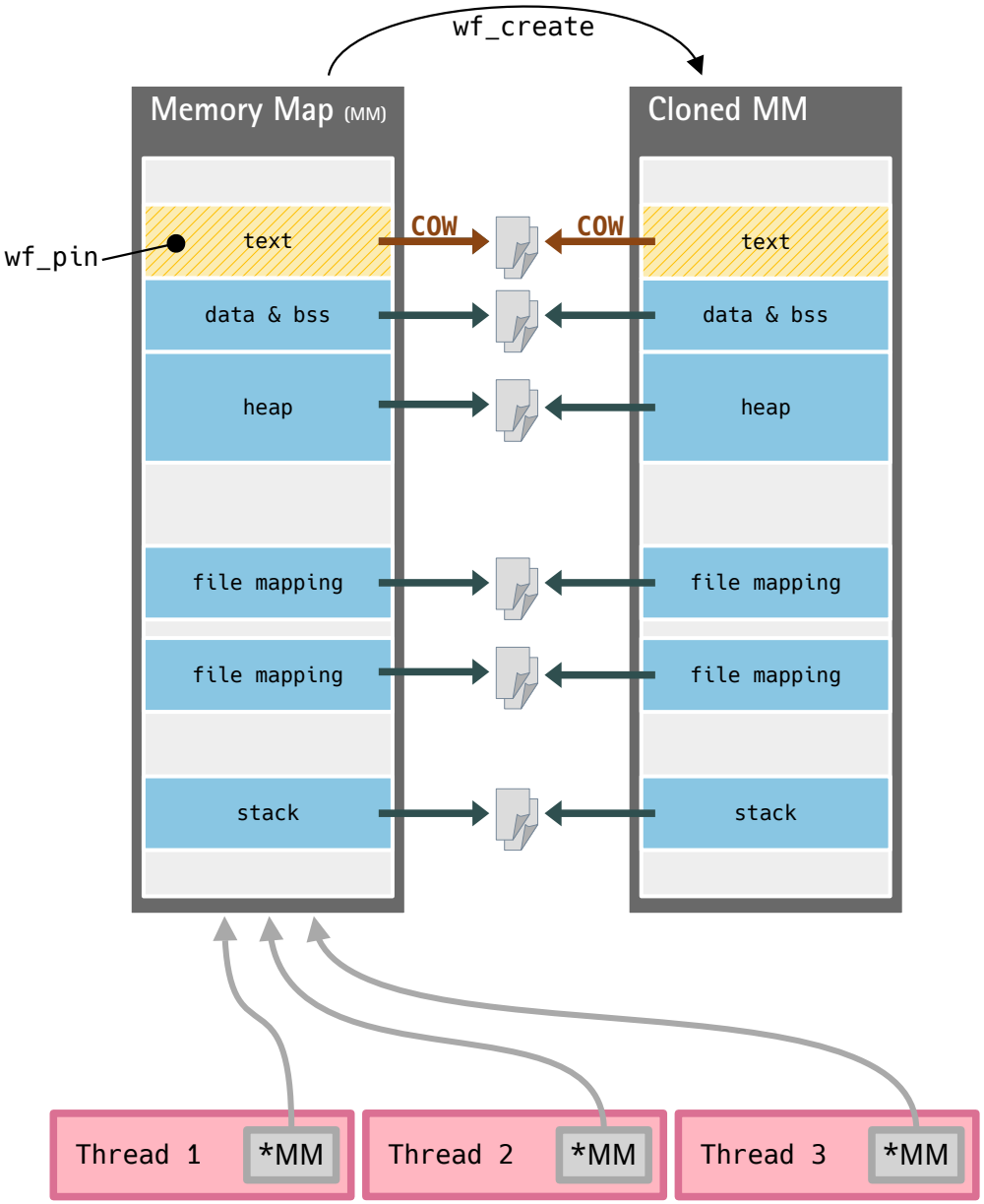

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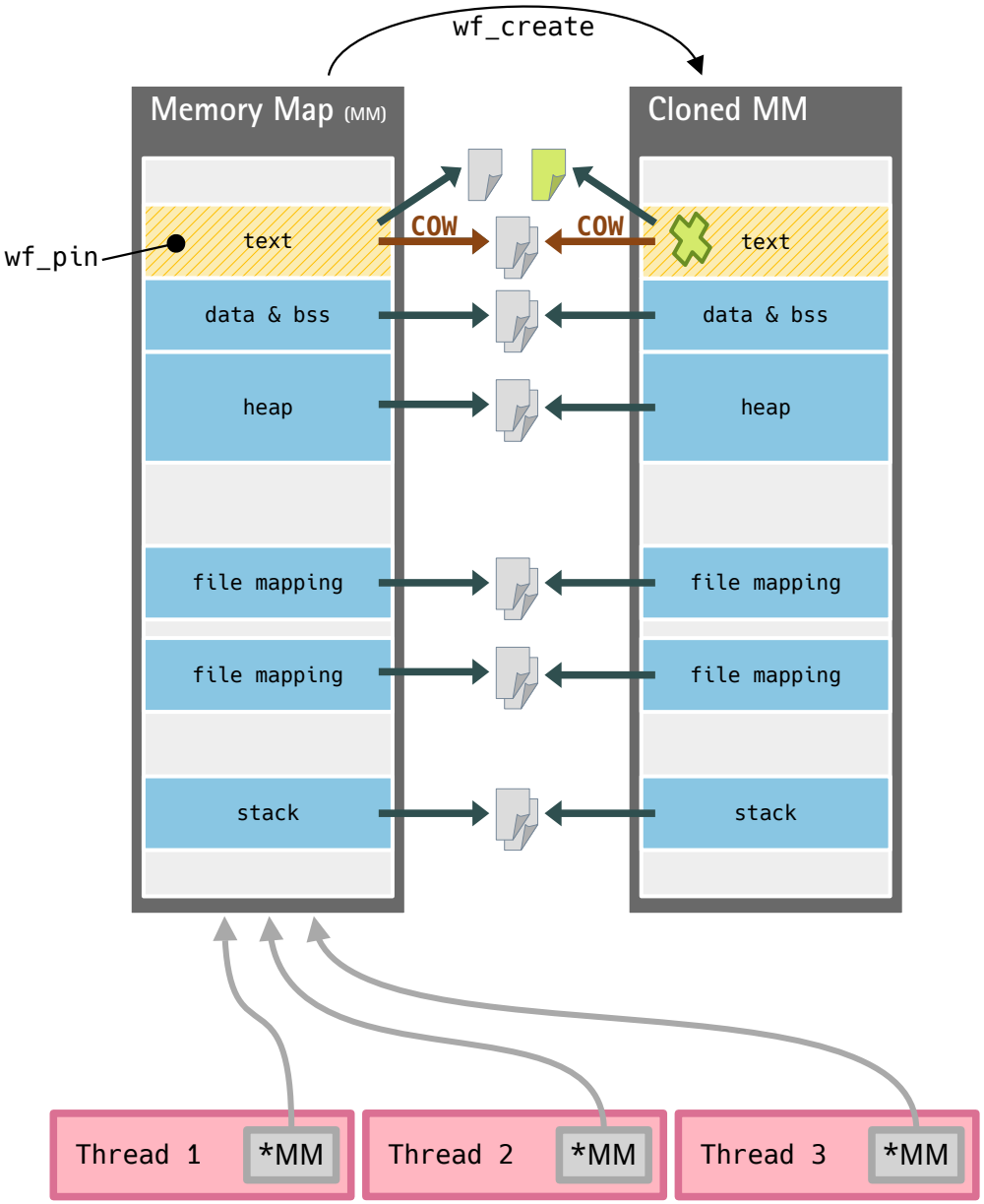

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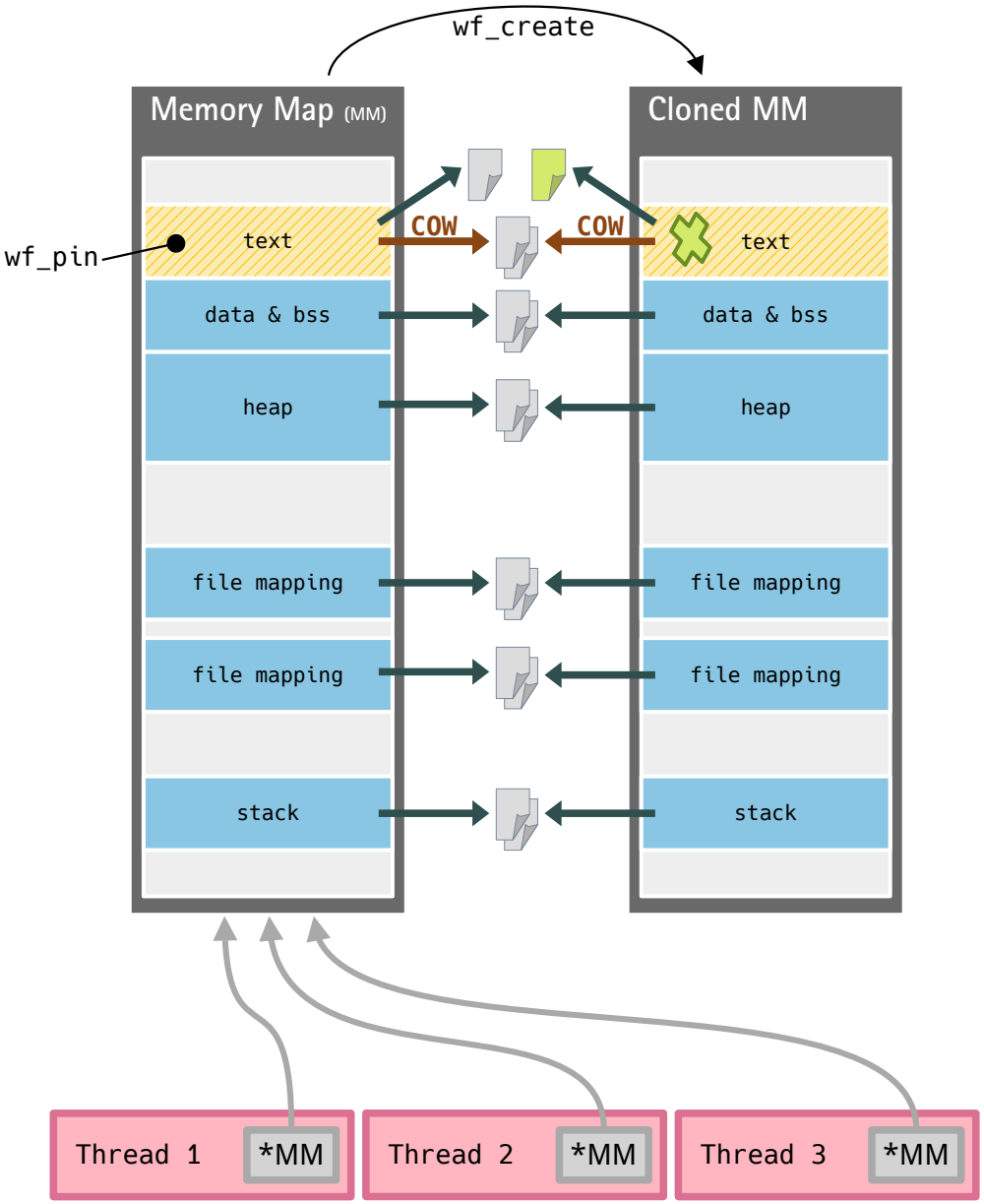

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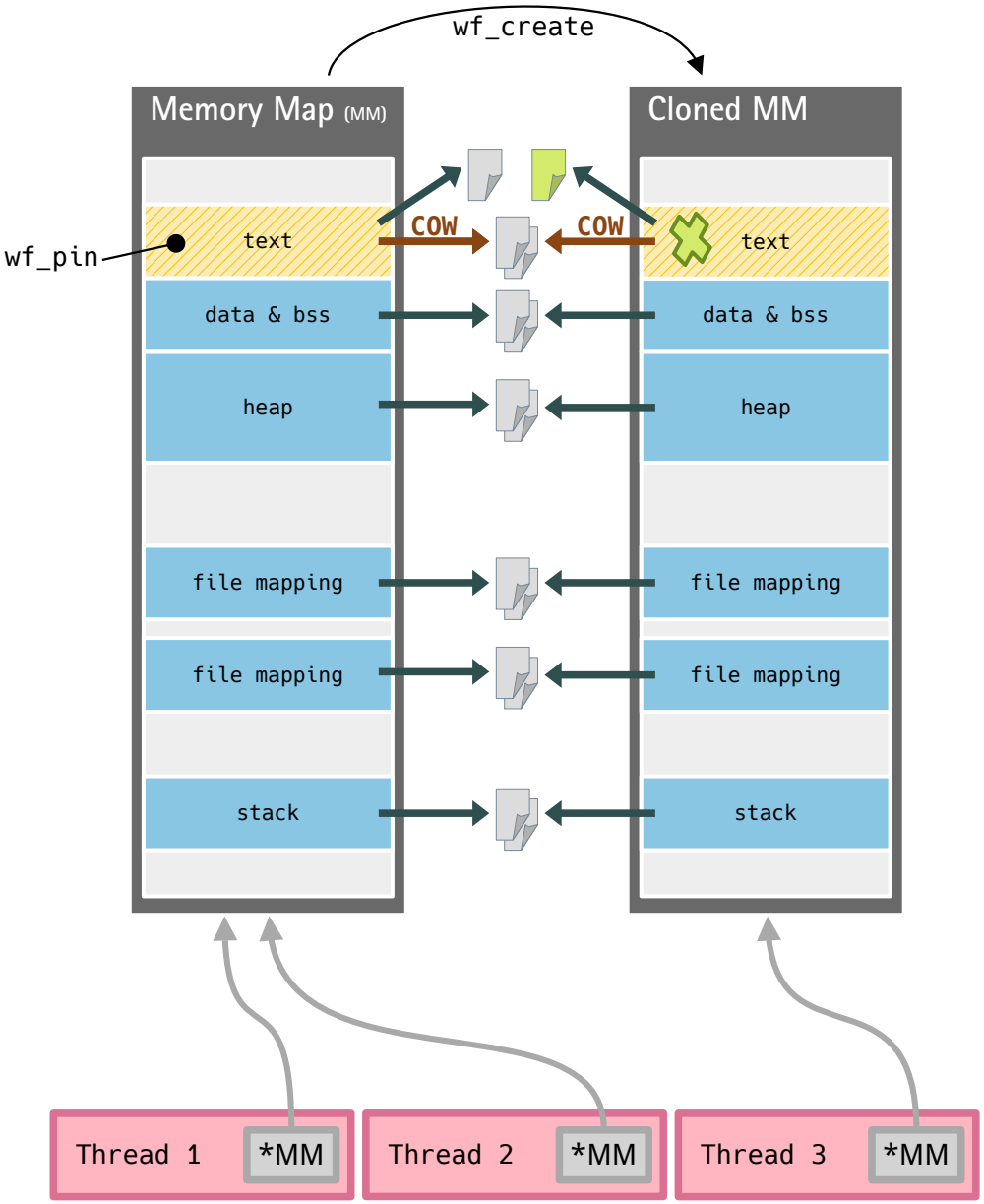

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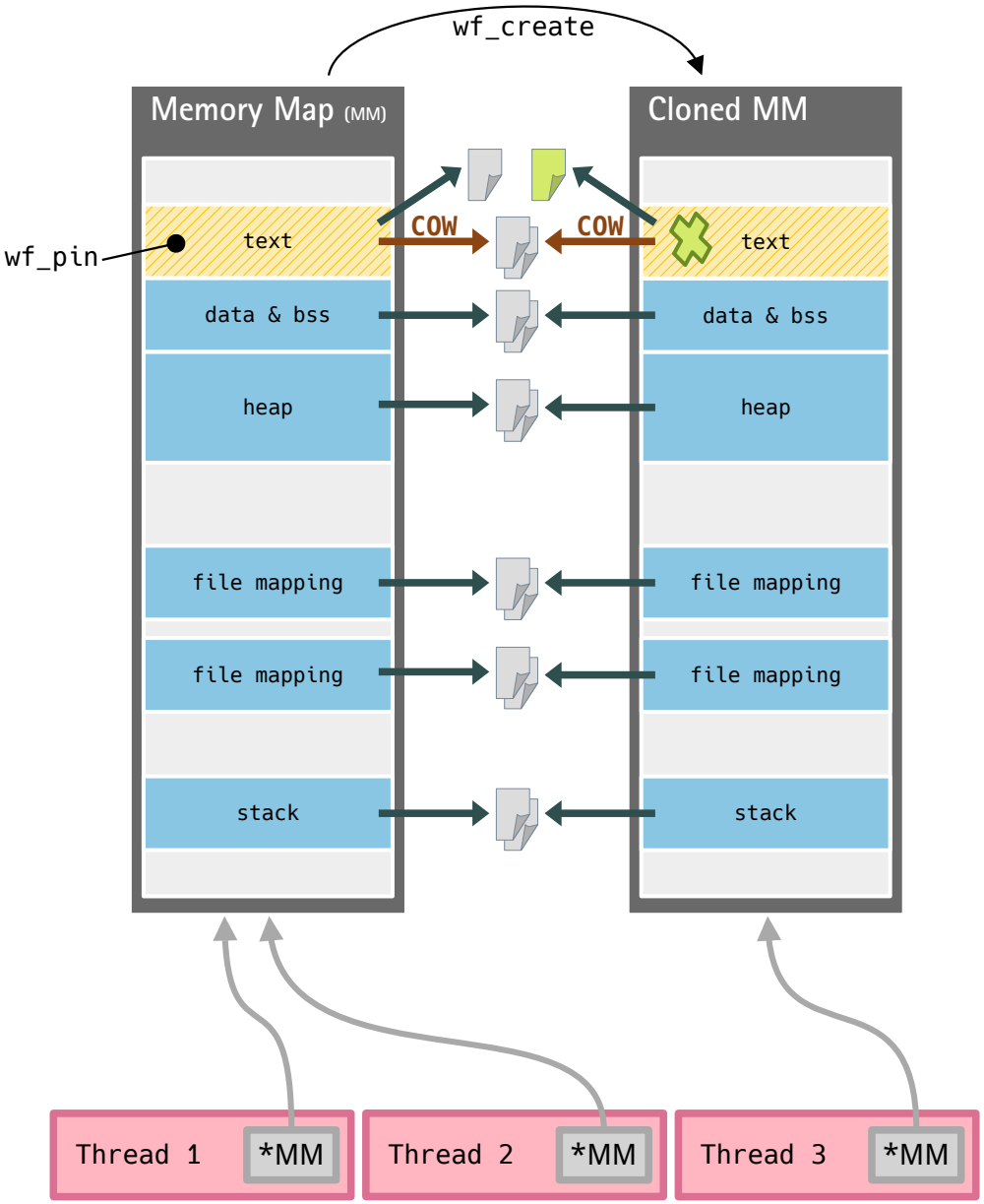

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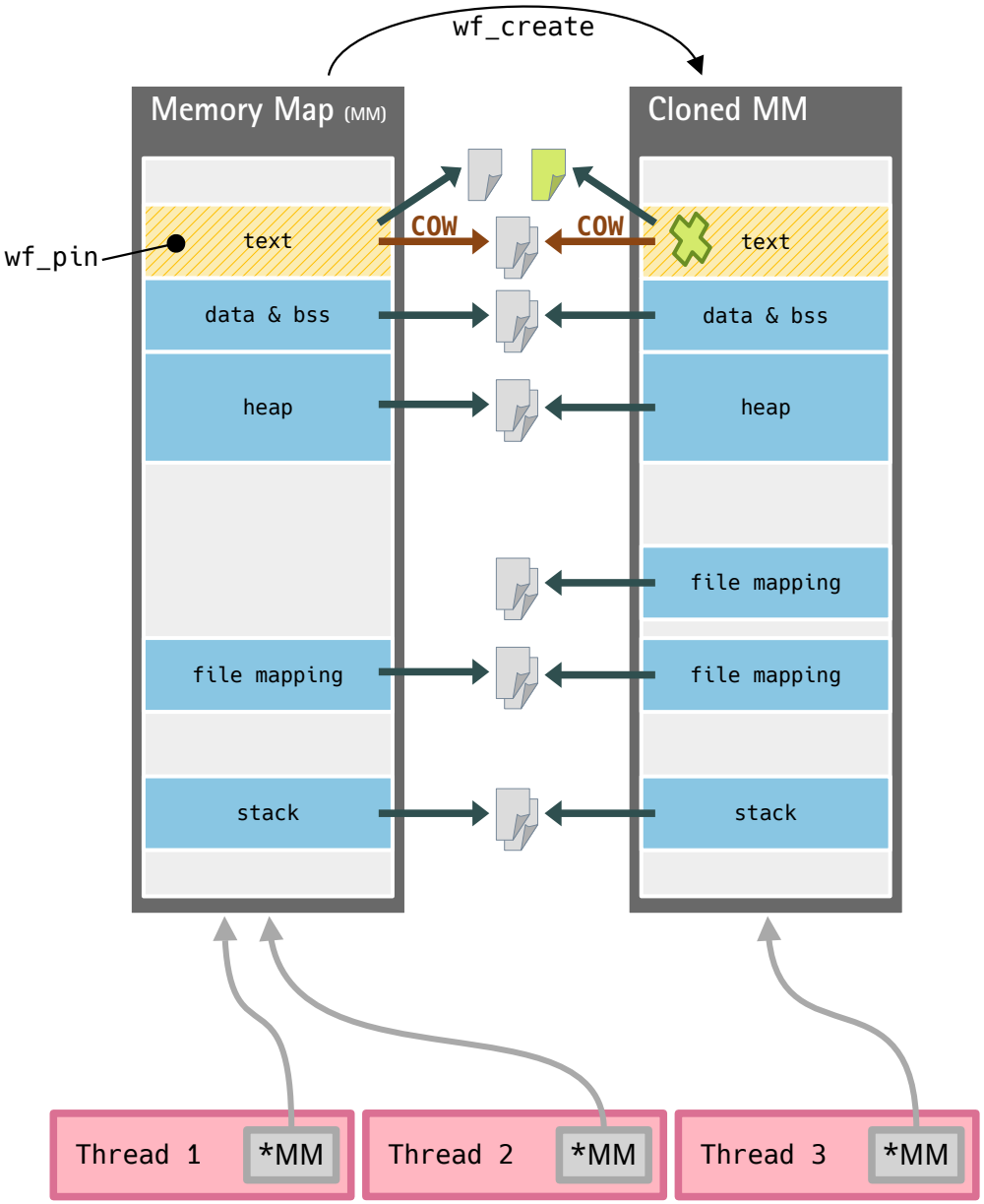

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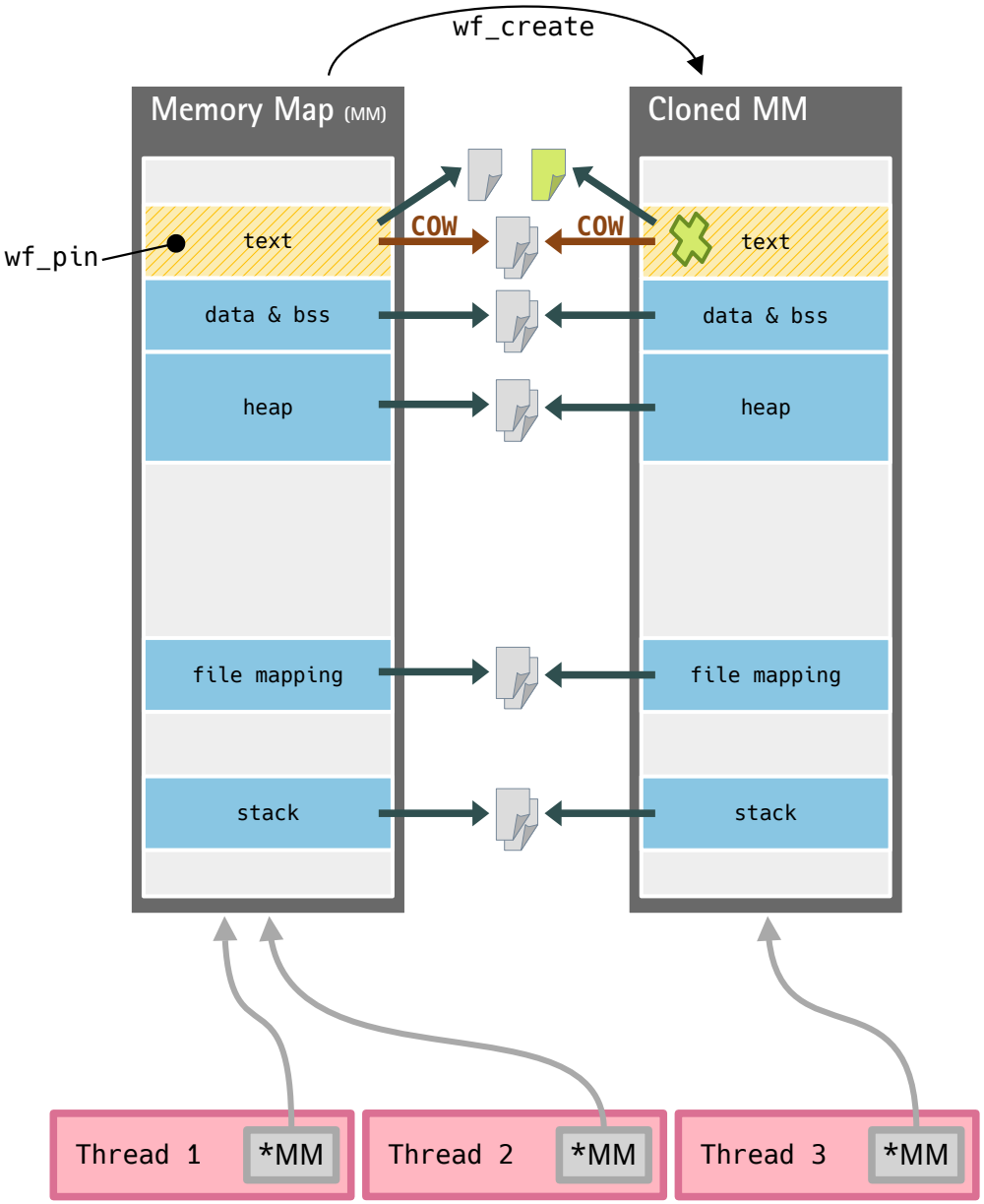

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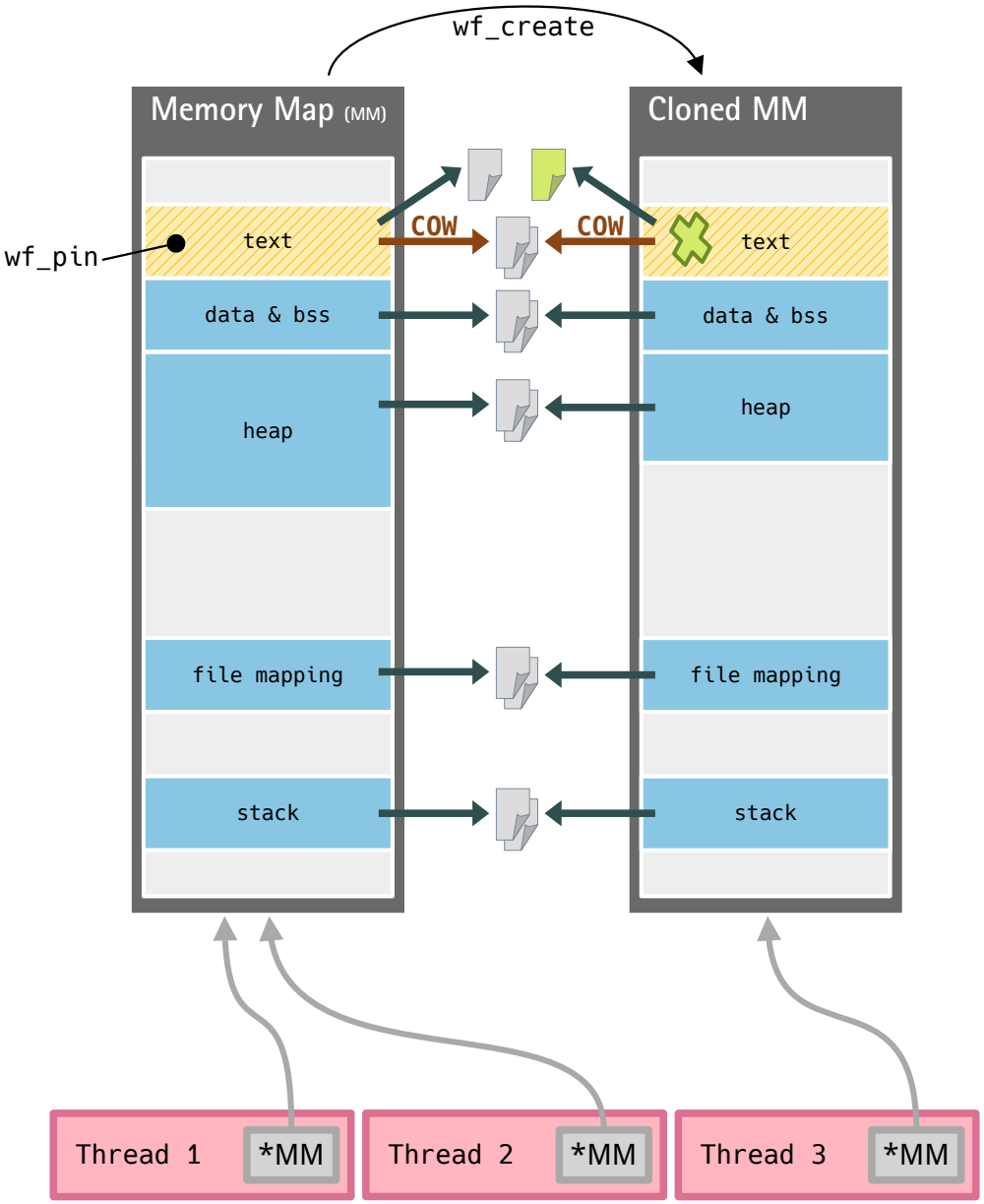

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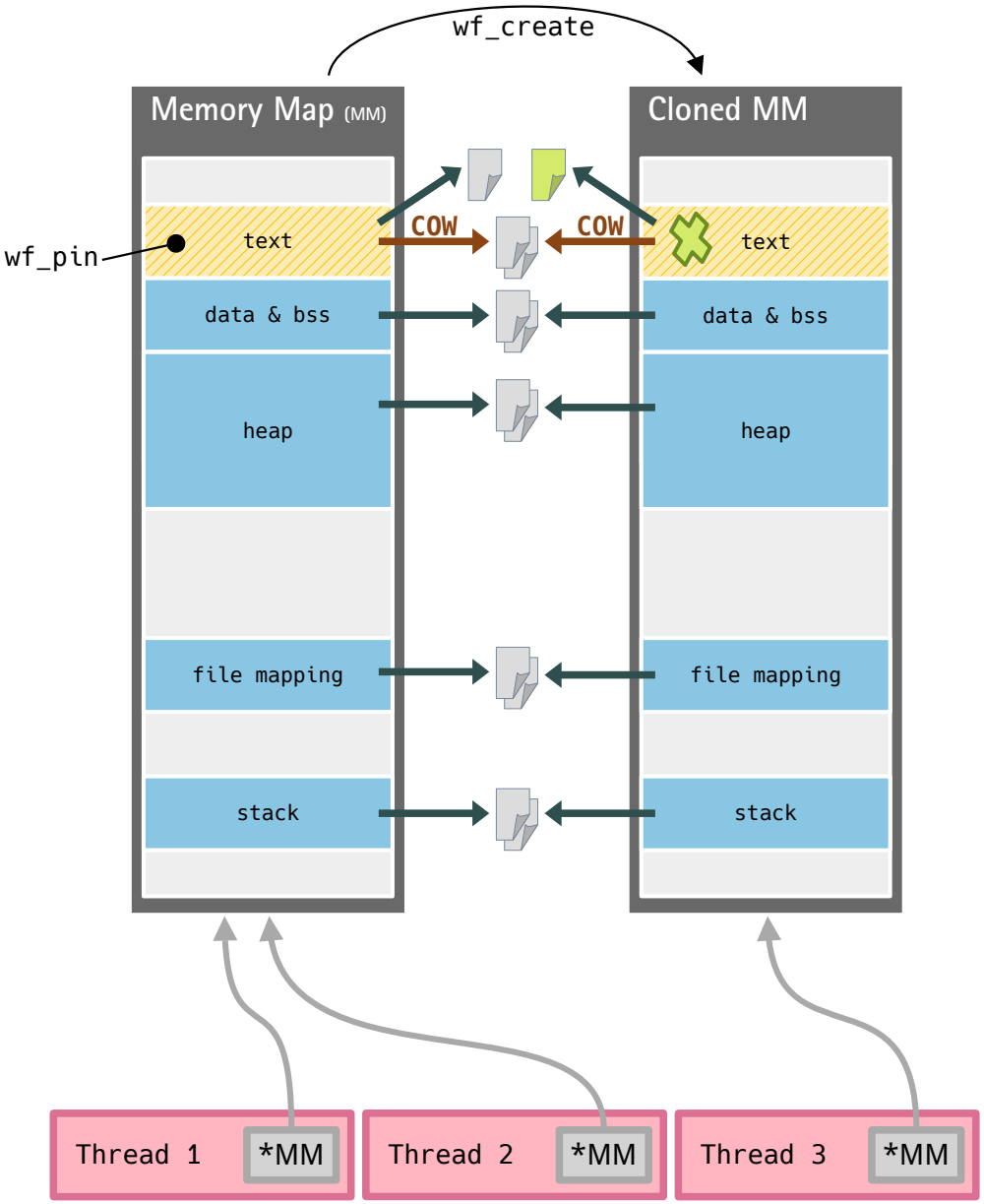

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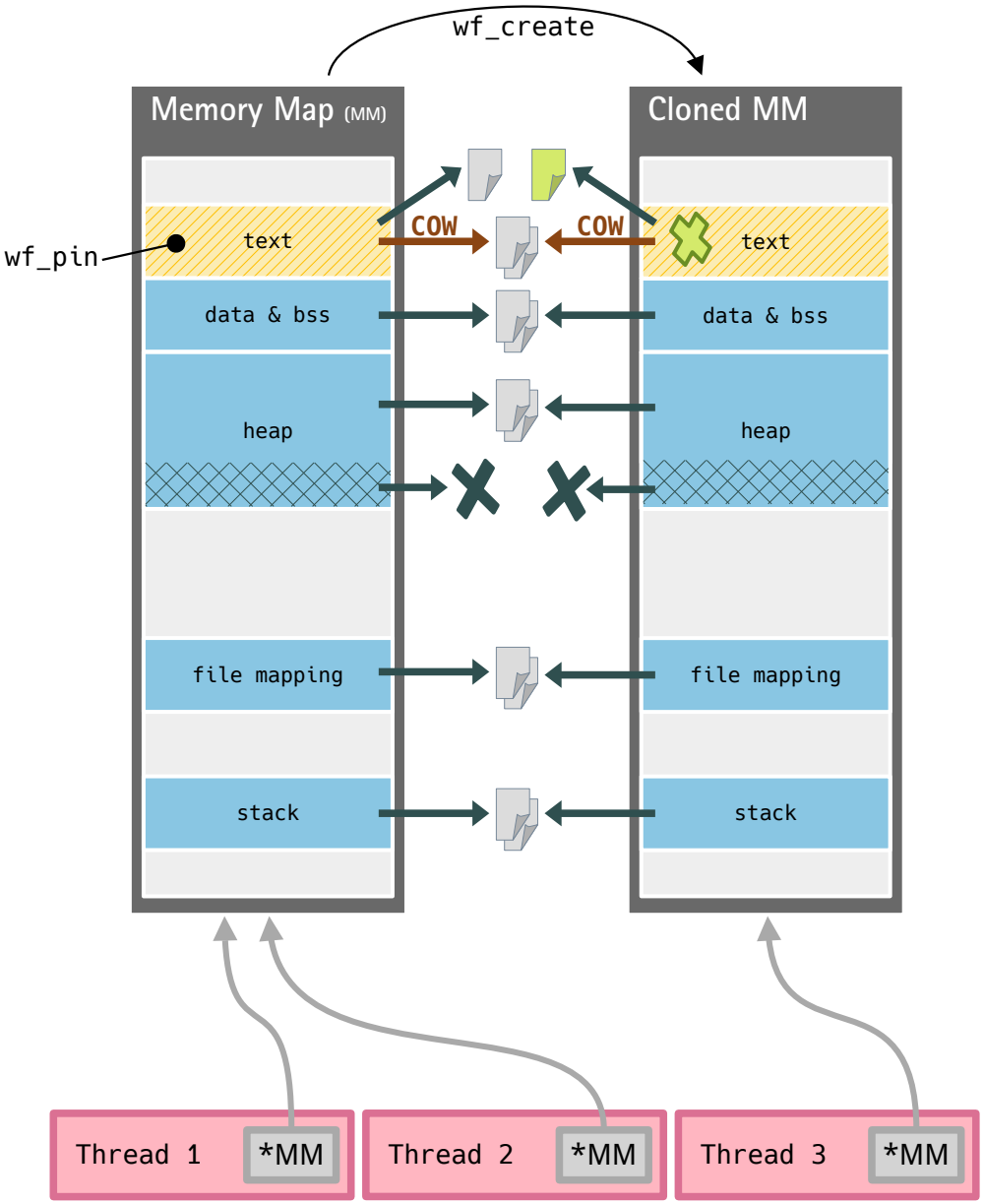

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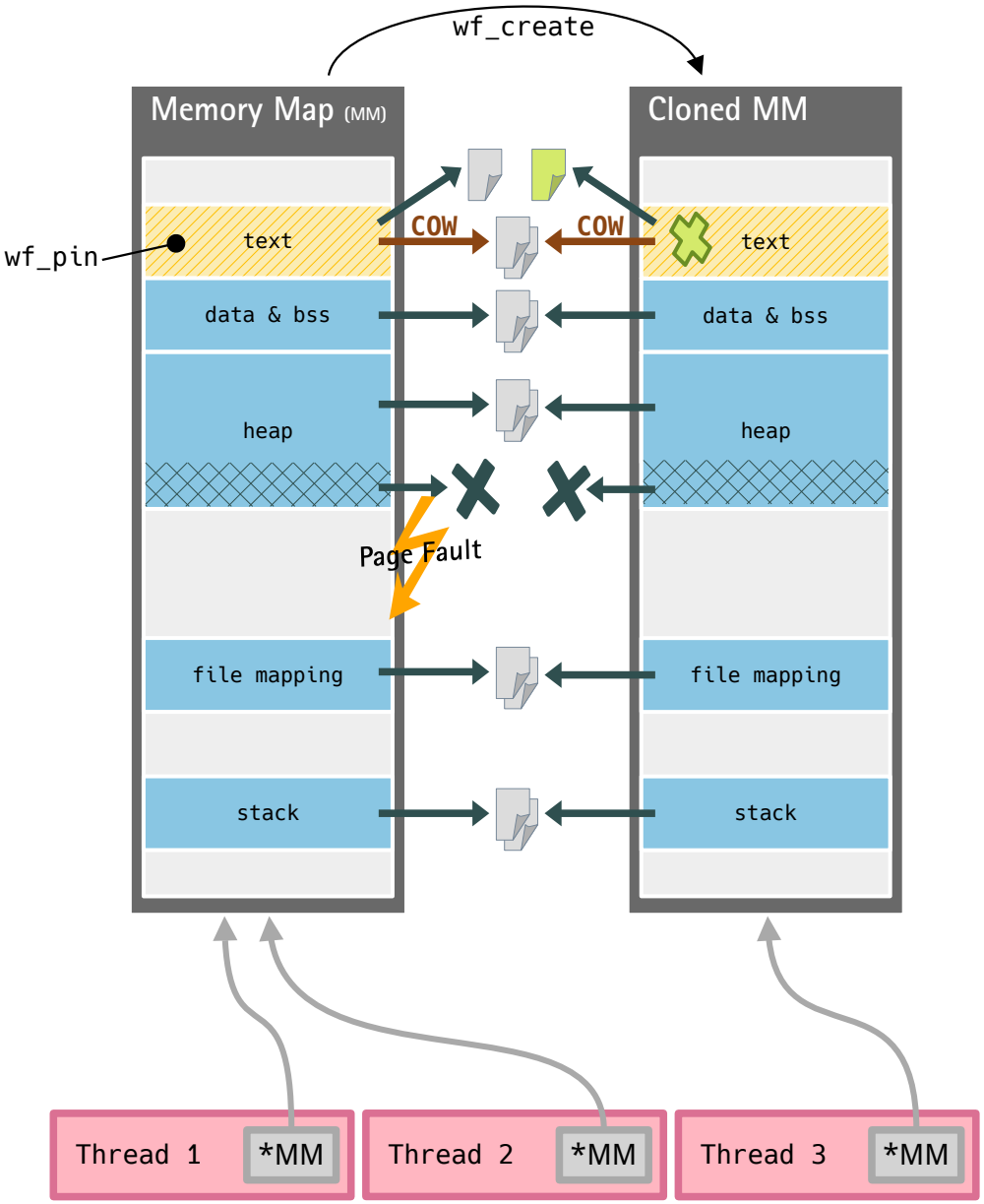

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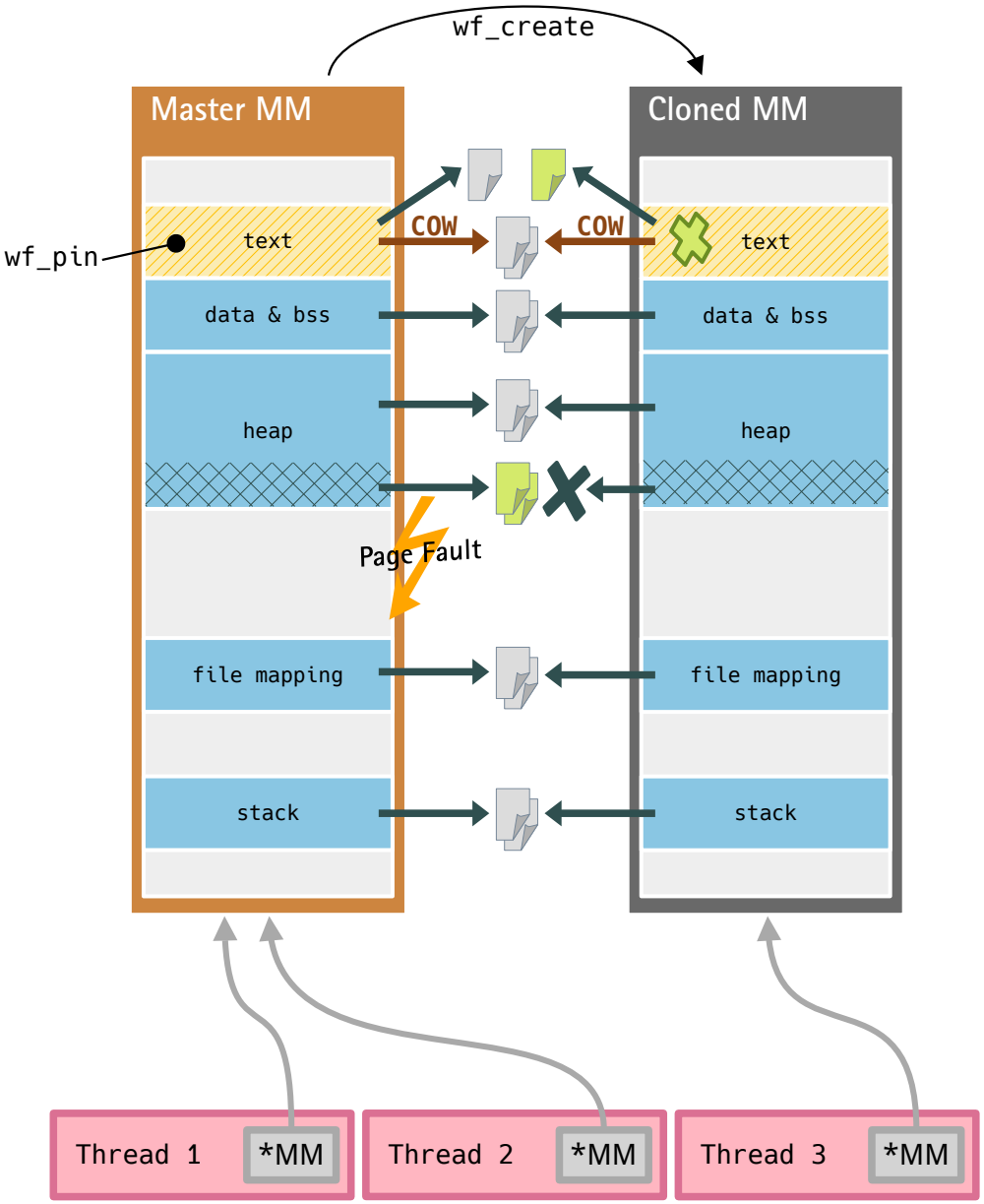

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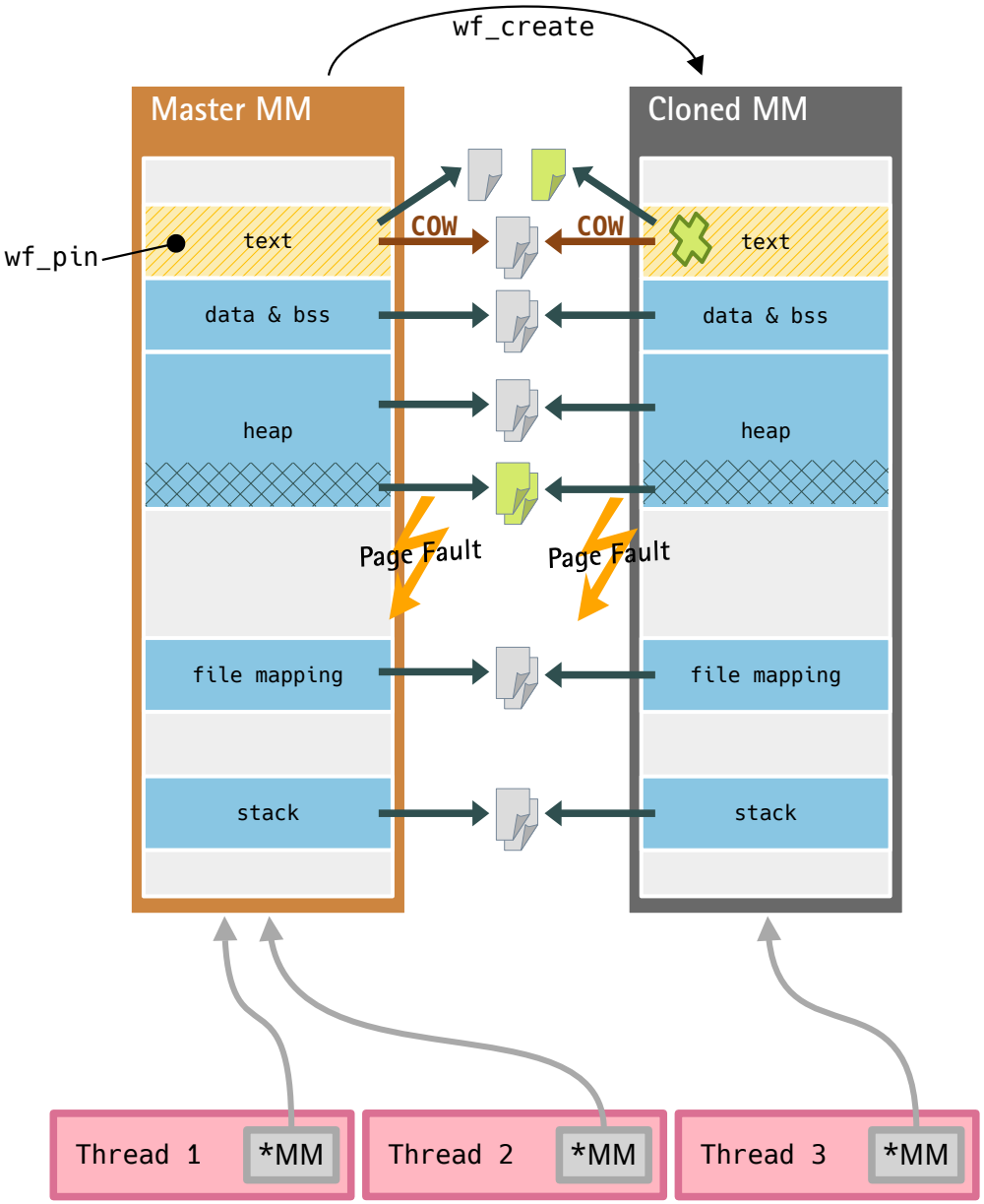

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Debian 10.0 packages and Debian patches (except MariaDB)

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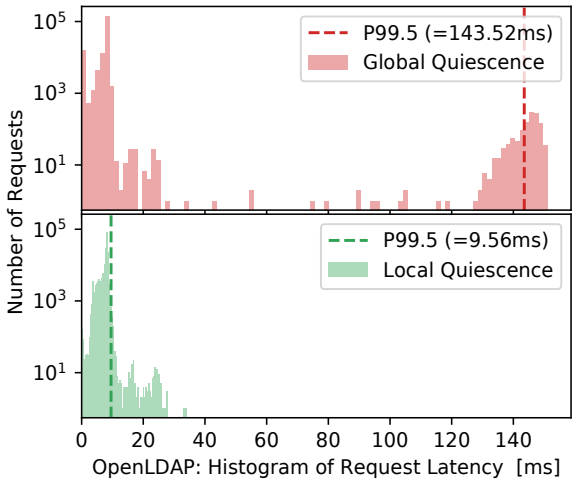
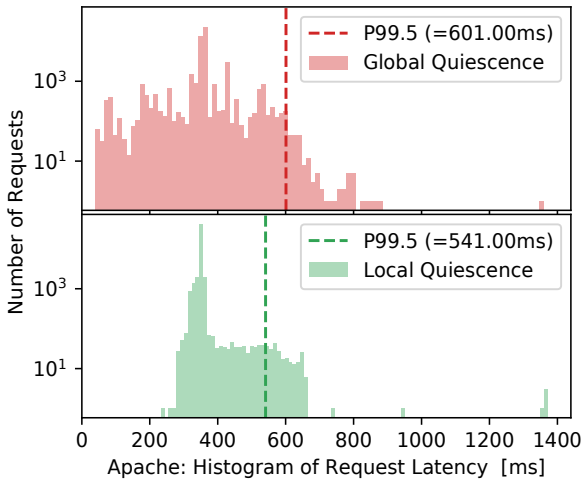
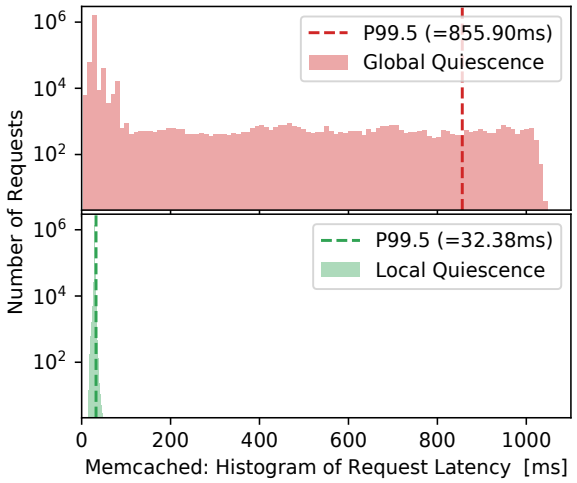
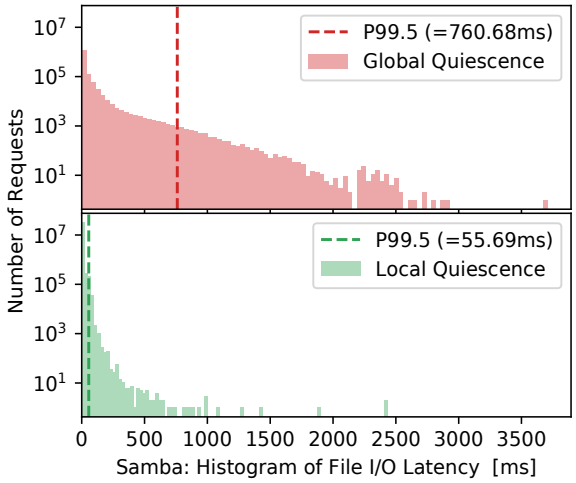
↓ **Generate patches via Kpatch**					39% (47%)	
kpatch'able	9 (2)	7 (7)	1 (1)	2 (2)	16 (5)	0 (0)

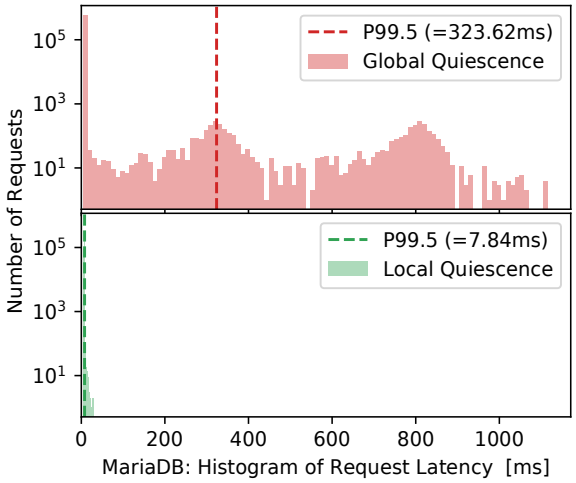
Evaluation: Request Latencies

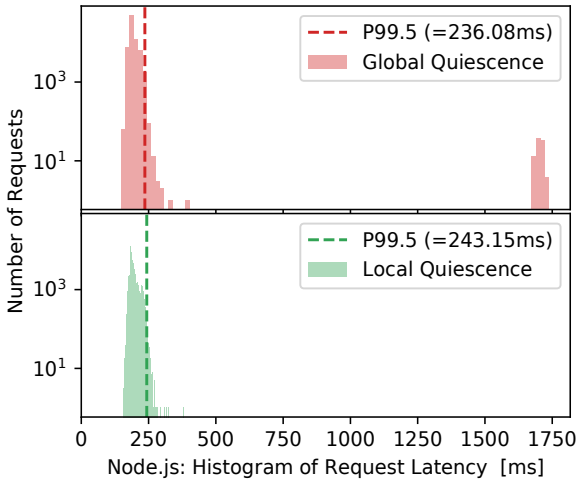












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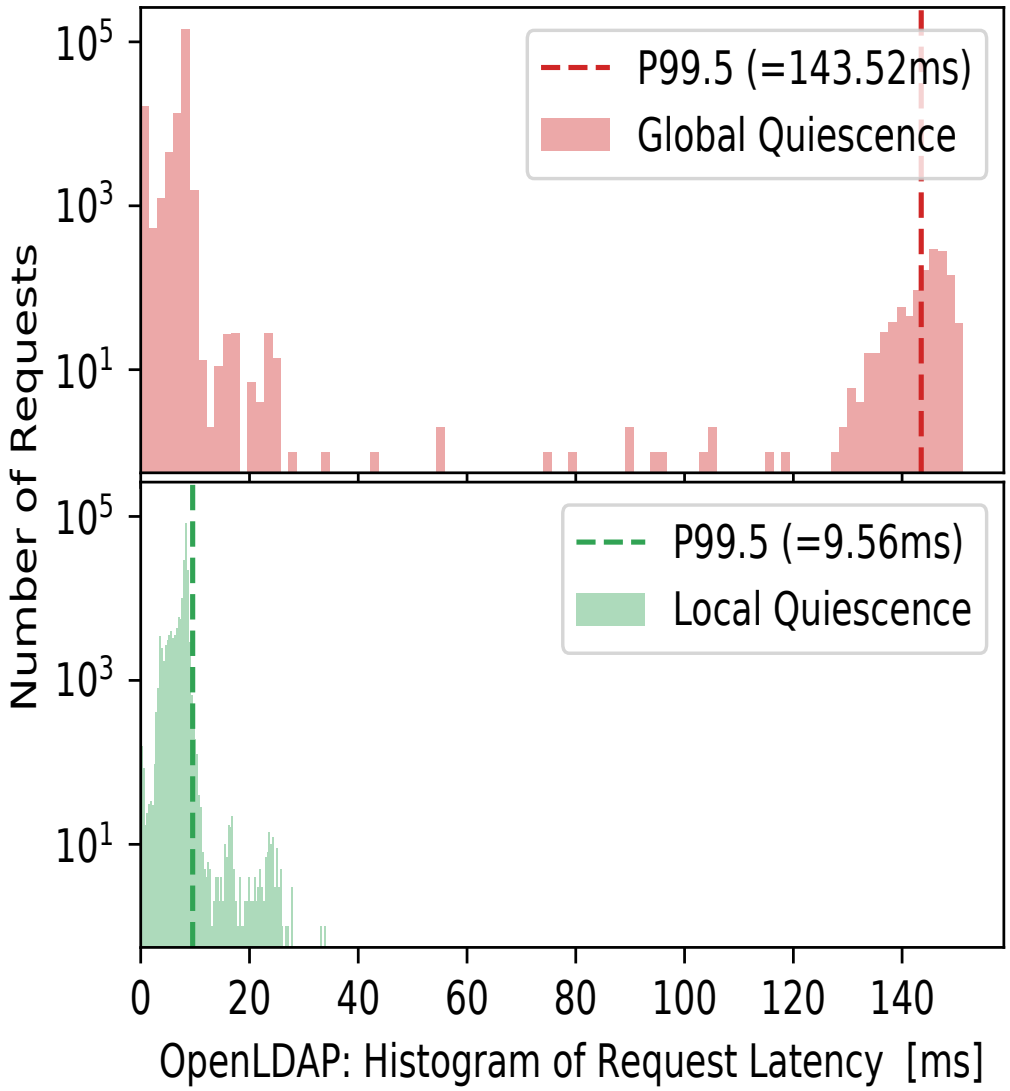

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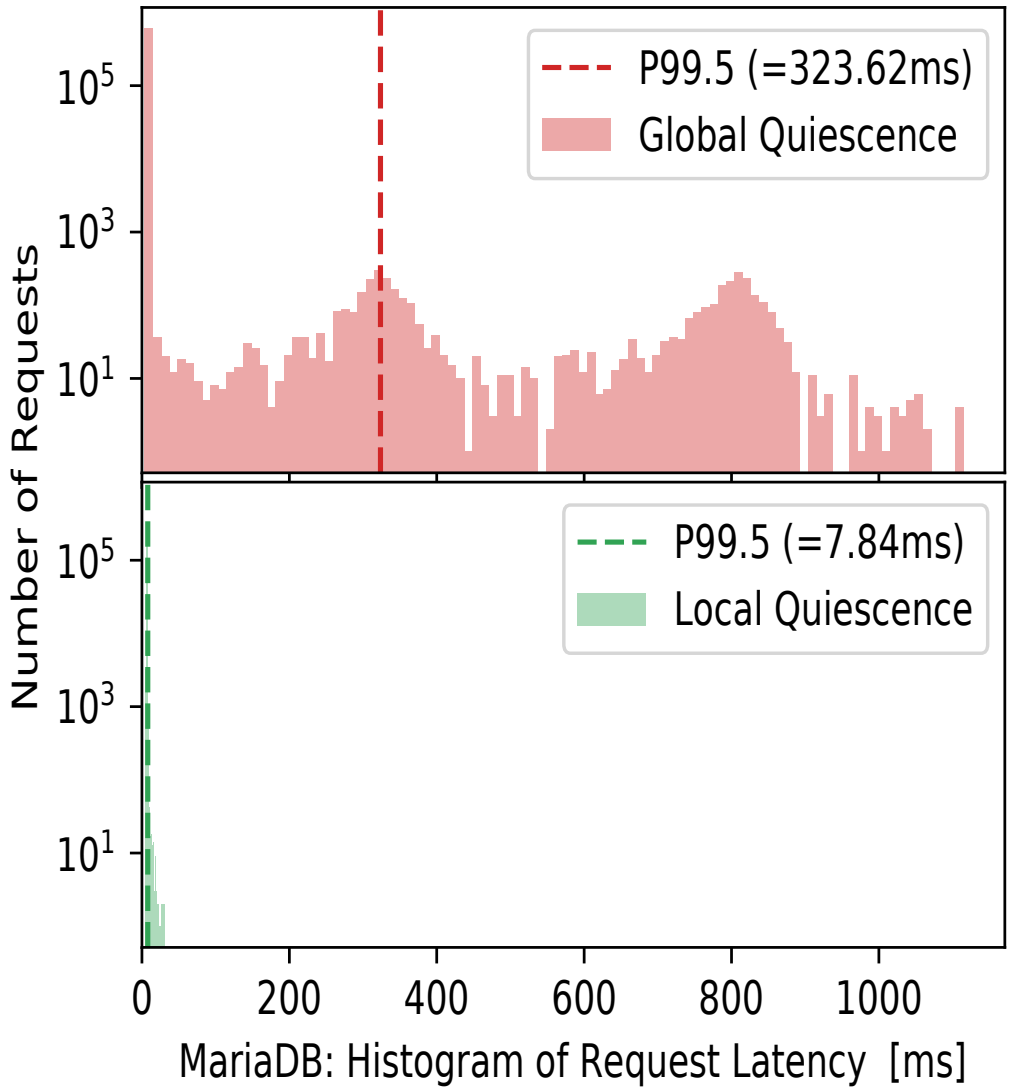

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- Memory (under load):

  132 KiB (Memcached) to **1808 KiB** (Node.js)

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Synchronized address-space clones with partial differences

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Possible applications

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- Path-specific kernel modification (→ Synthesis)
- Implementation of dynamic variability (→ Multiverse)
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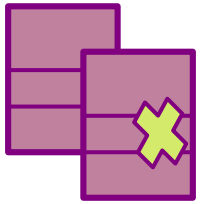
Conclusion



Wait-Free Code Patching
via Address-Space Generations

- Goal: Reduce global quiescence to local quiescence
  - Easier to establish
  - Maintain quality of service
- Approach: Synchronized address-space clones
- Evaluation: 6 server applications
  - Successful application of code-only patches
  - Improved tail latencies during patching

Thank you for your attention.

Try it:
https://www.sra.uni-hannover.de/p/wfpatch

rommel@sra.uni-hannover.de