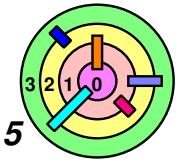
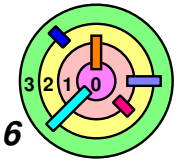
Scheduling in Hard Real Time Systems

- Known chores and durations
  - find schedule satisfying constraints
    - each job has a *completion deadline*
  - uniprocessor
    - rate-monotonic scheduling of *cyclic chores*, i.e., *periodic tasks*
      - $t_i \rightarrow T_i, P_i$ where T is *execution time* and P is *period*
      - e.g., a job is required to execute 2 seconds every 6 seconds
      - deadline is implied
    - Earliest Deadline First (EDF)
      - $t_i \rightarrow d_i$ where d is a *deadline*
      - optimality proof exists under certain conditions
  - multiprocessor
    - often NP-complete ...



Assumptions

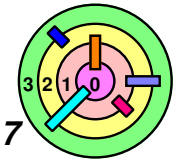
- Interrupts don't interfere (too much) with schedule
  - bounded interrupt delays
- Execution time really is predictable
  - what about effects of caching and paging?



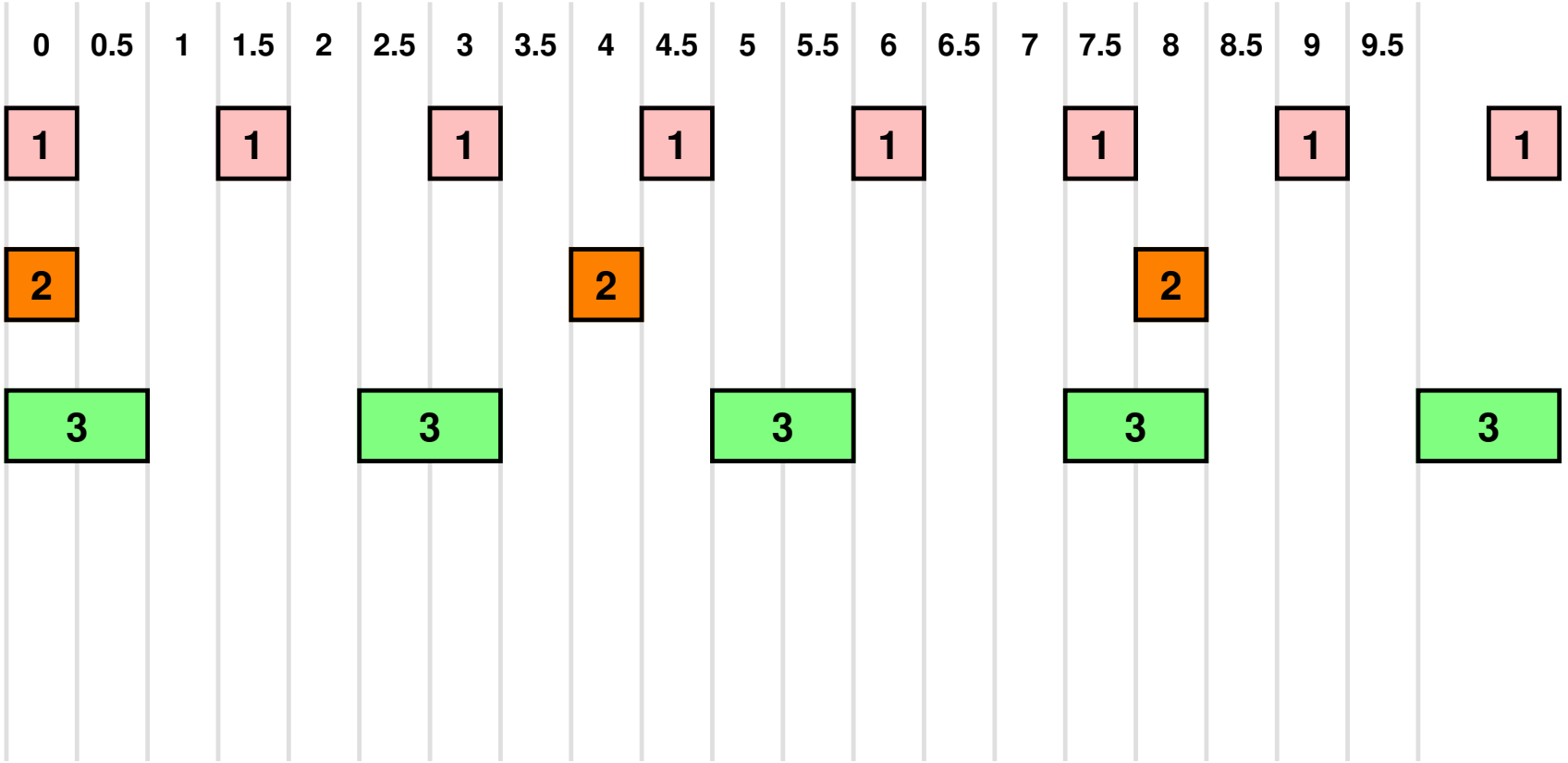
Rate-Monotonic Scheduling

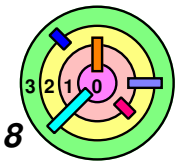
- **Periodic chores**
  - period P_i
  - *per-cycle* processing time $T_i \ (\leq P_i)$
    - T_i / P_i is the *utilization (or "duty cycle")* of chore *i*
  - necessary condition for feasibility: $\sum_{i=0}^{n-1} (T_i / P_i) \leq 1$
- **Rate-monotonic scheduling**
  - each chore *i* is handled by a thread with *priority* $1/P_i$
  - *preemptive*, *priority scheduling*
  - works when $\sum_{i=0}^{n-1} (T_i / P_i) \leq n(2^{1/n}-1)$
  - $= \ln 2 \approx 0.6931$ in the limit

n	$n(2^{1/n}-1)$
1	1
2	0.8284
3	0.7798
4	0.7568
5	0.7435
...	...



Scenario 1





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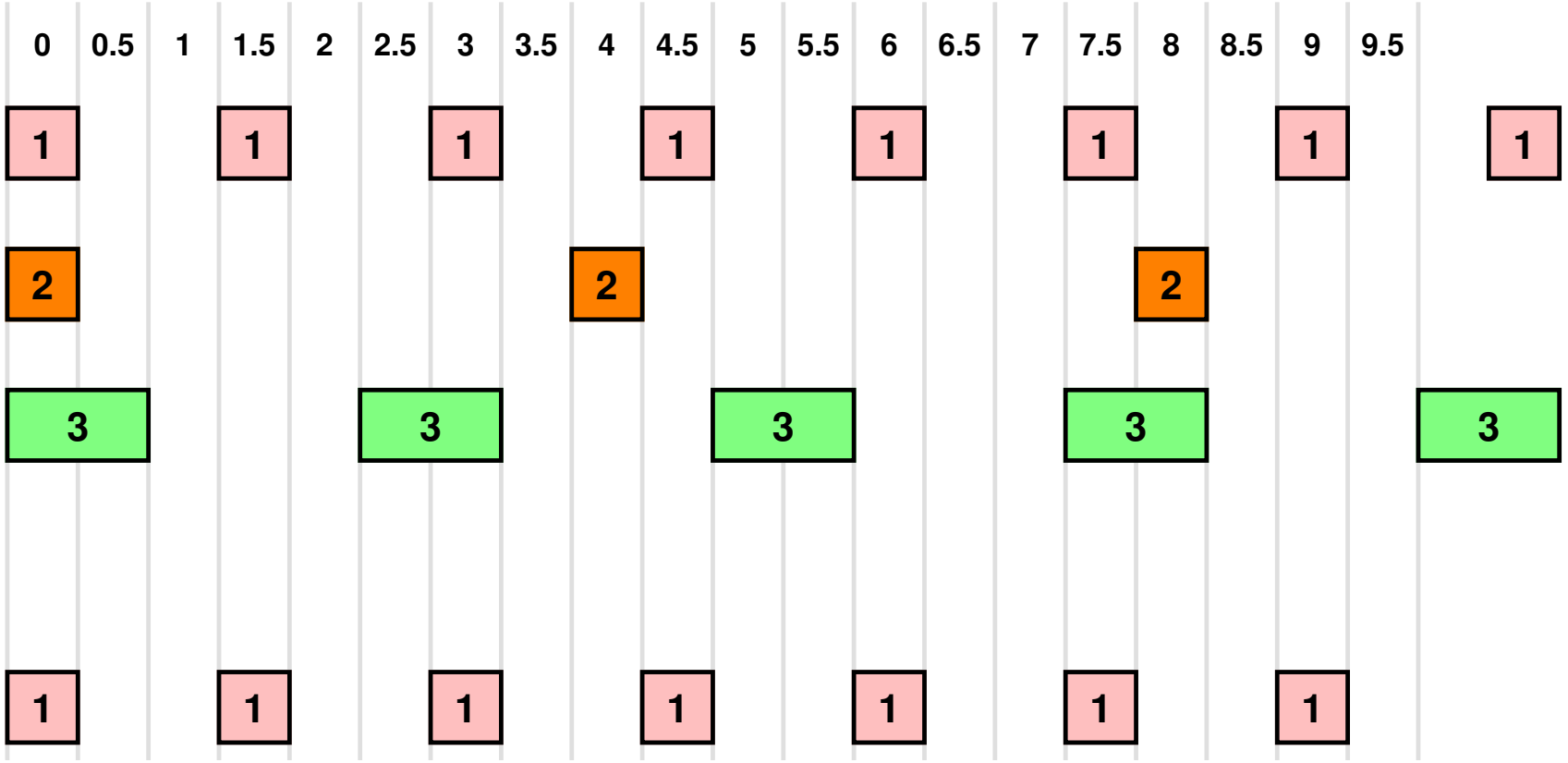

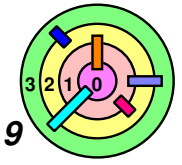

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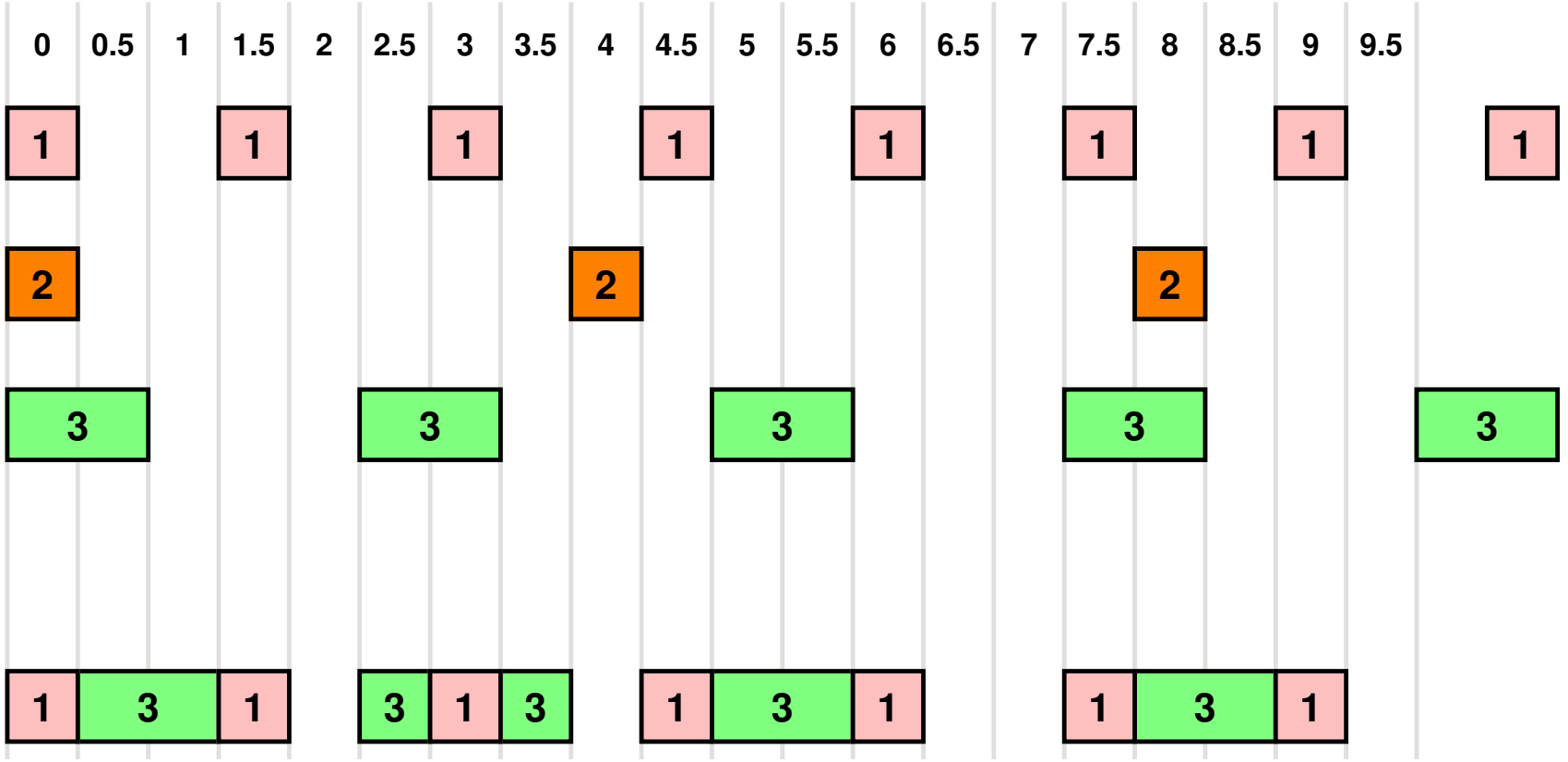

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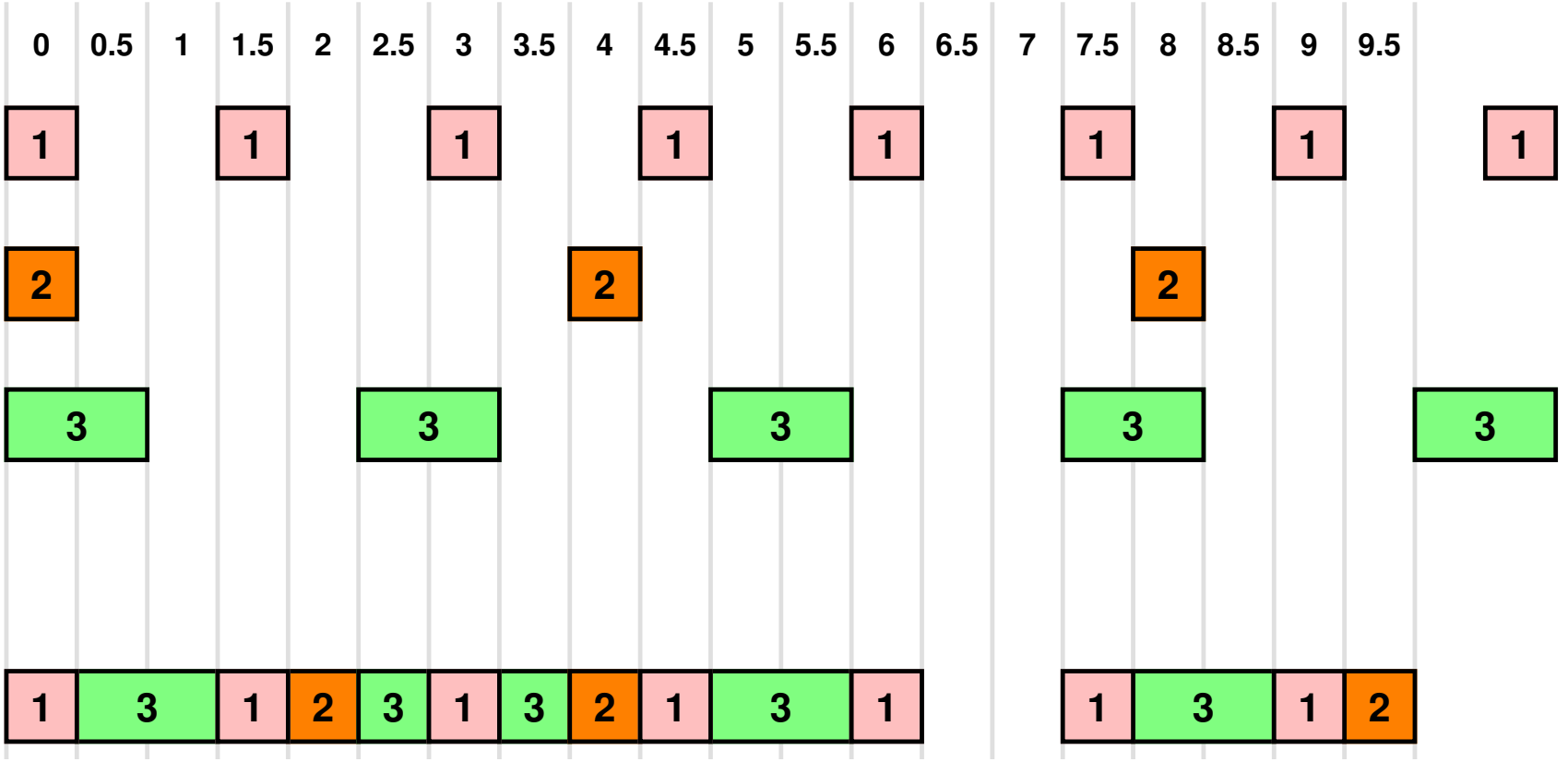
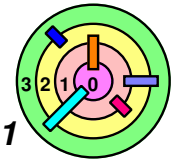


- rate-monotonic scheduler succeeded
  - need to simulate till time = 60 to be certain



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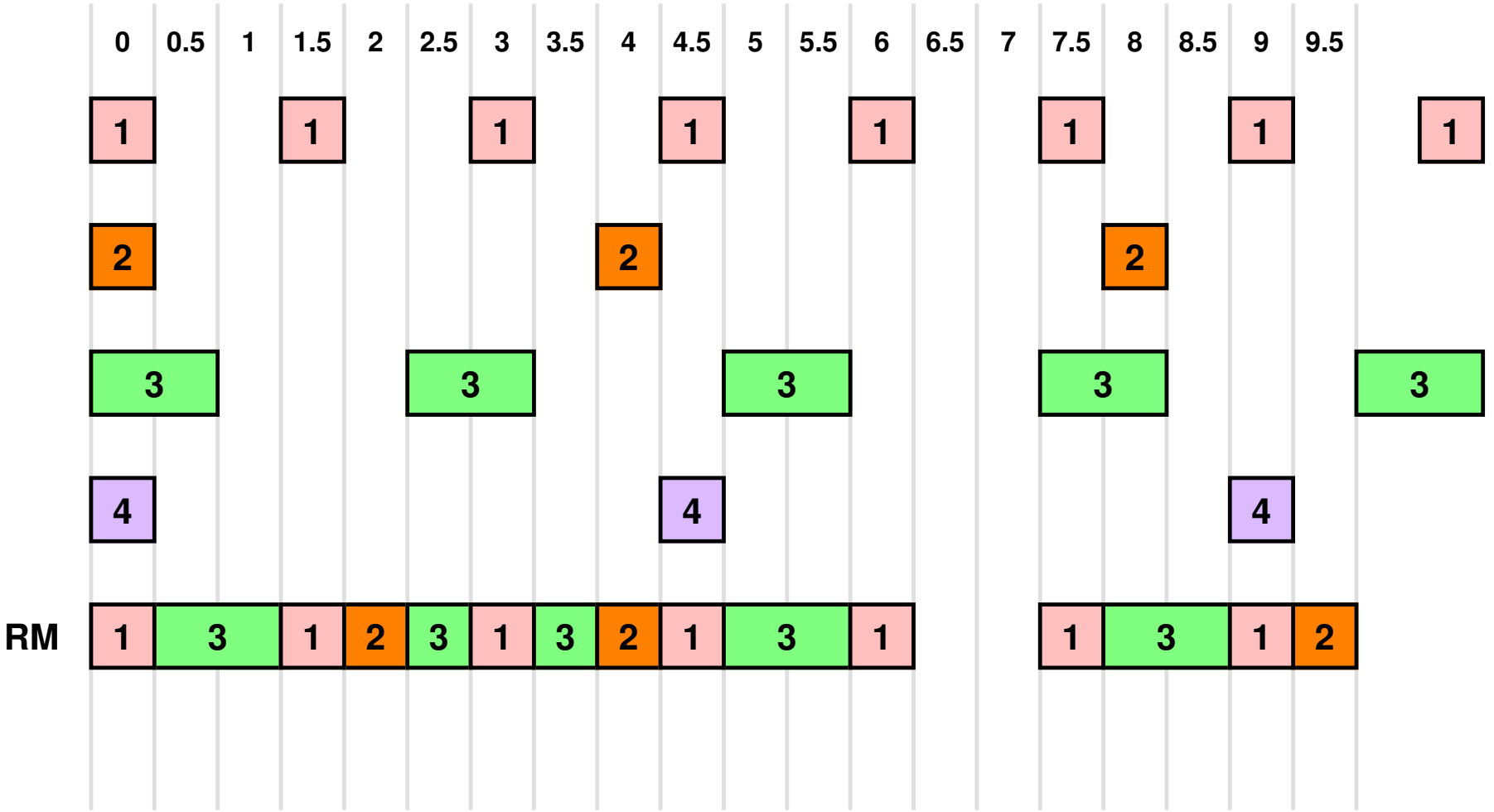
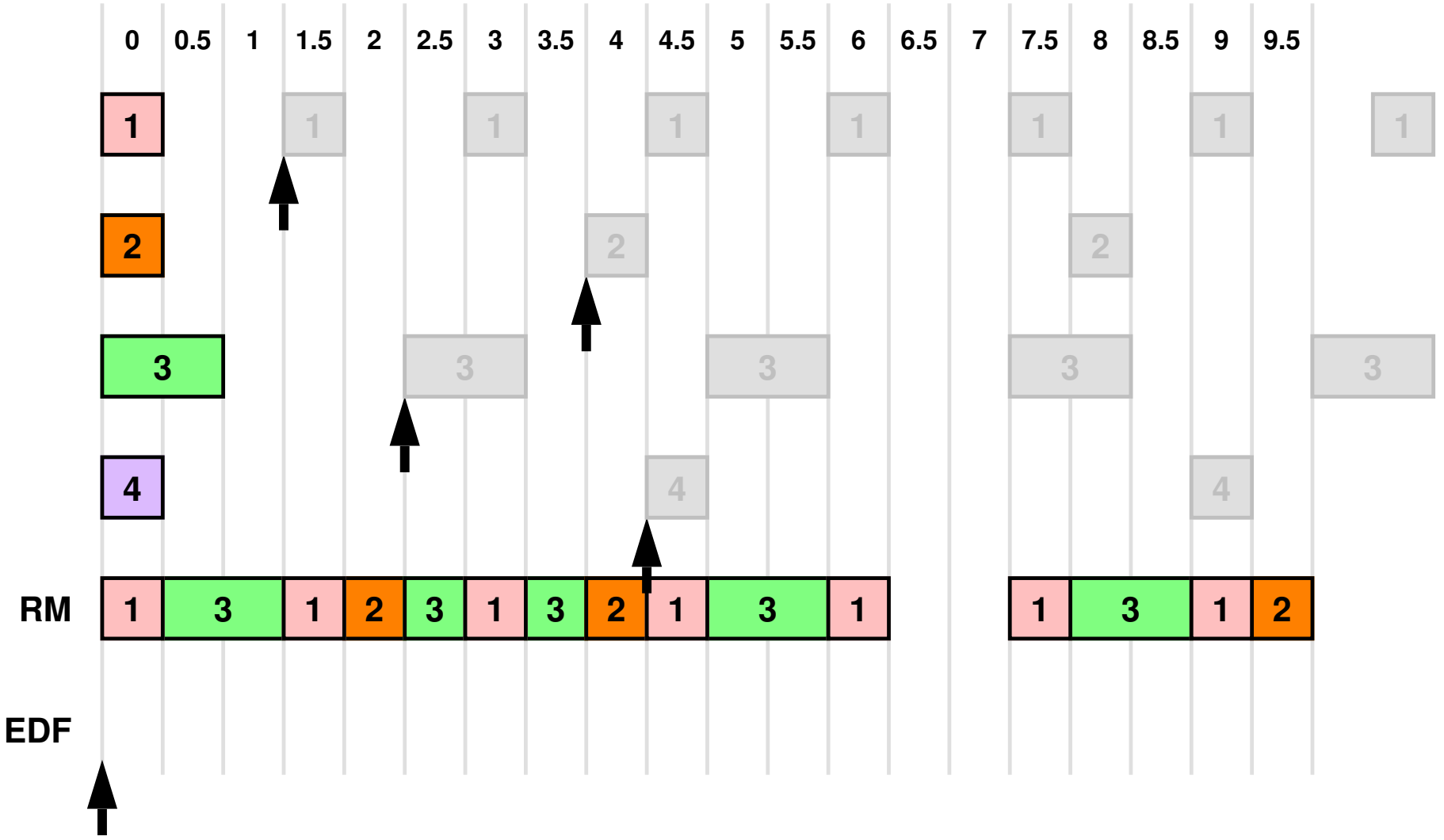


- rate-monotonic scheduler would fail in this case
- try EDF

Earliest Deadline First



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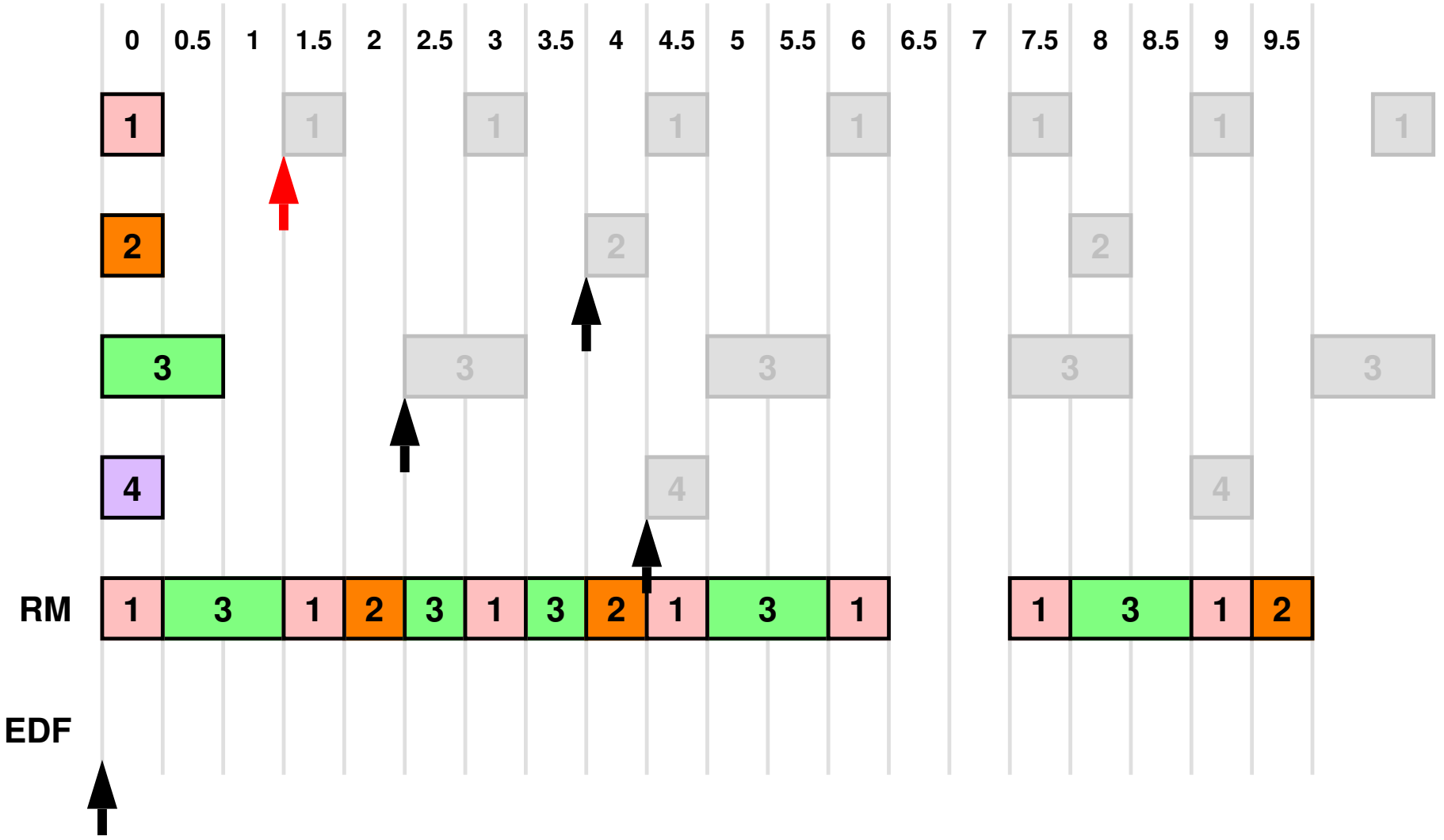

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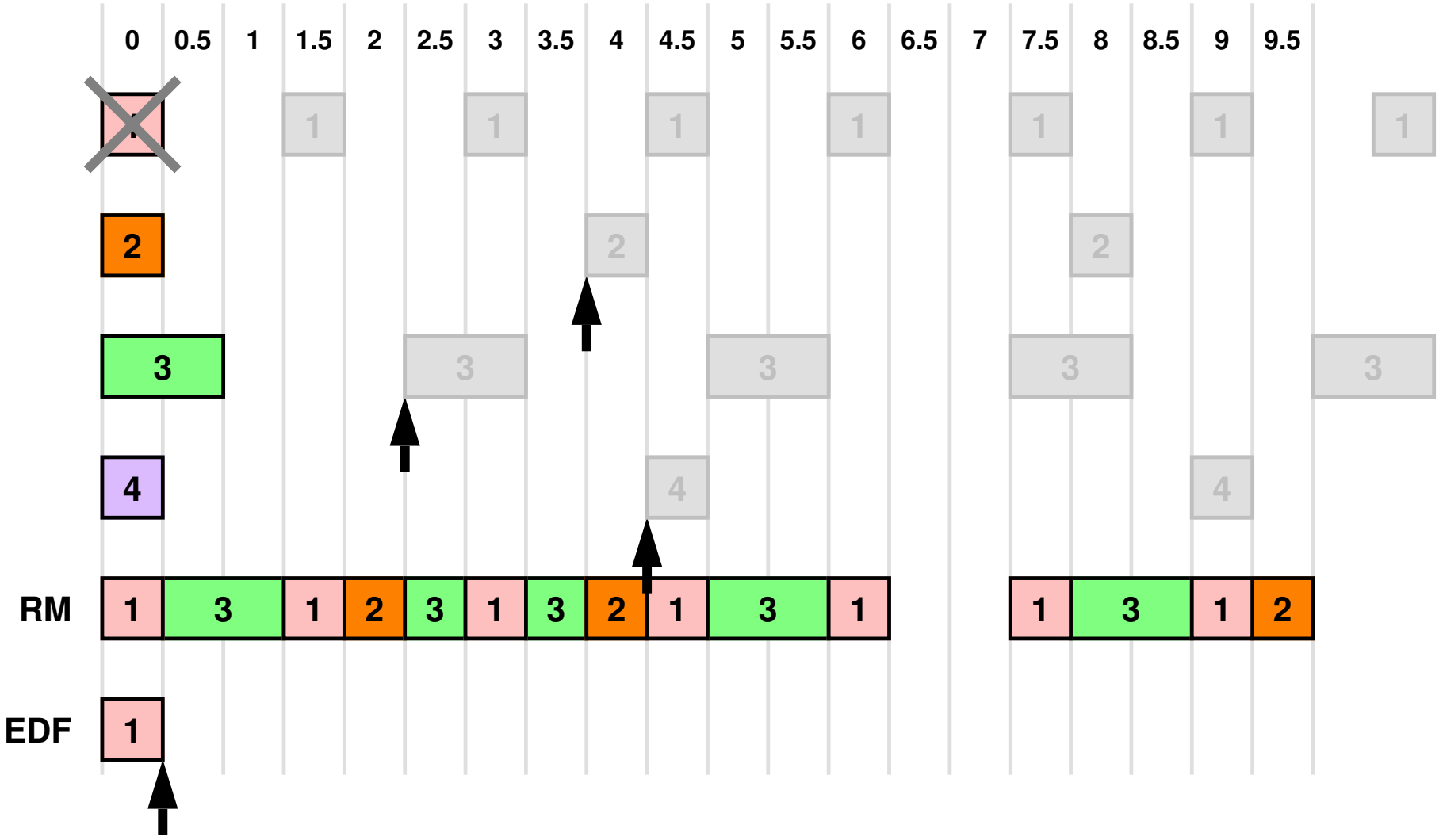

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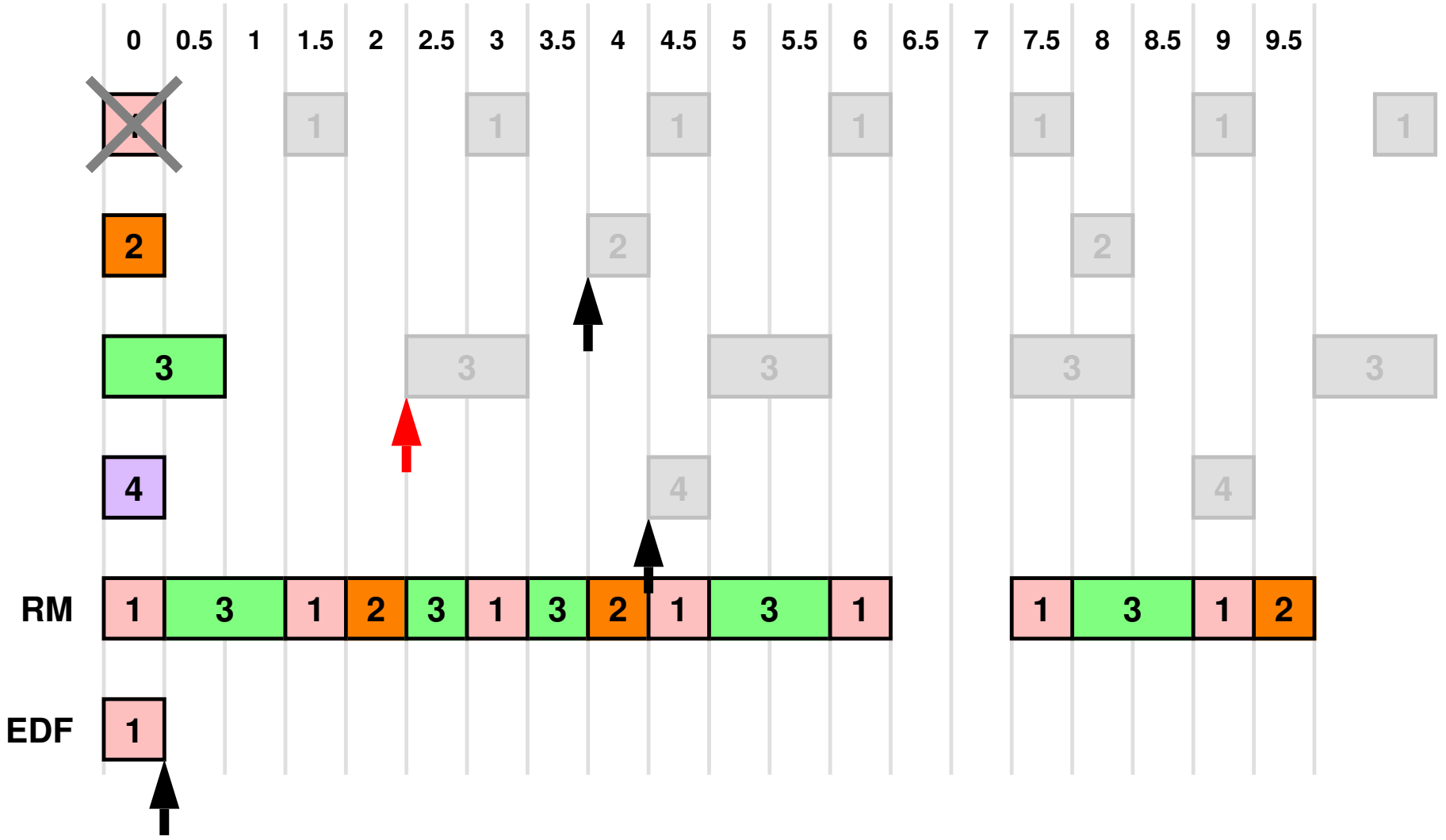

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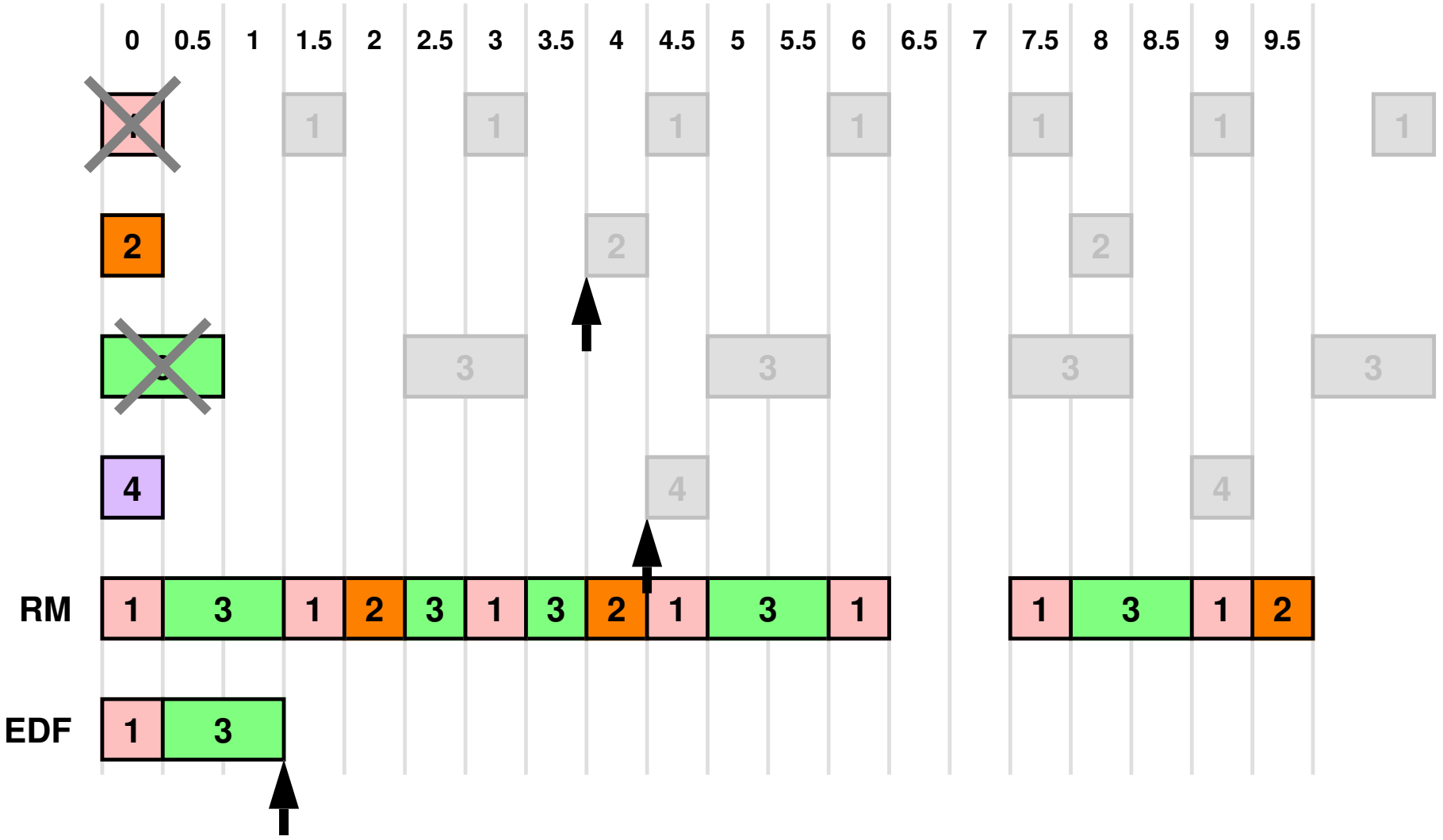

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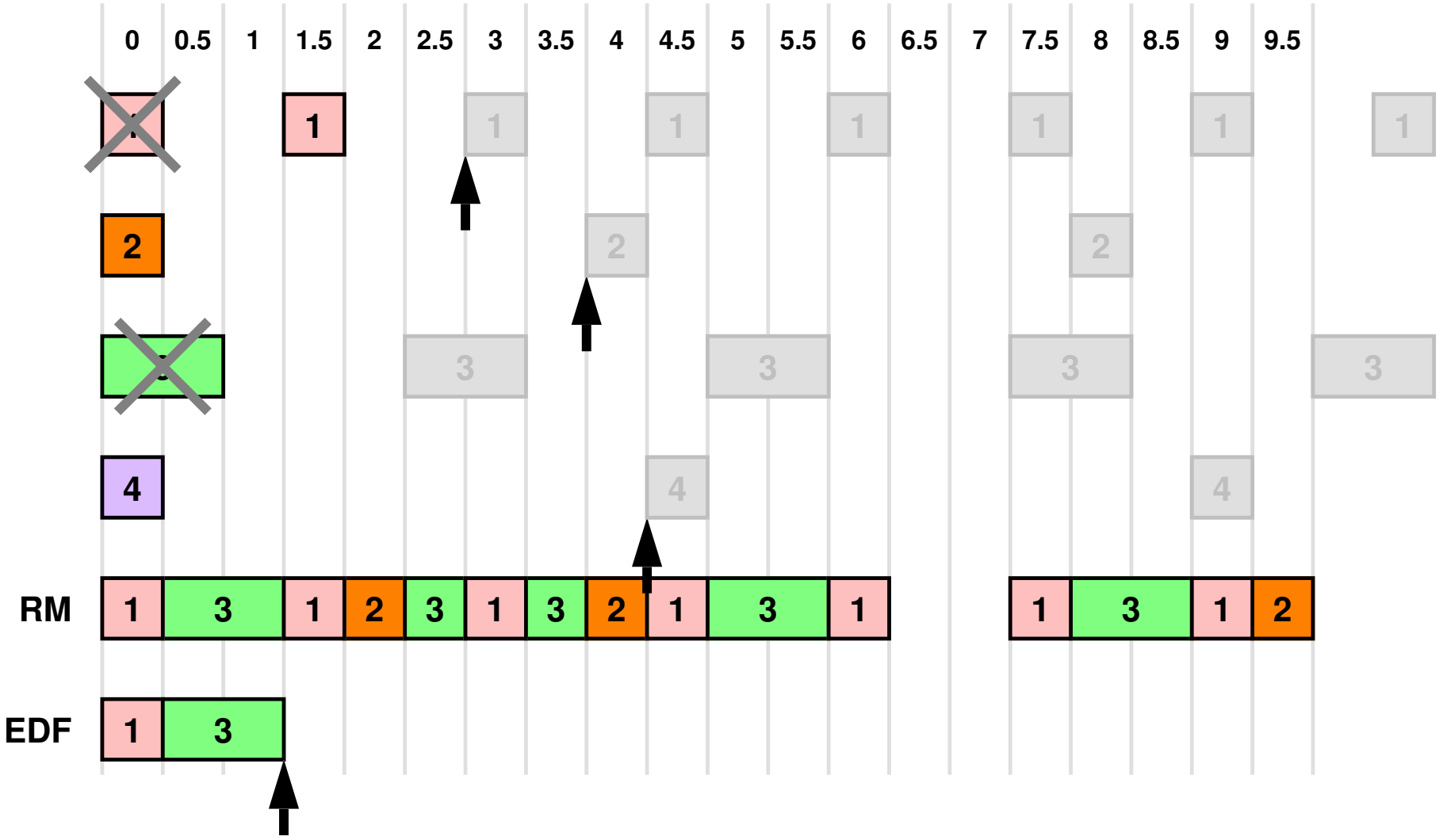

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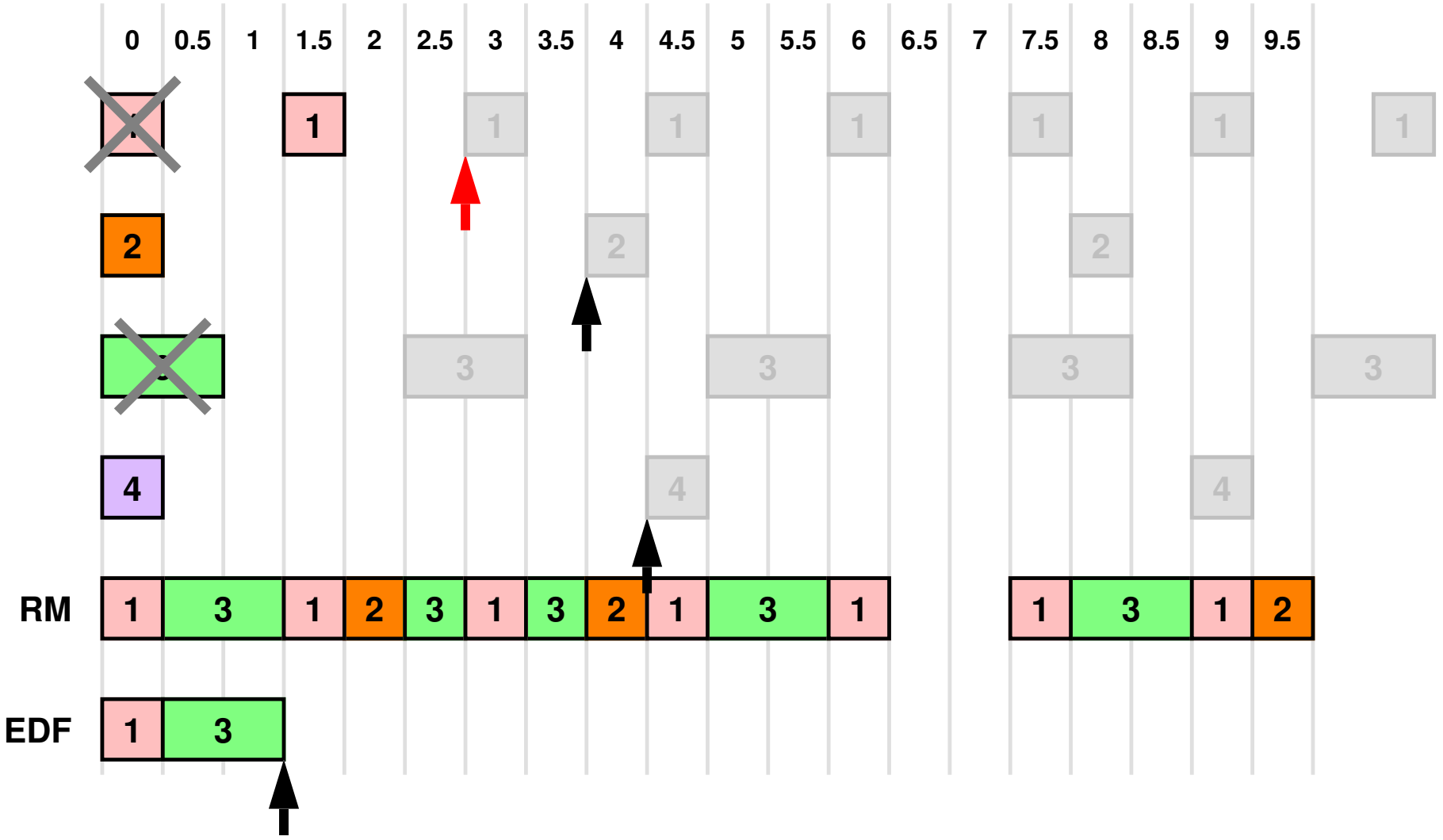

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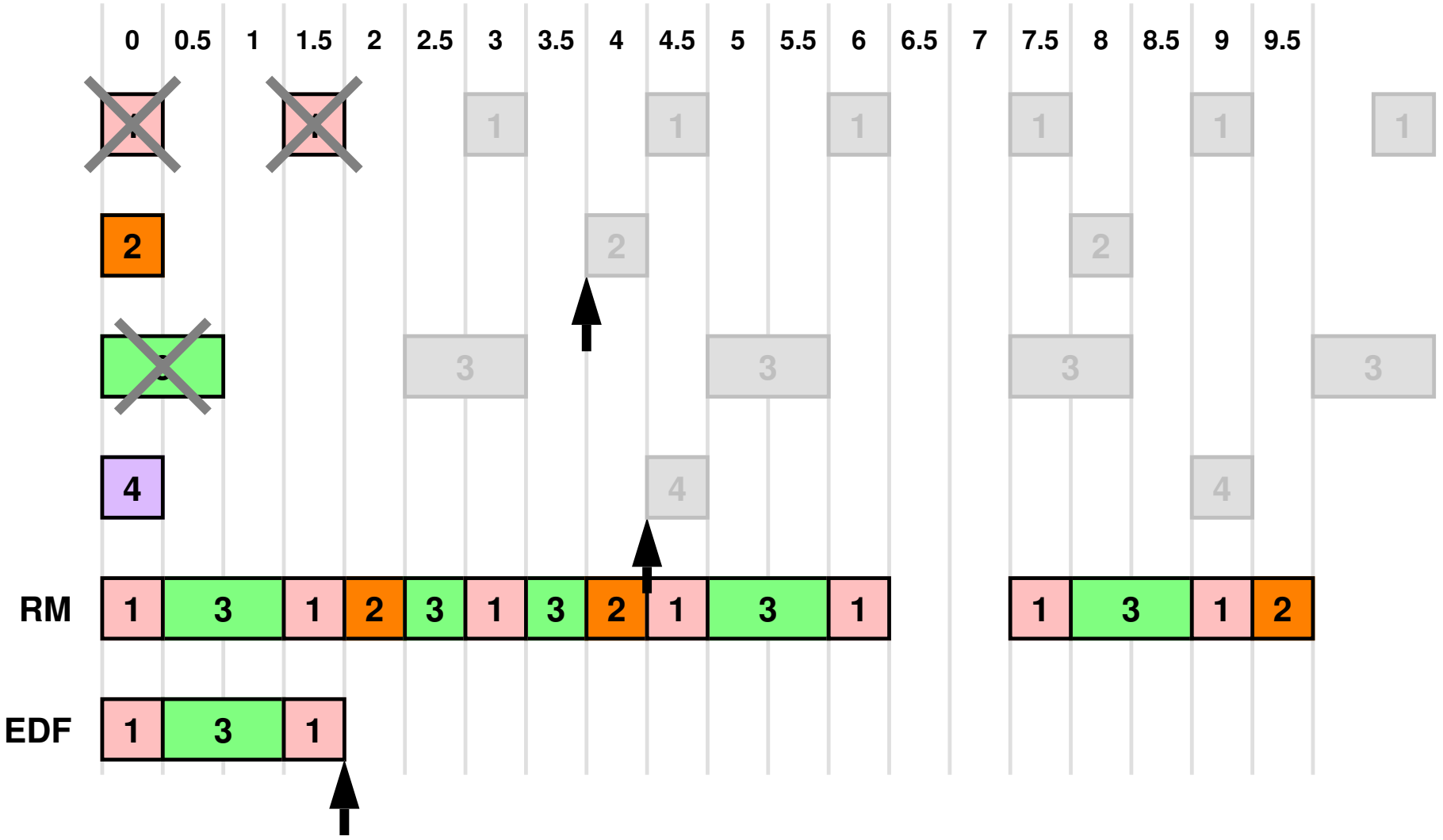

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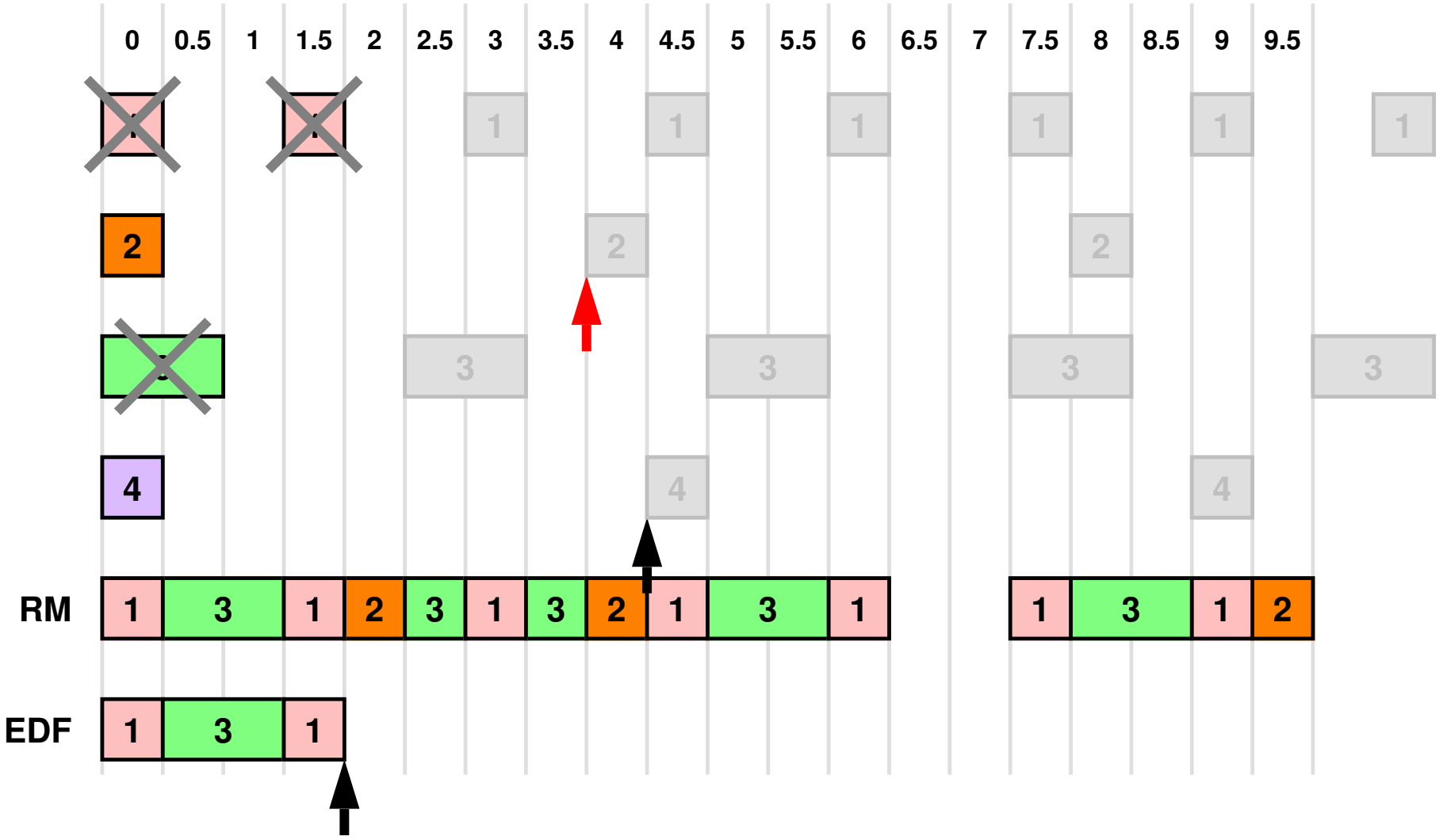

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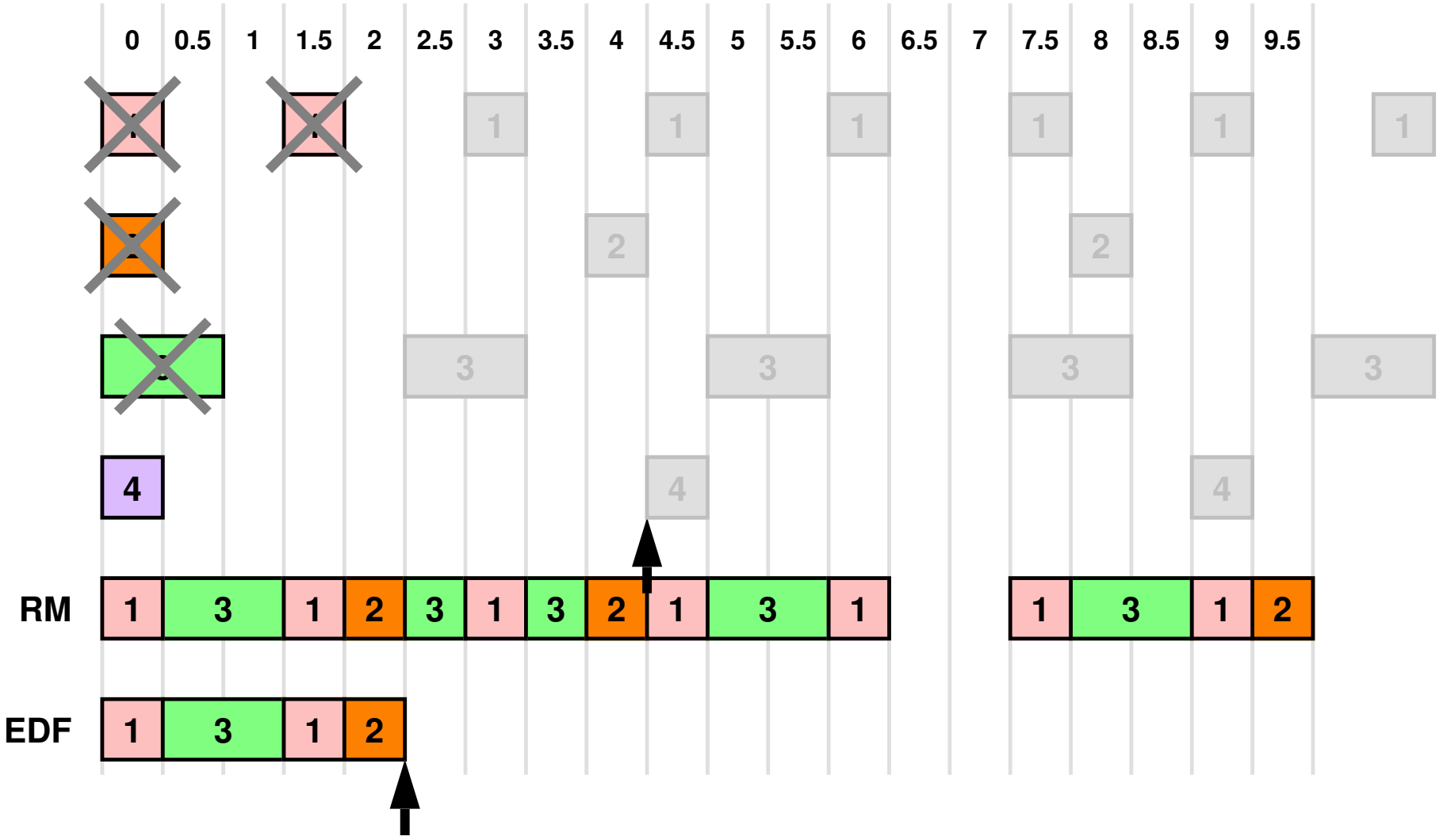

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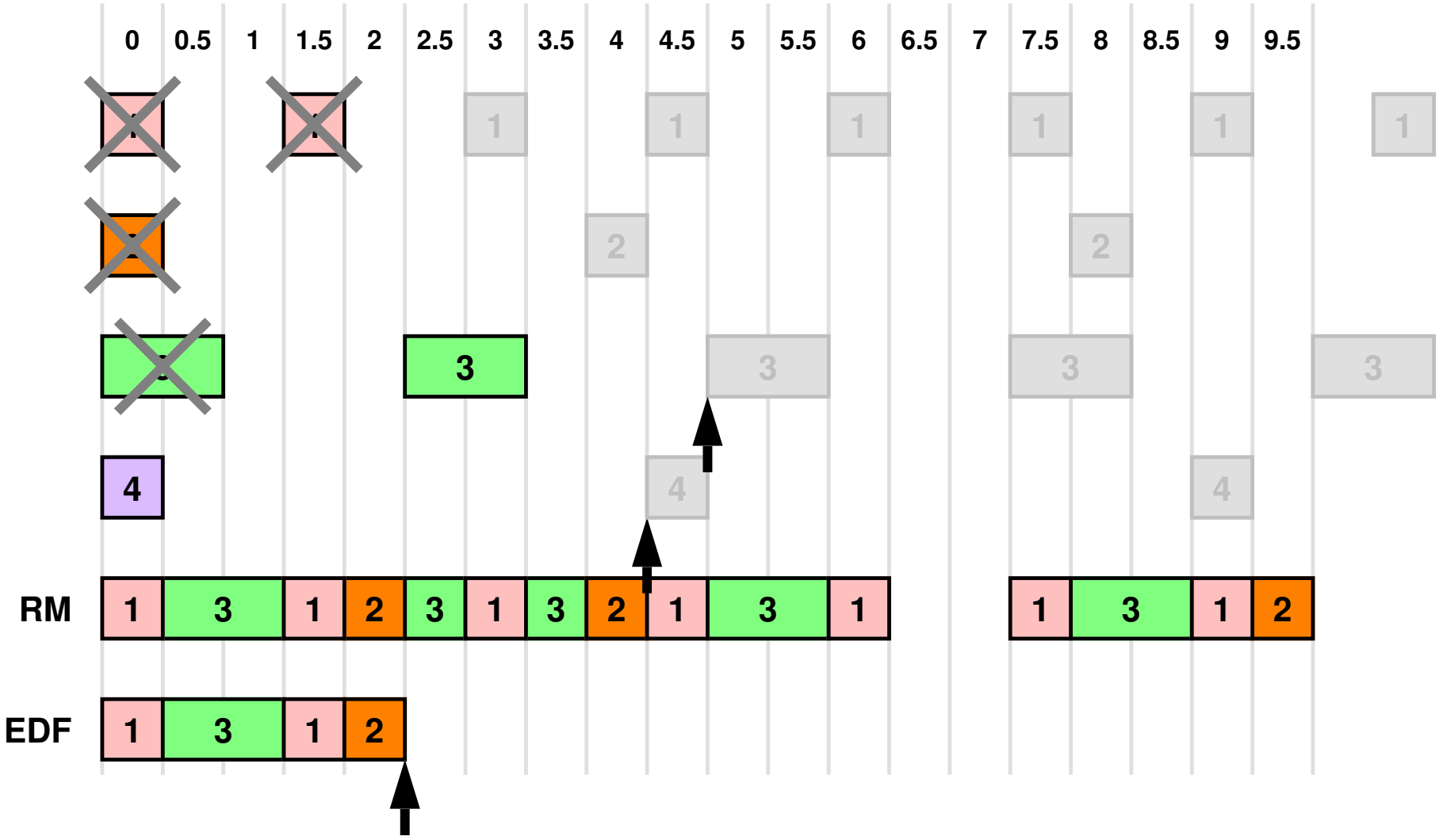

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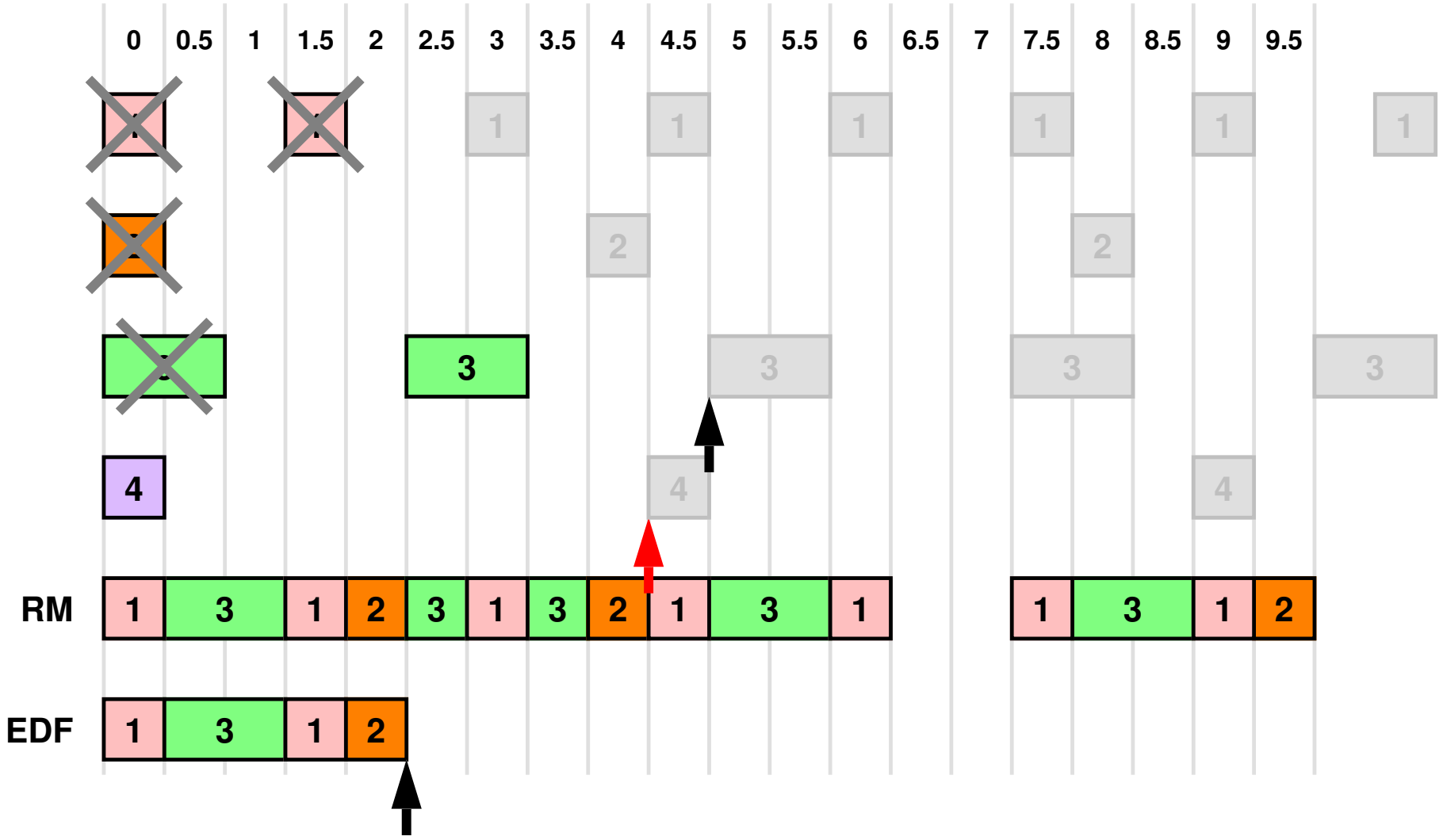

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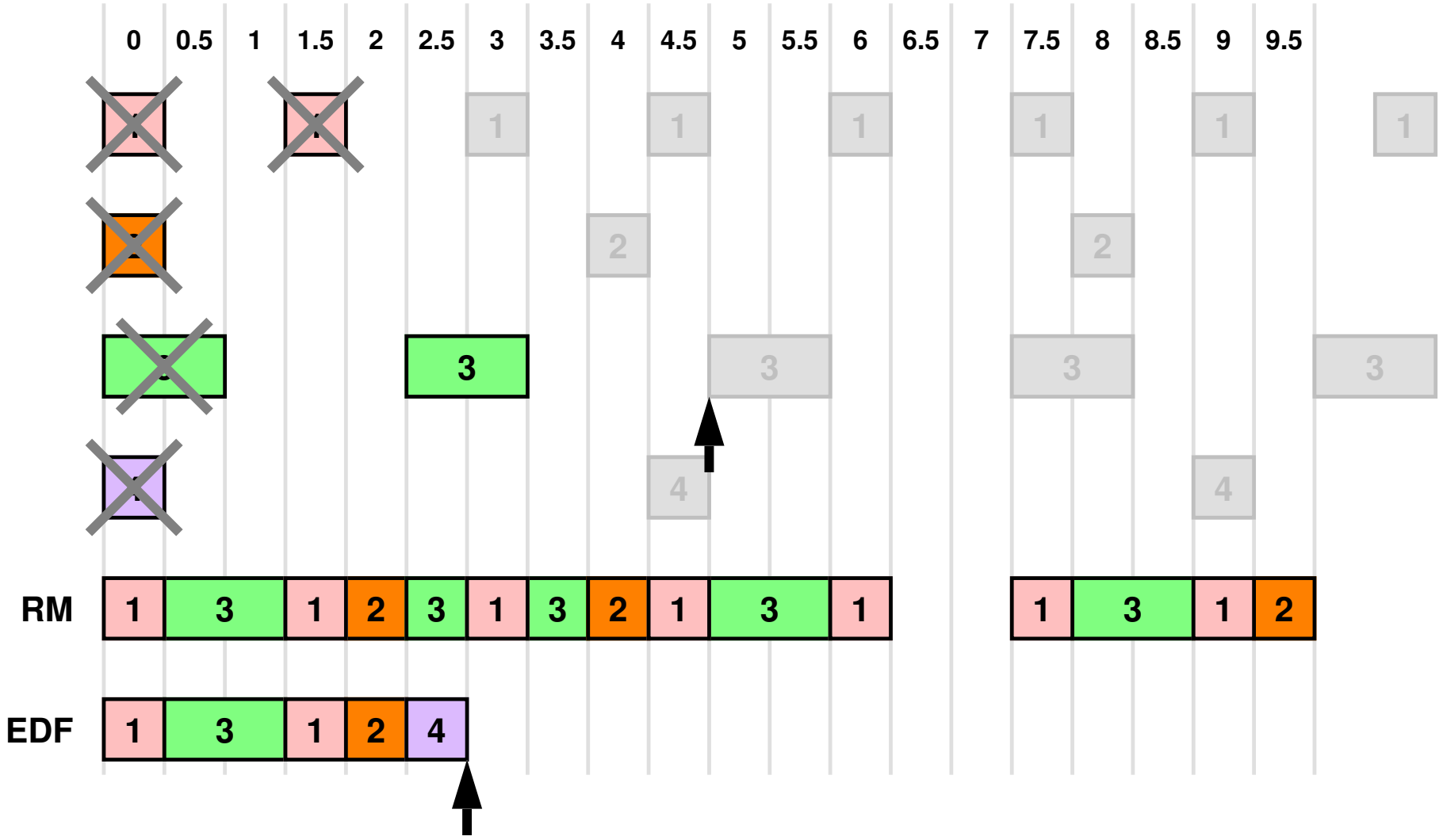

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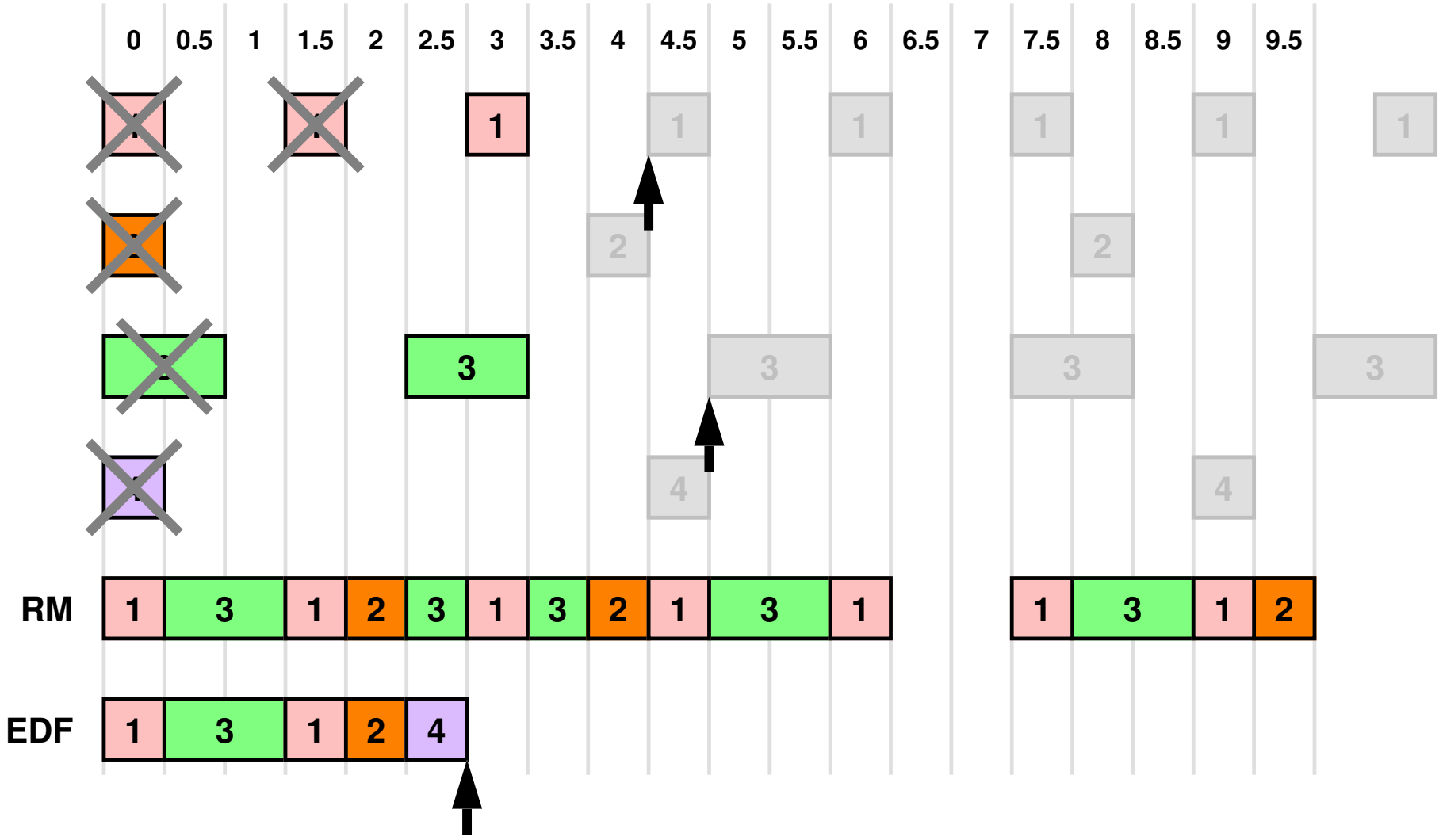

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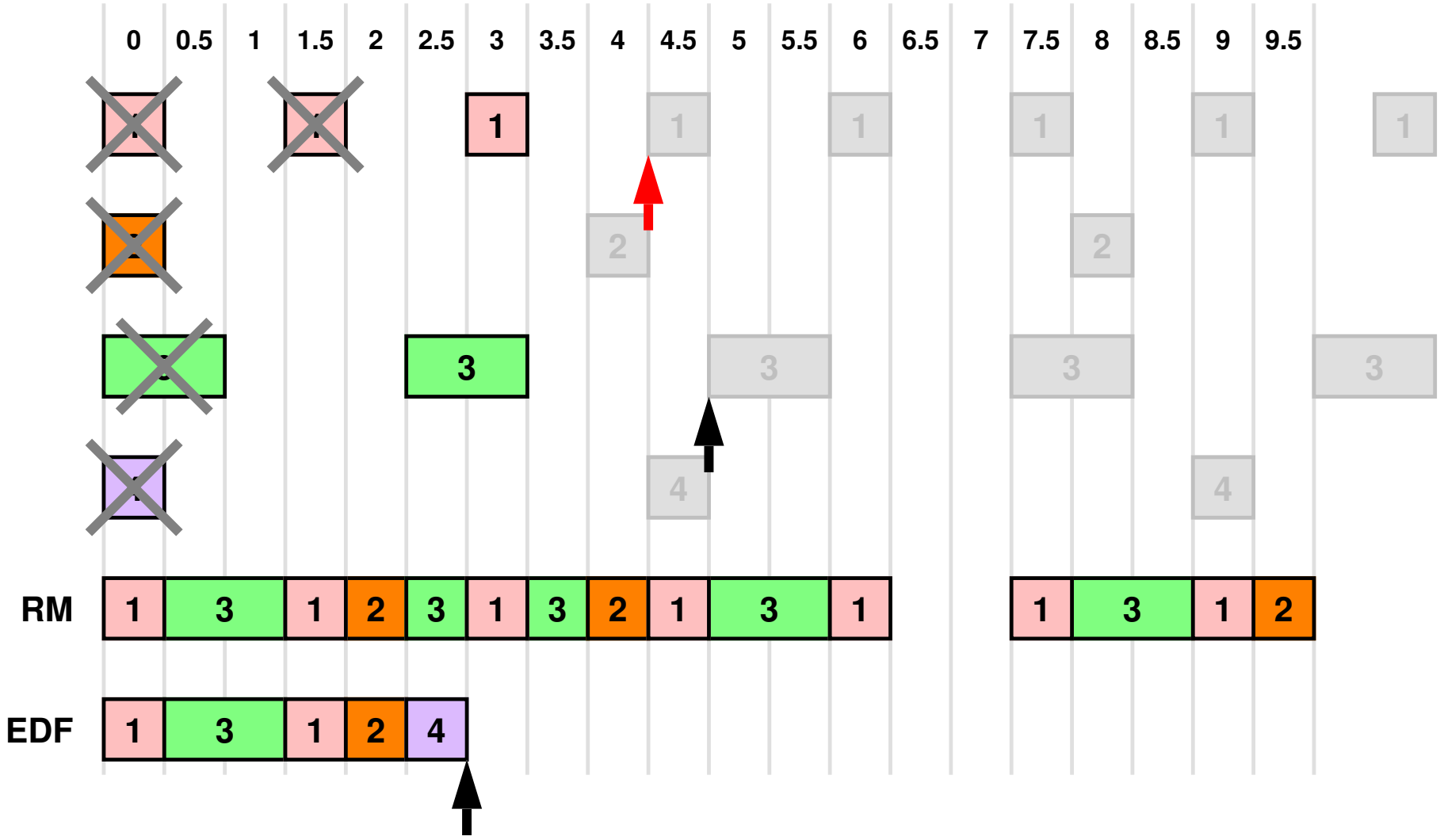

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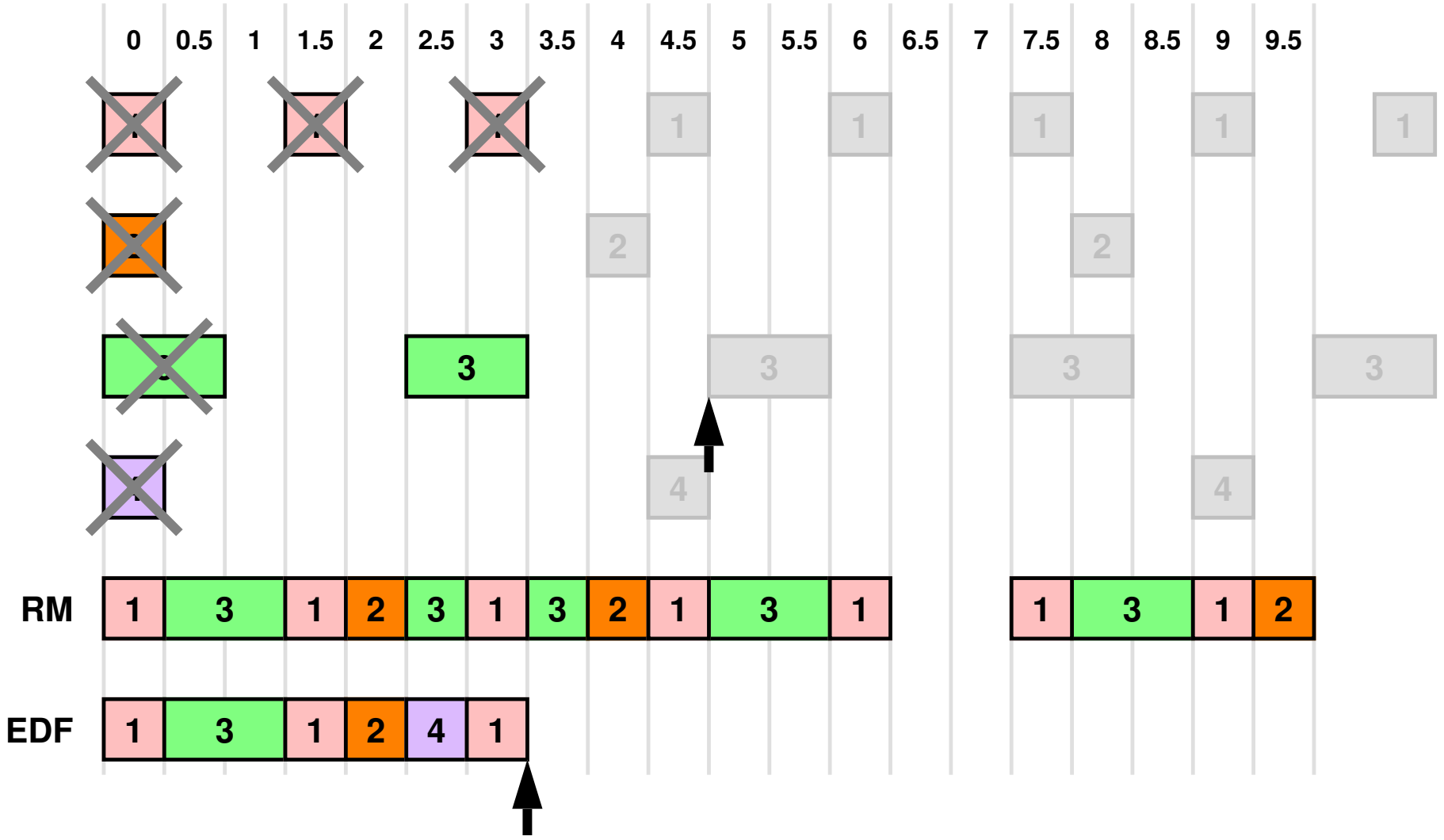

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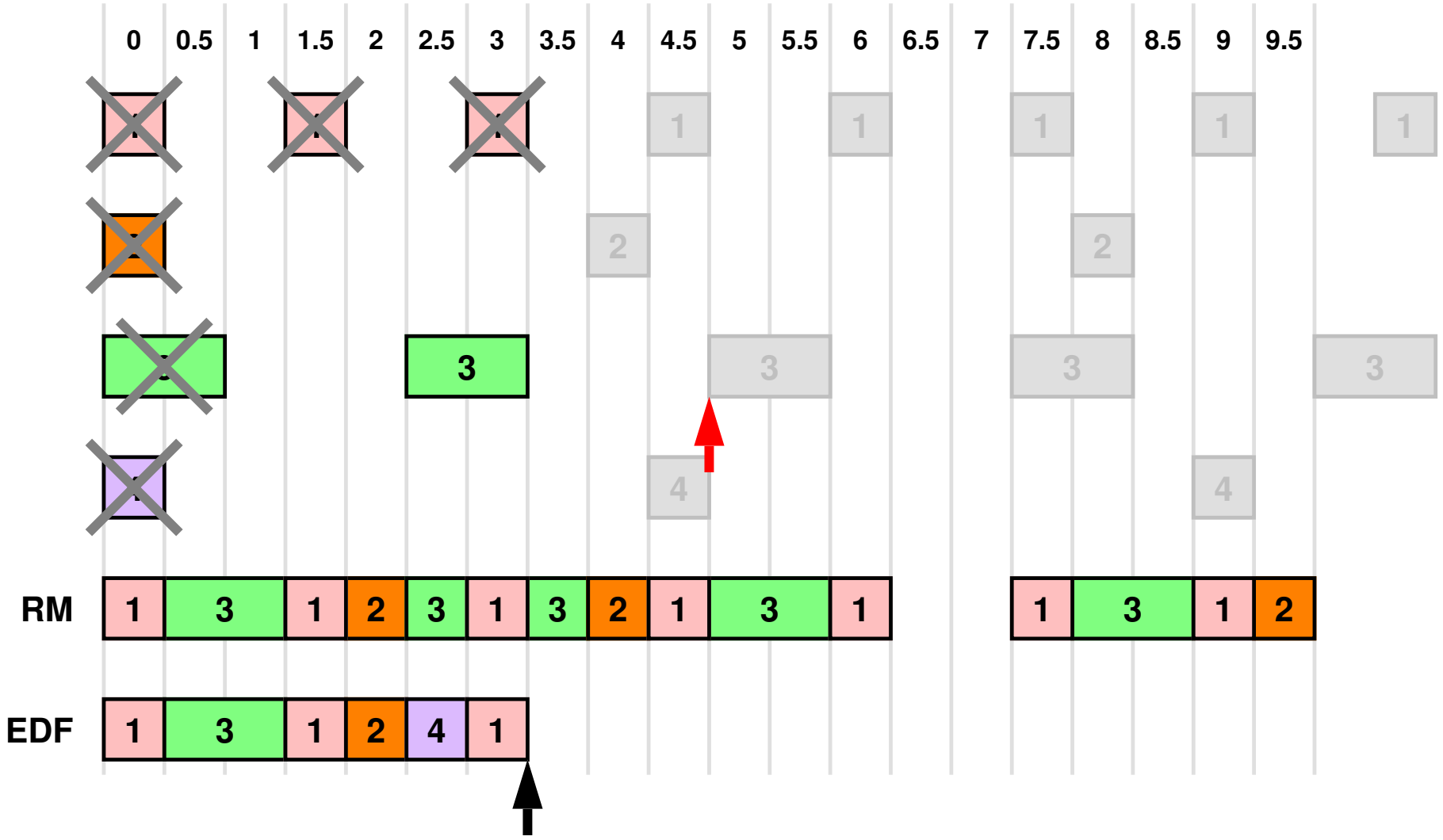

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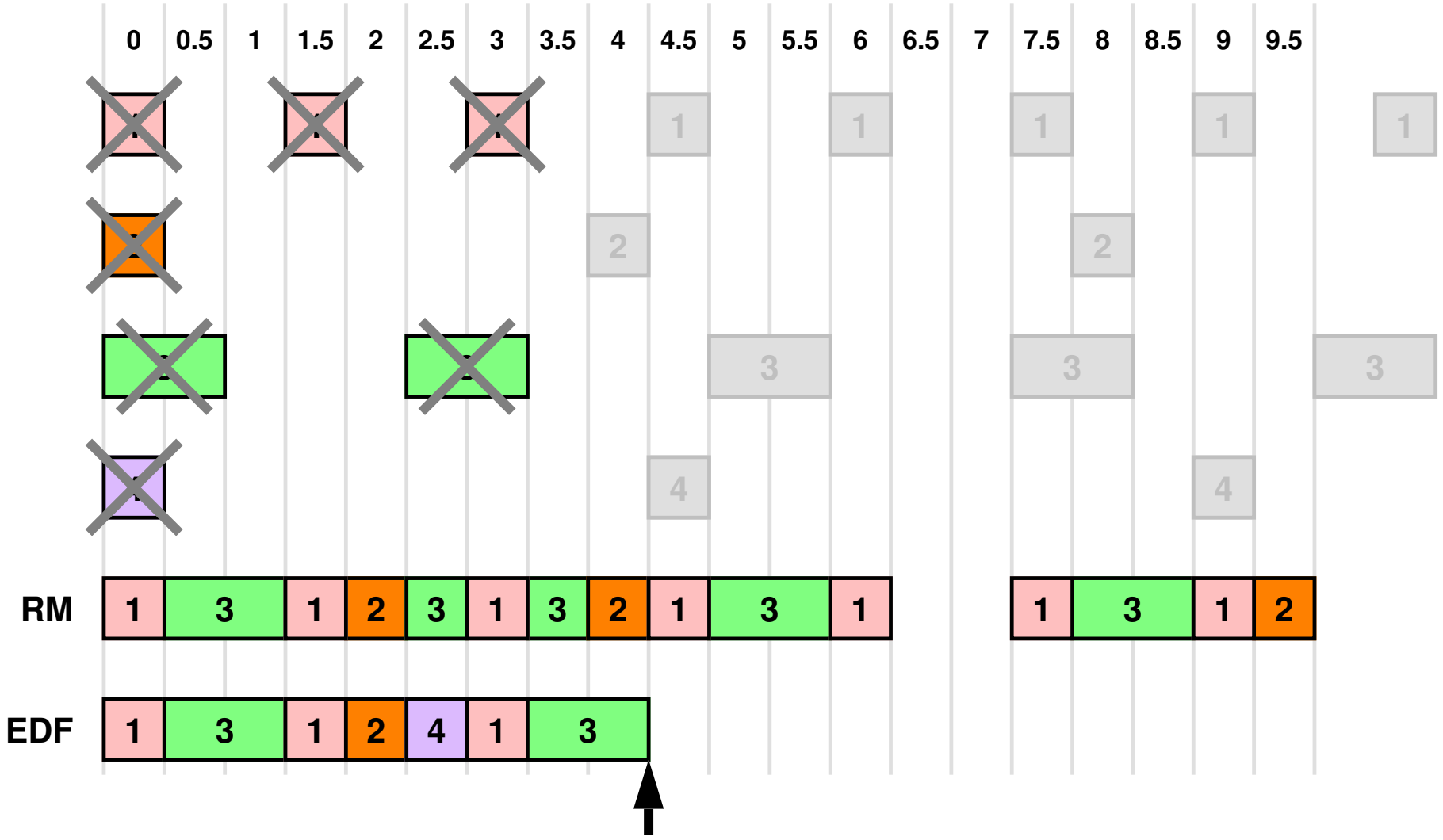

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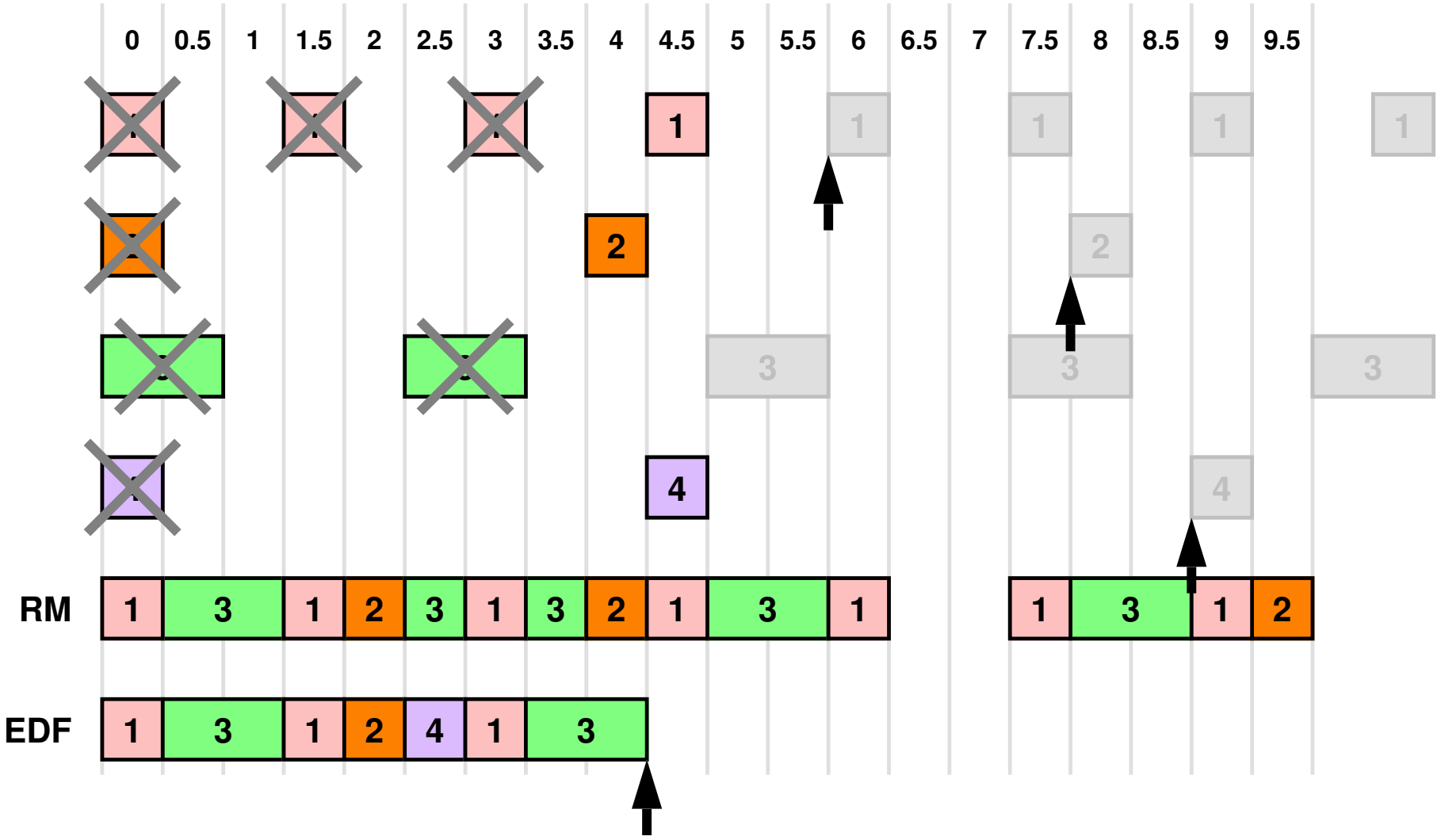

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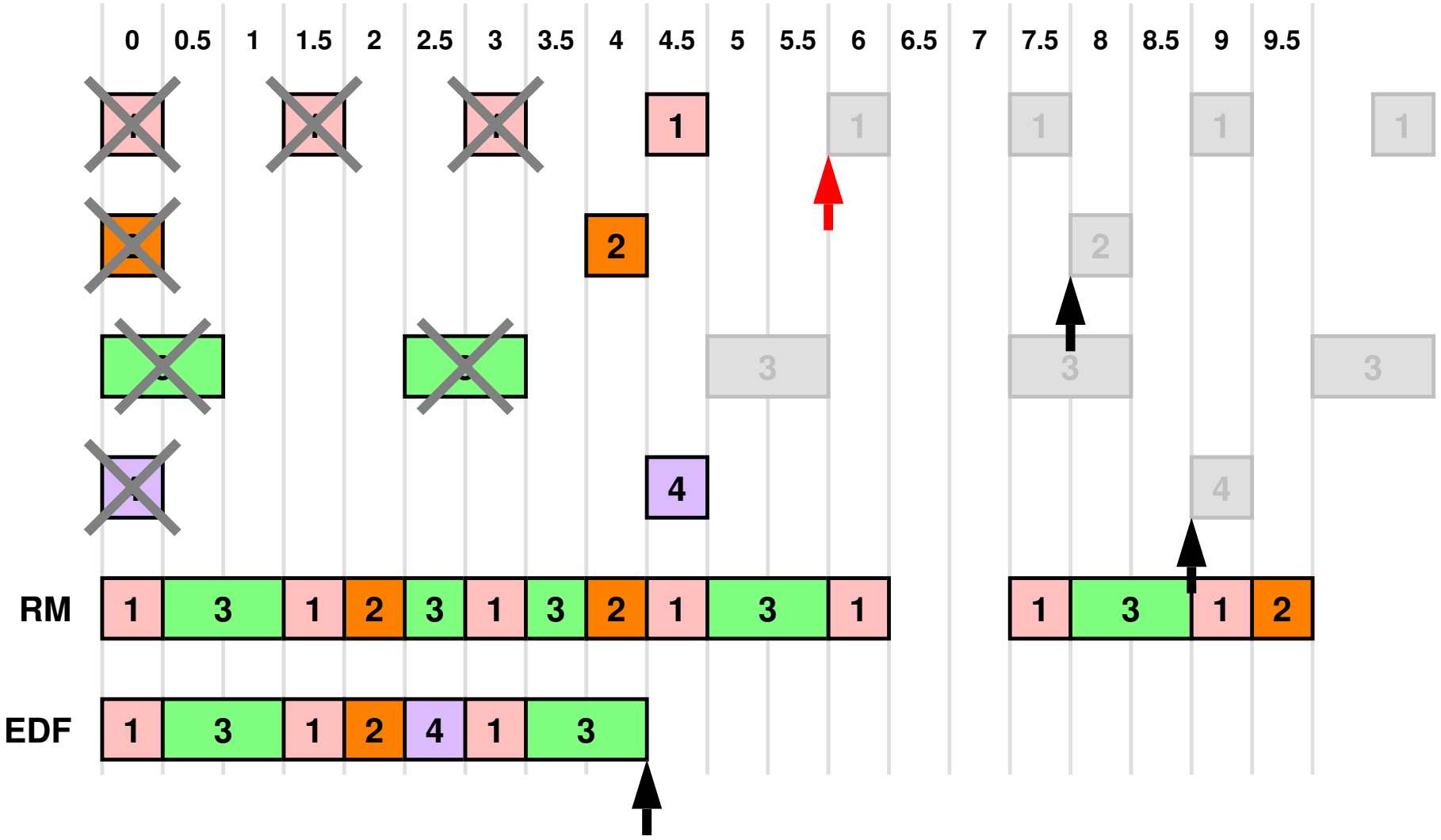

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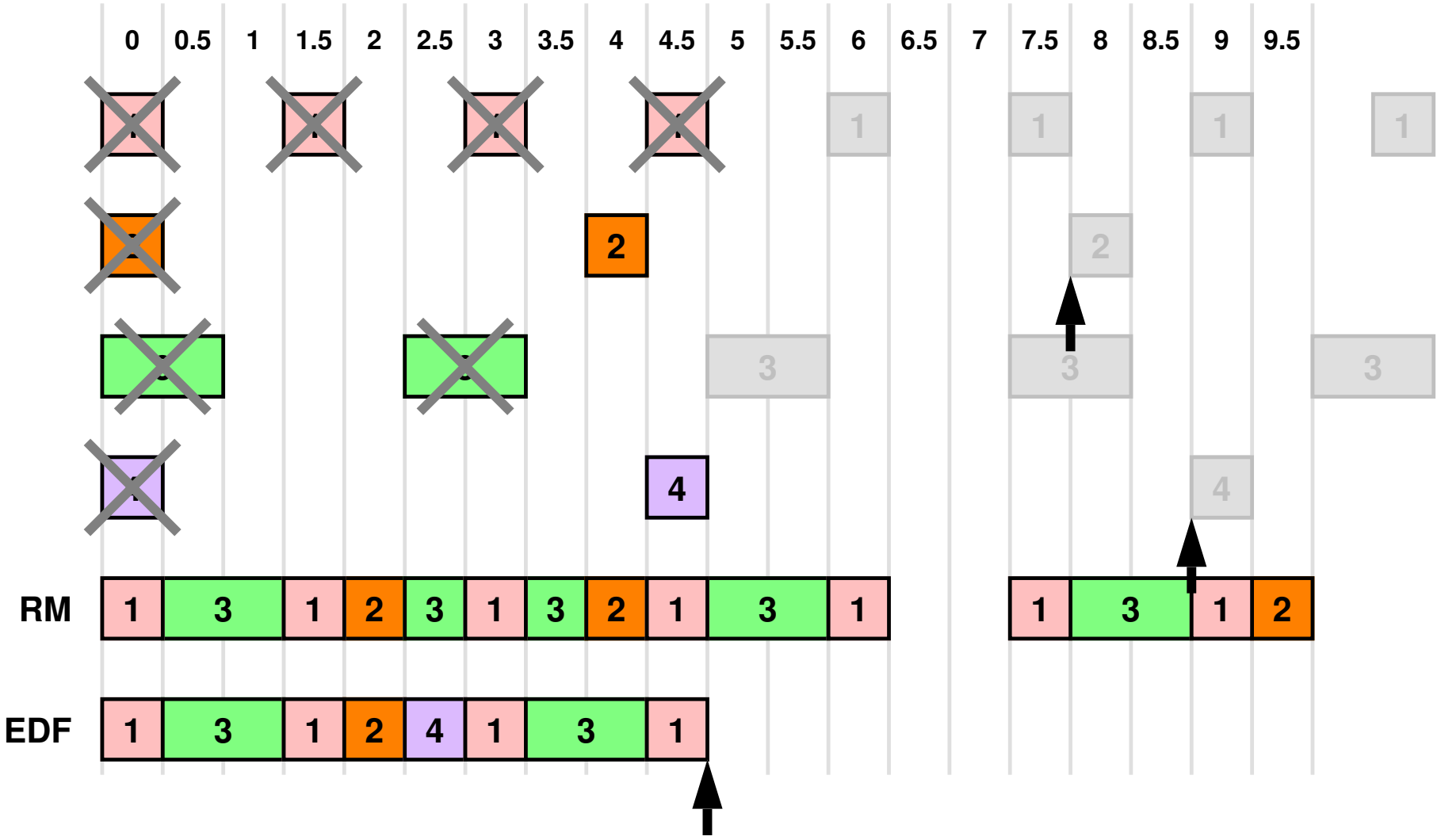

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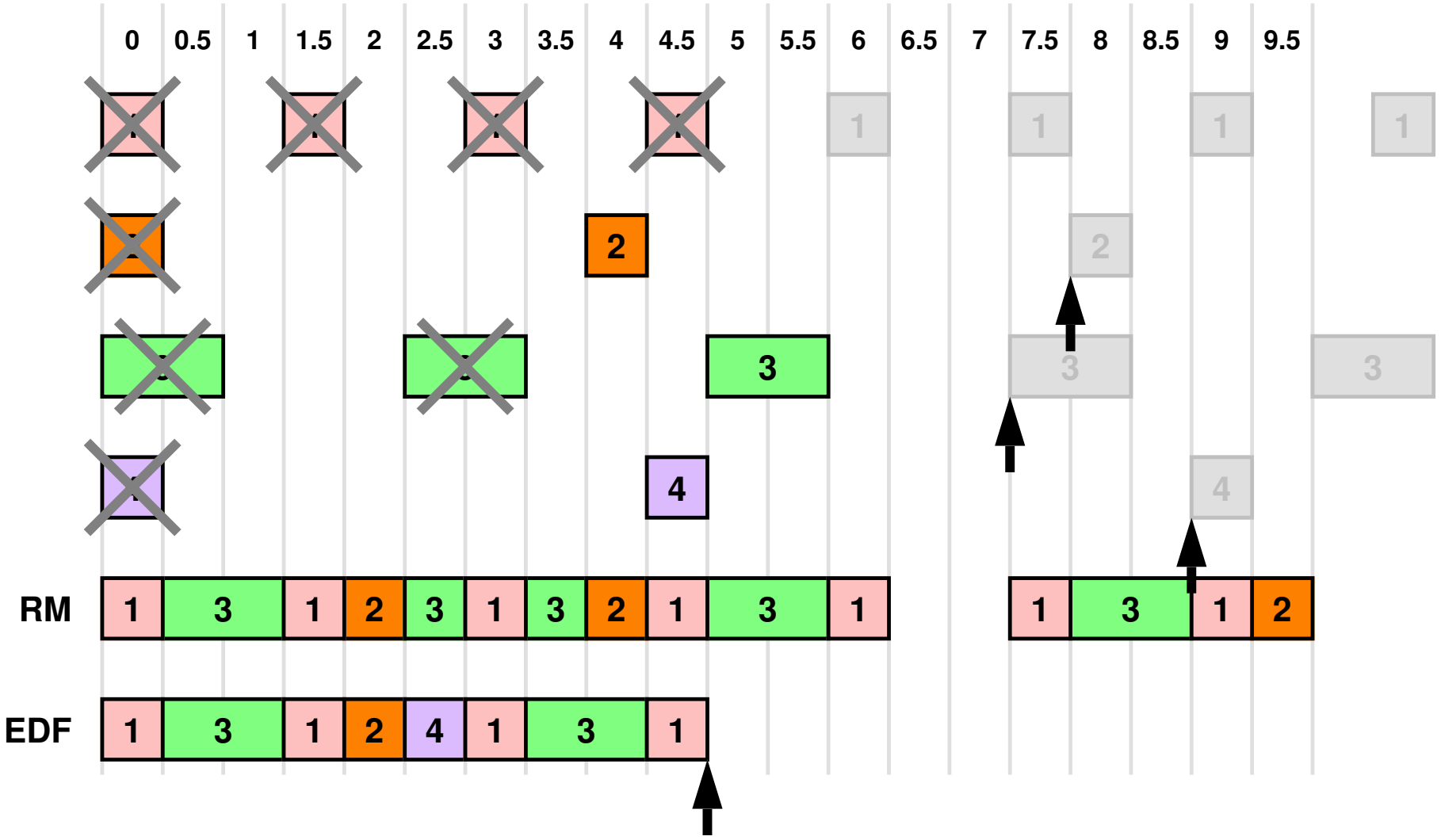

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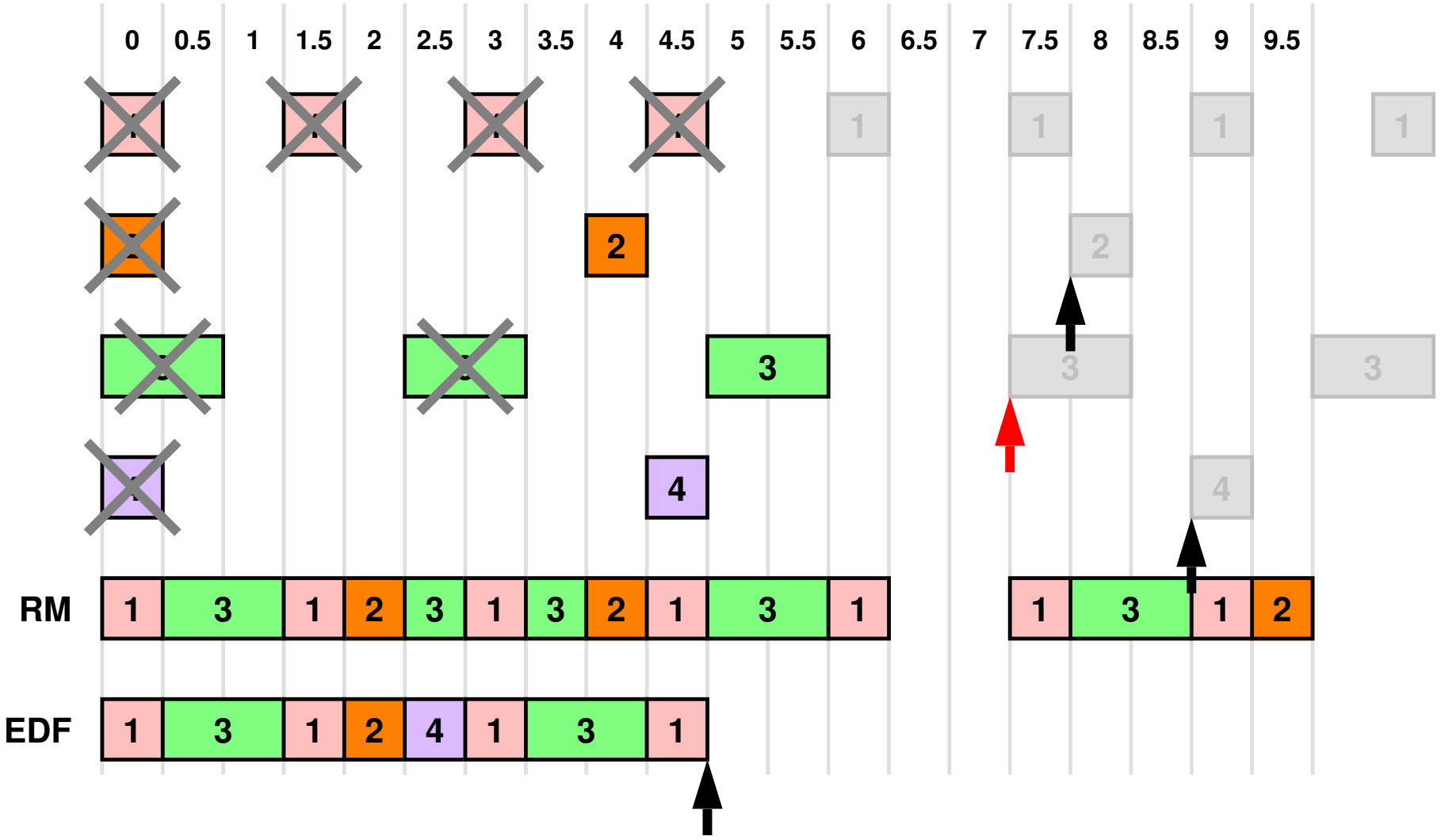

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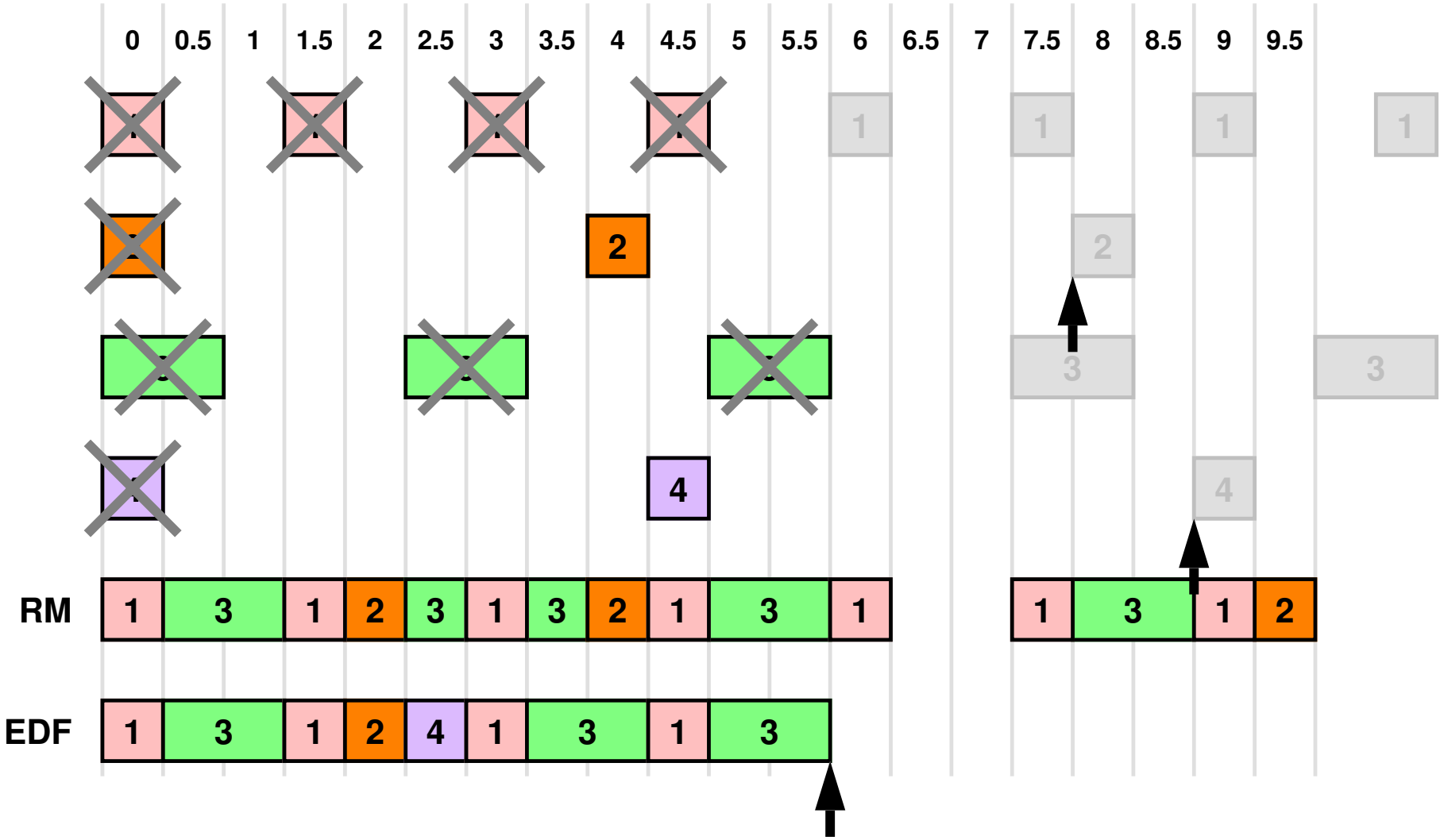

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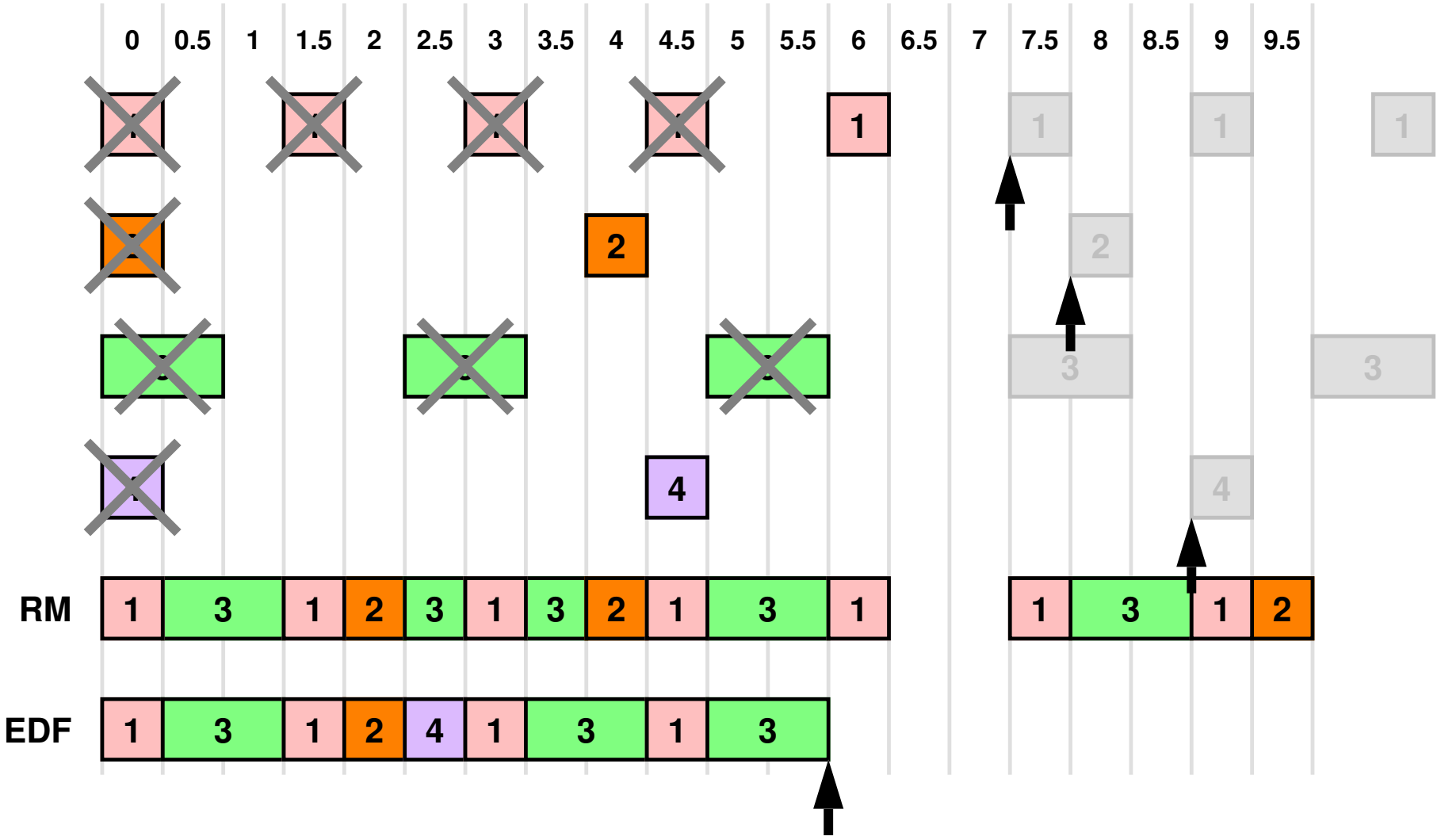

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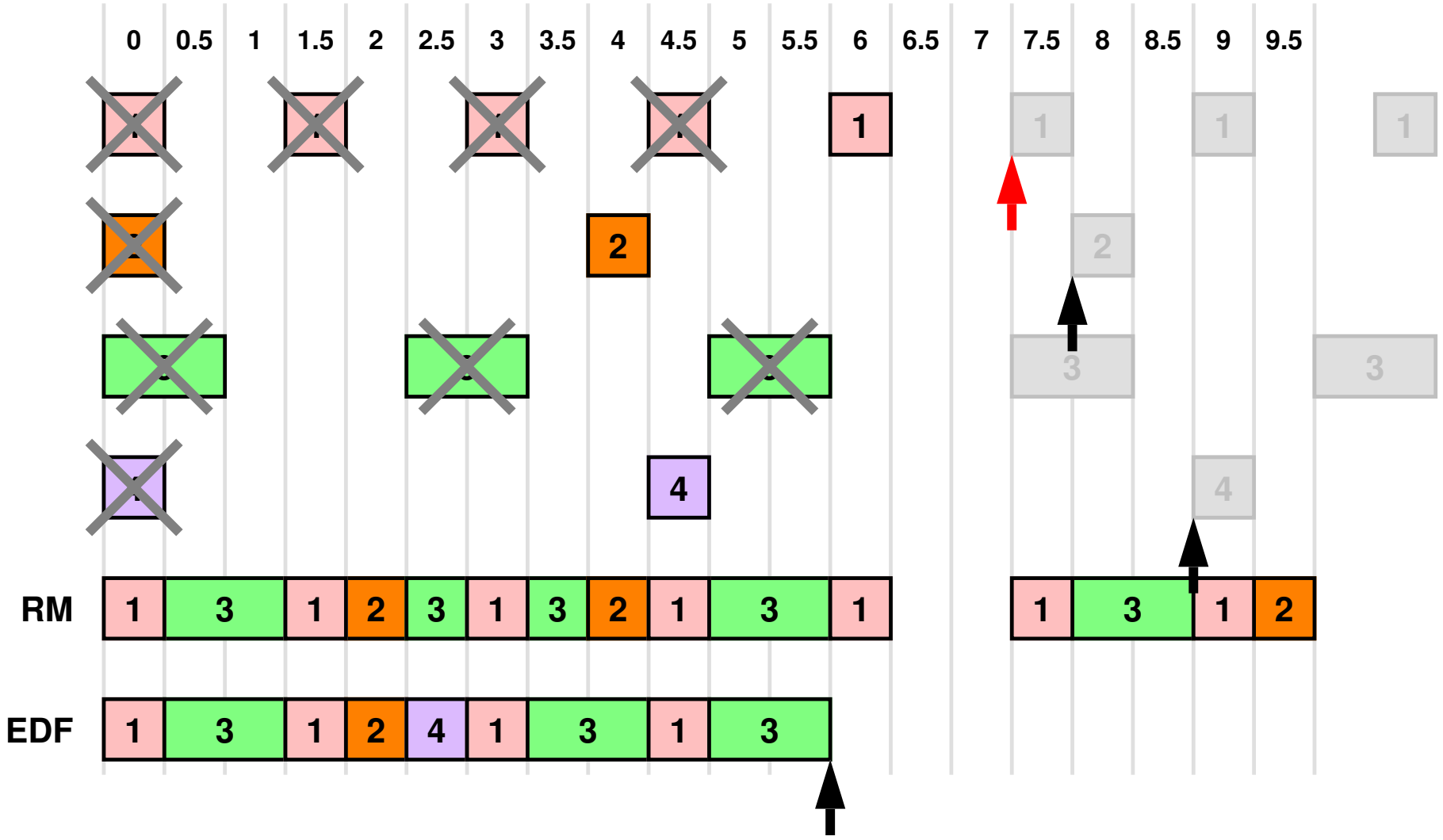

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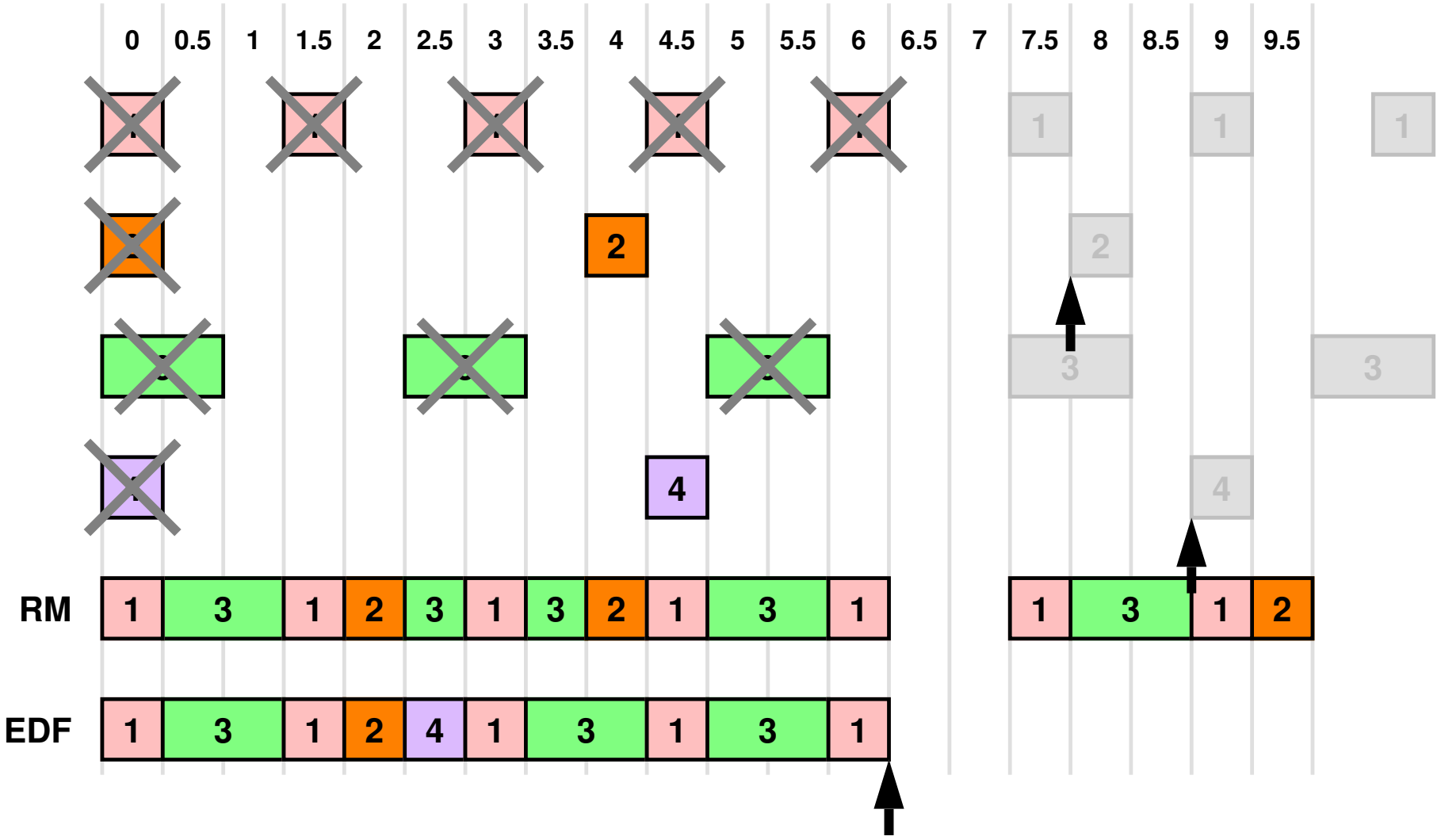

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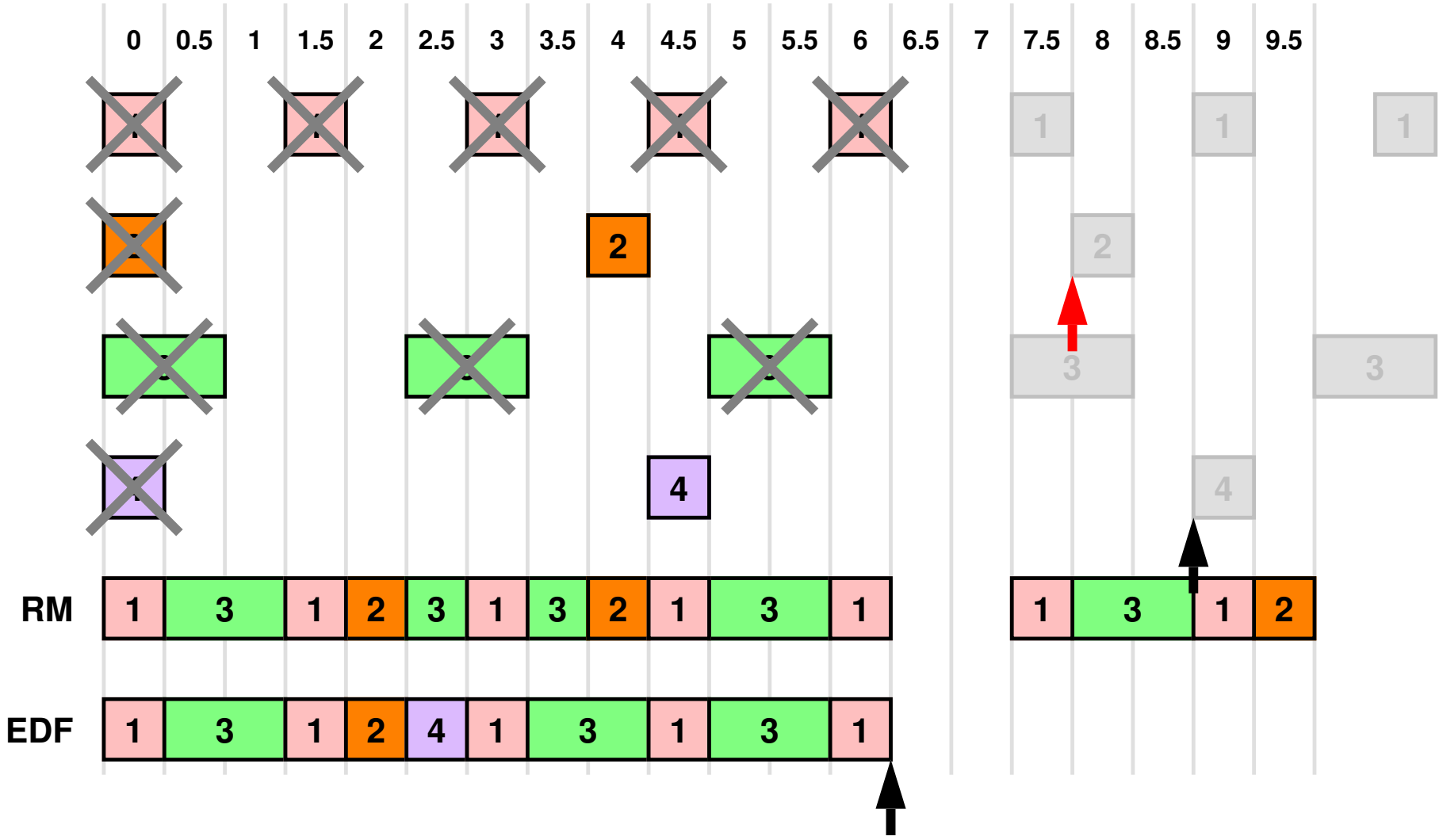

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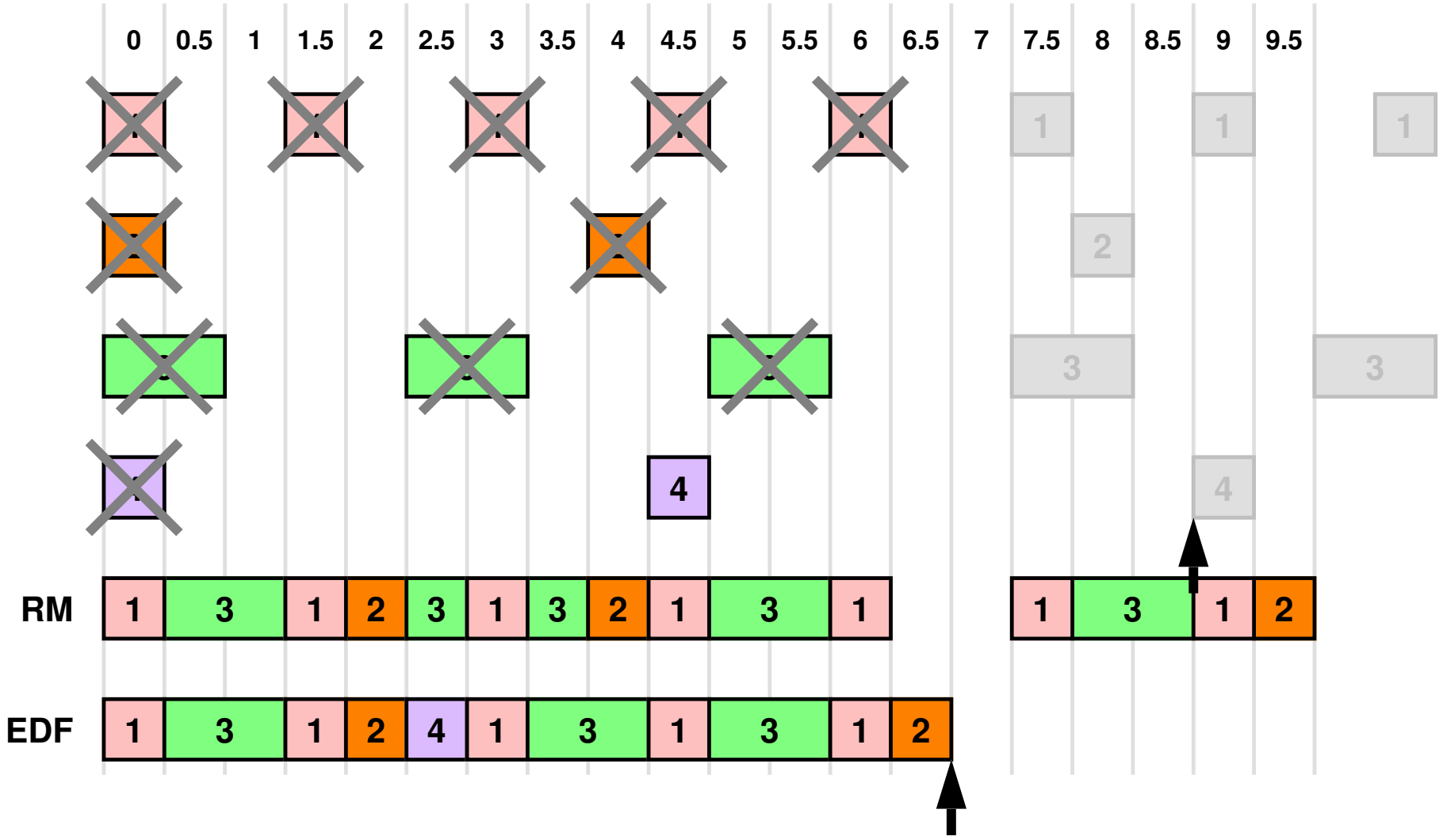

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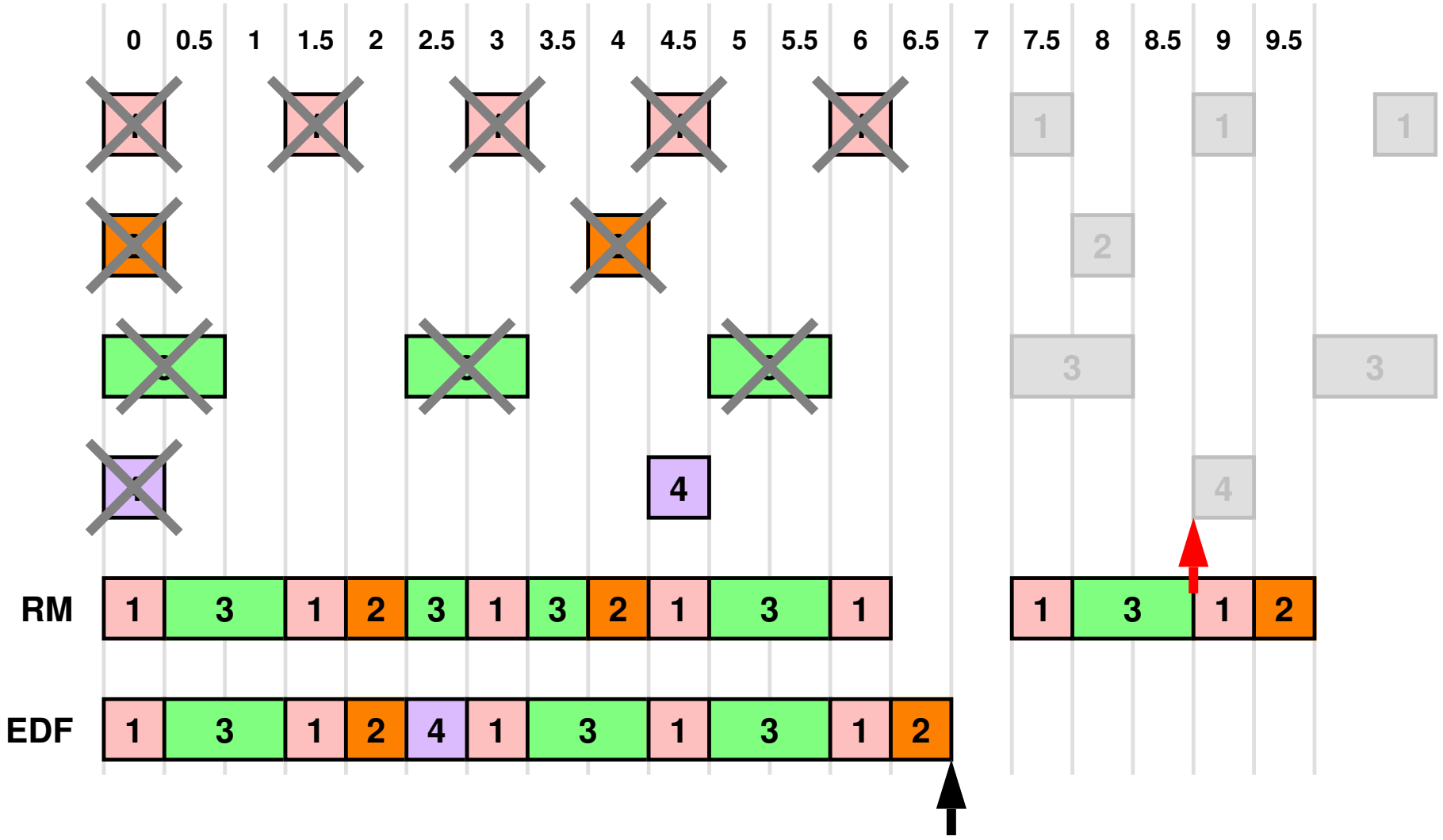

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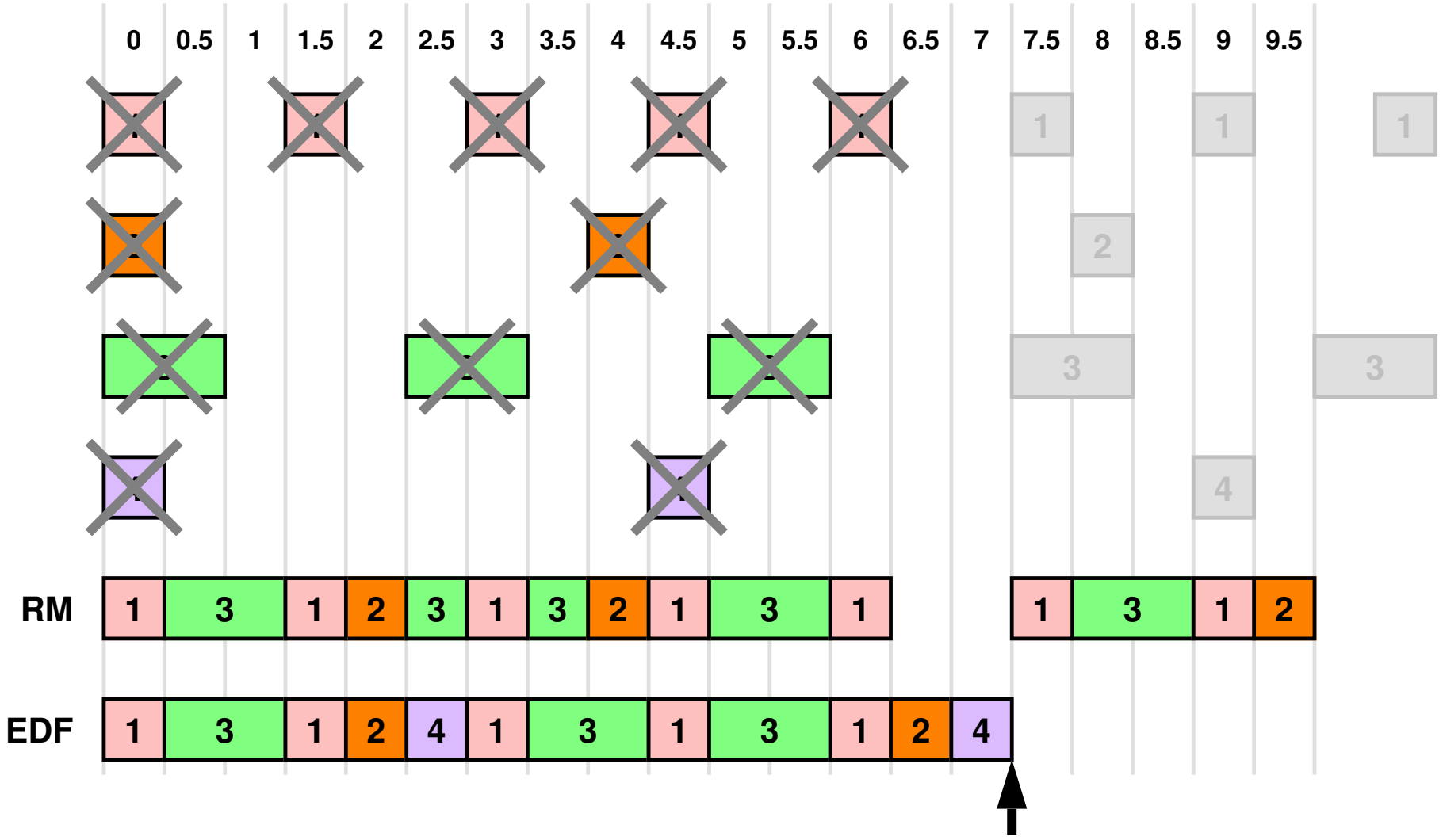

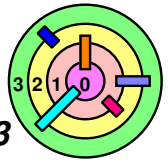

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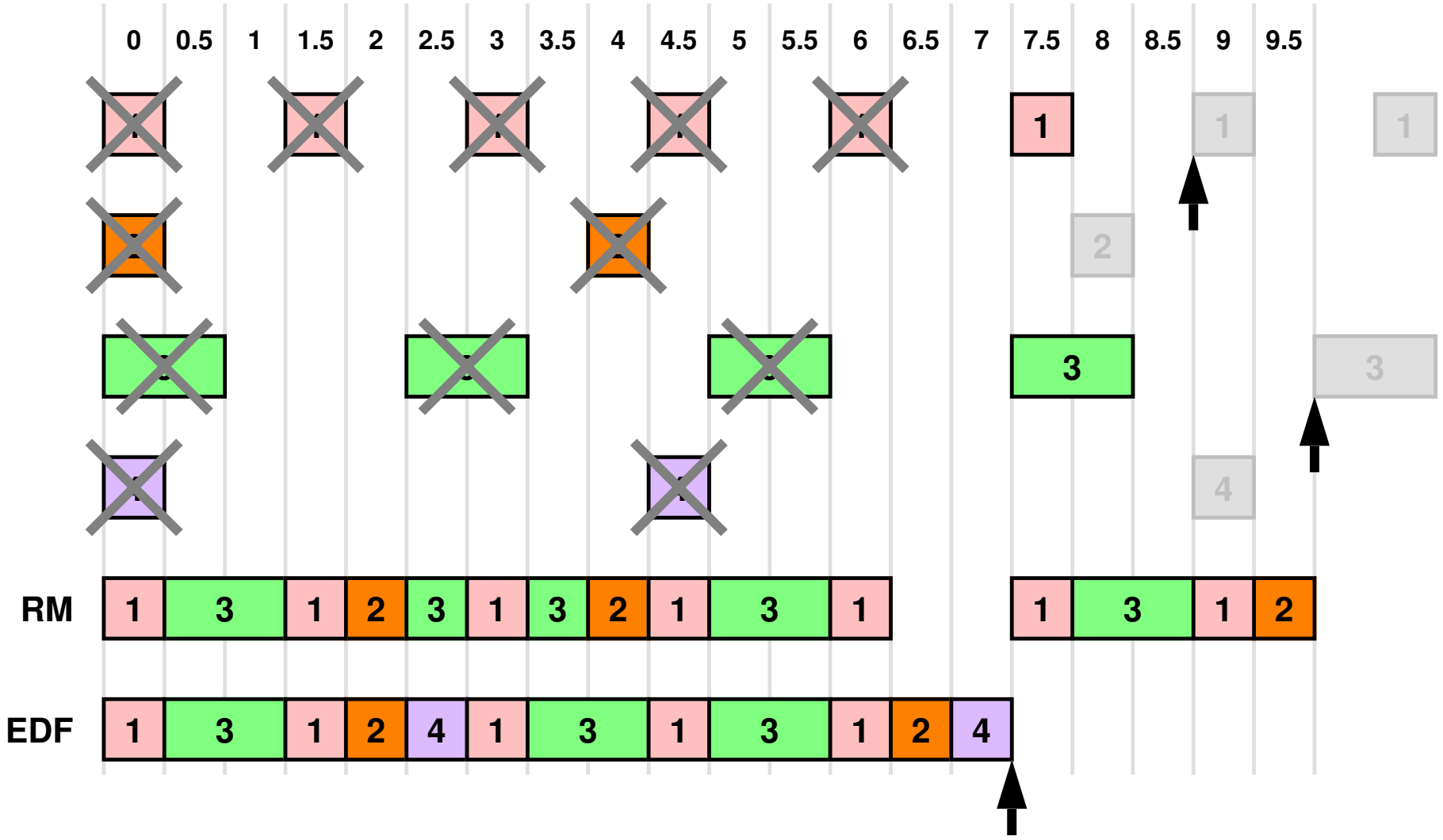

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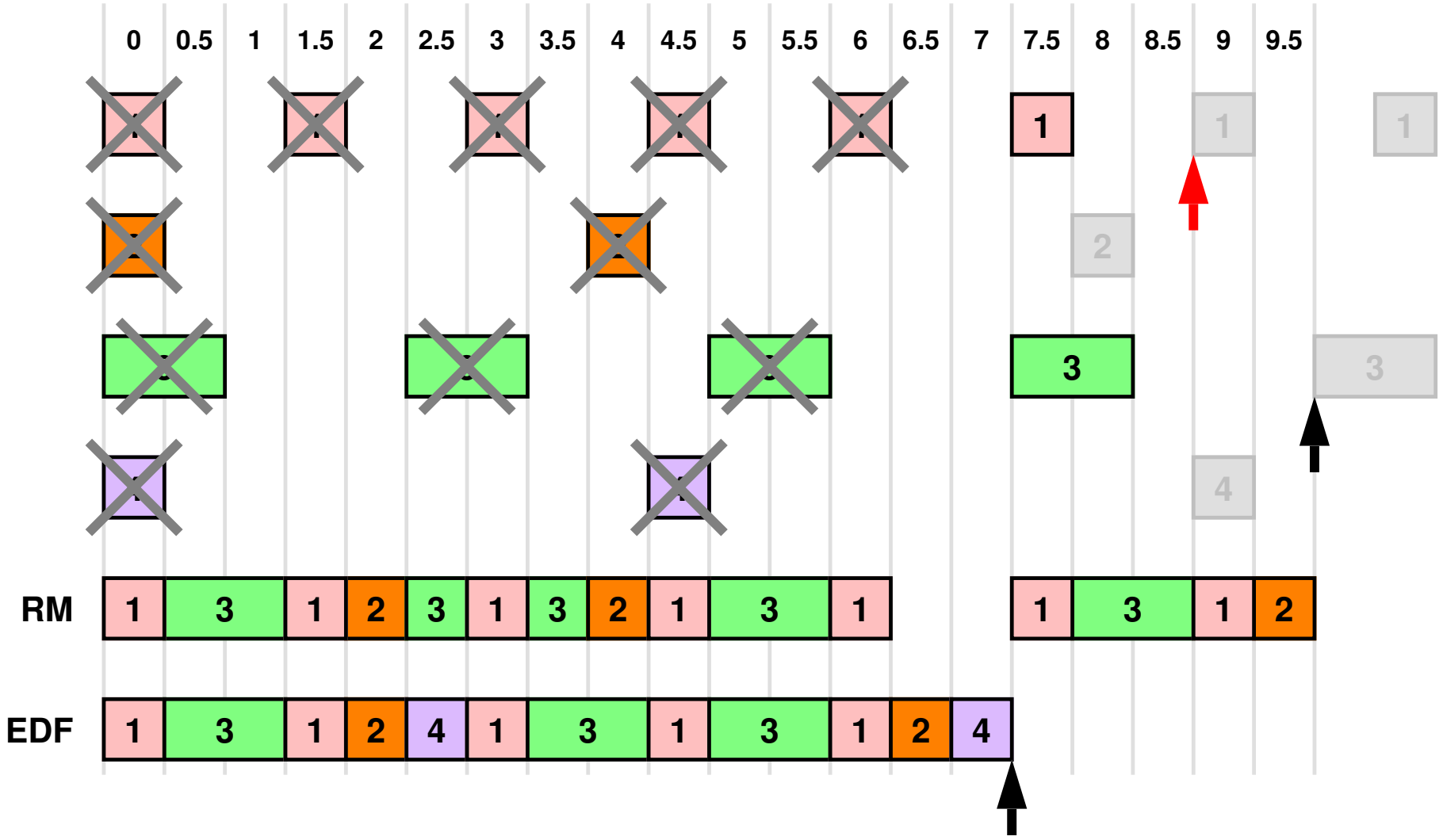

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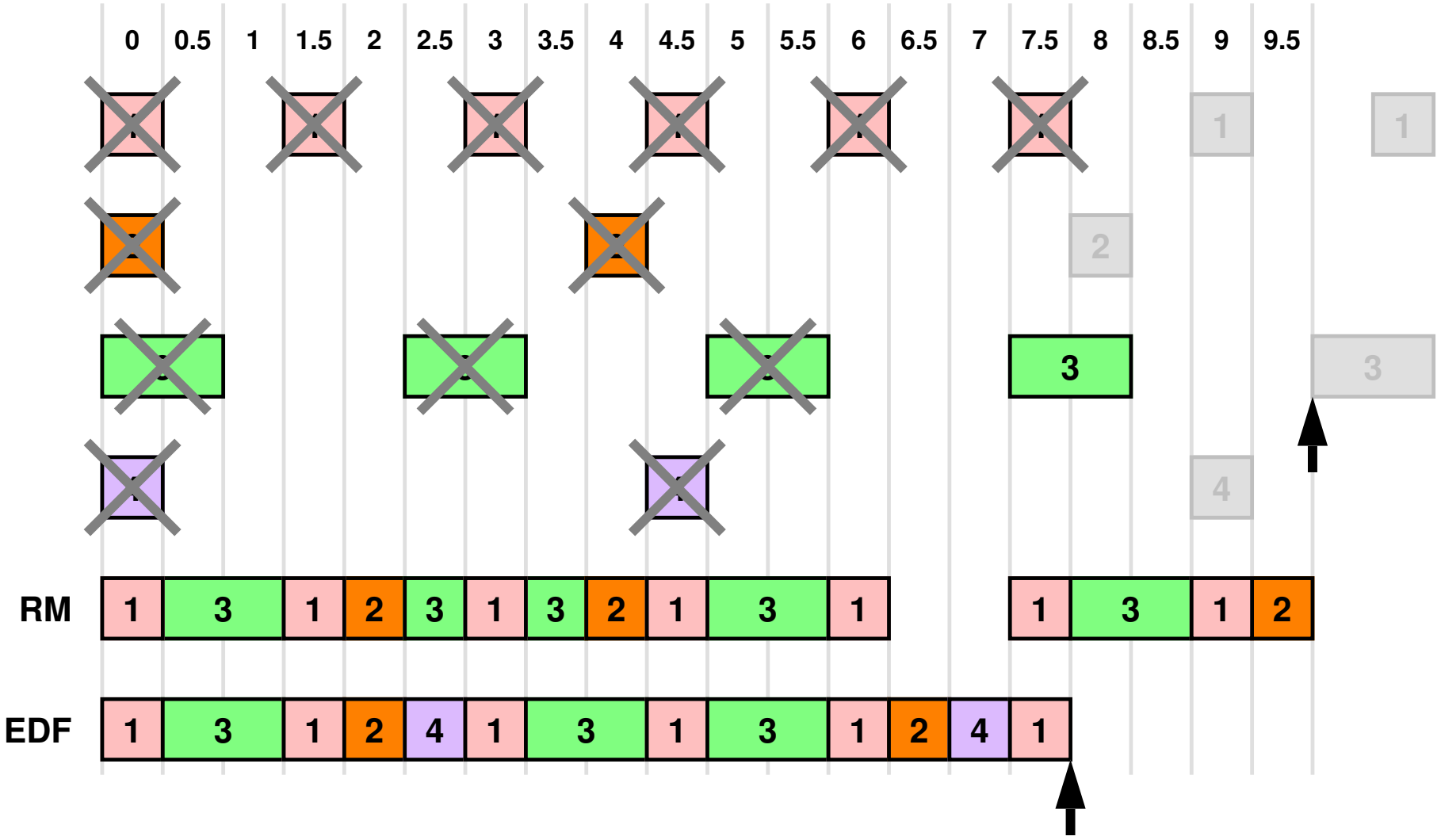

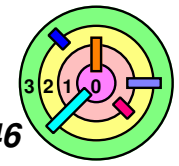

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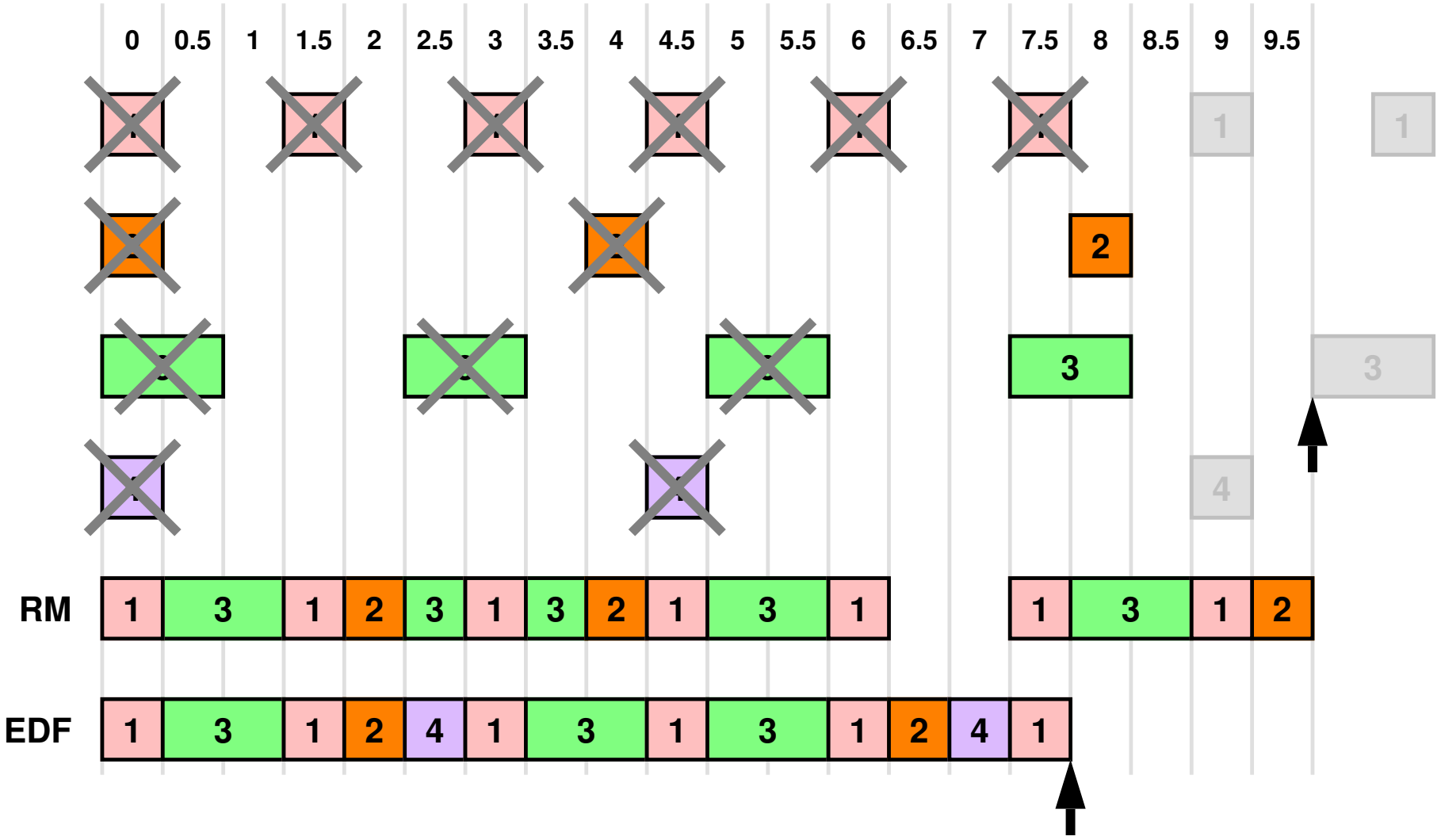

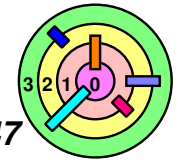

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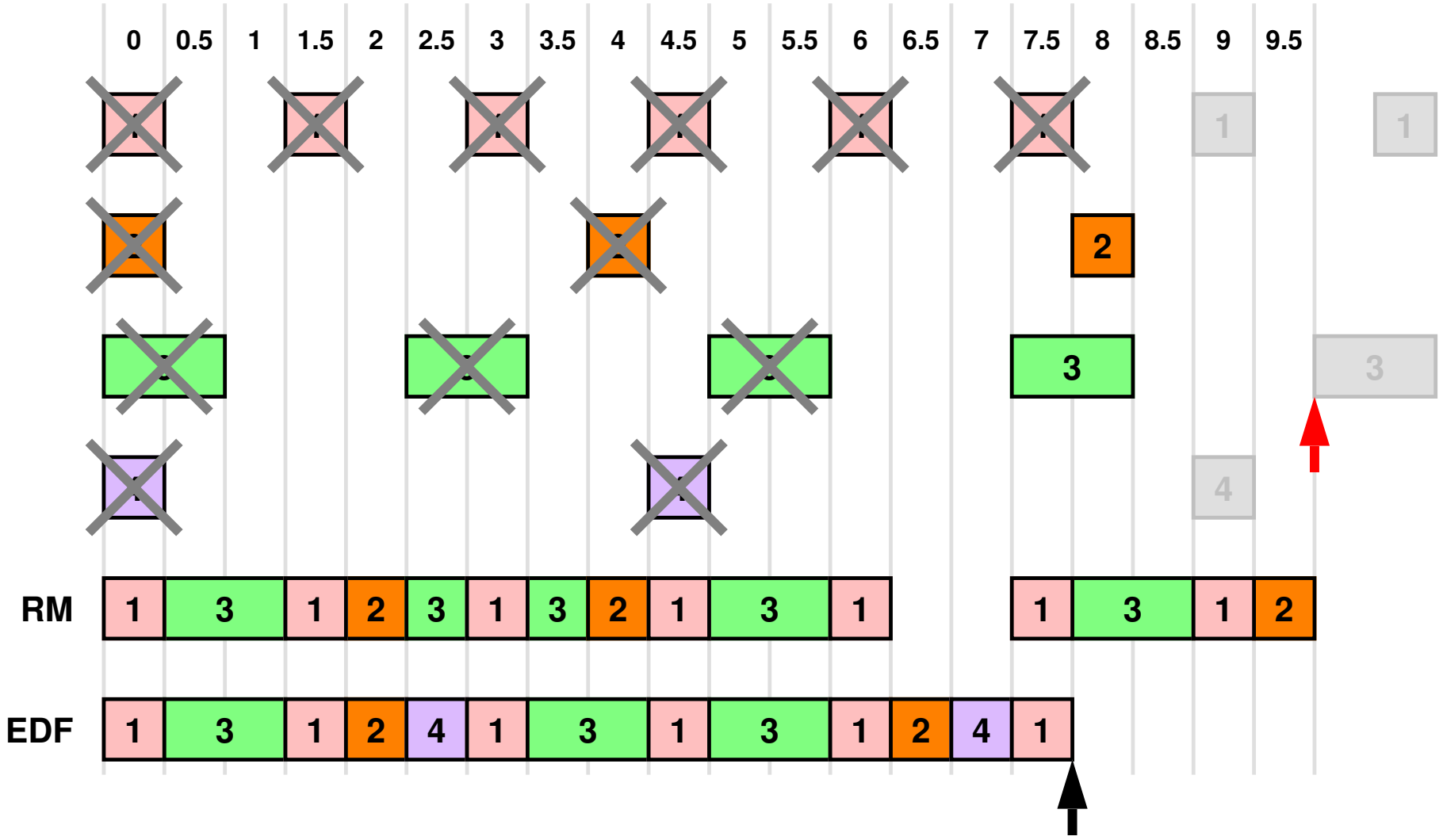

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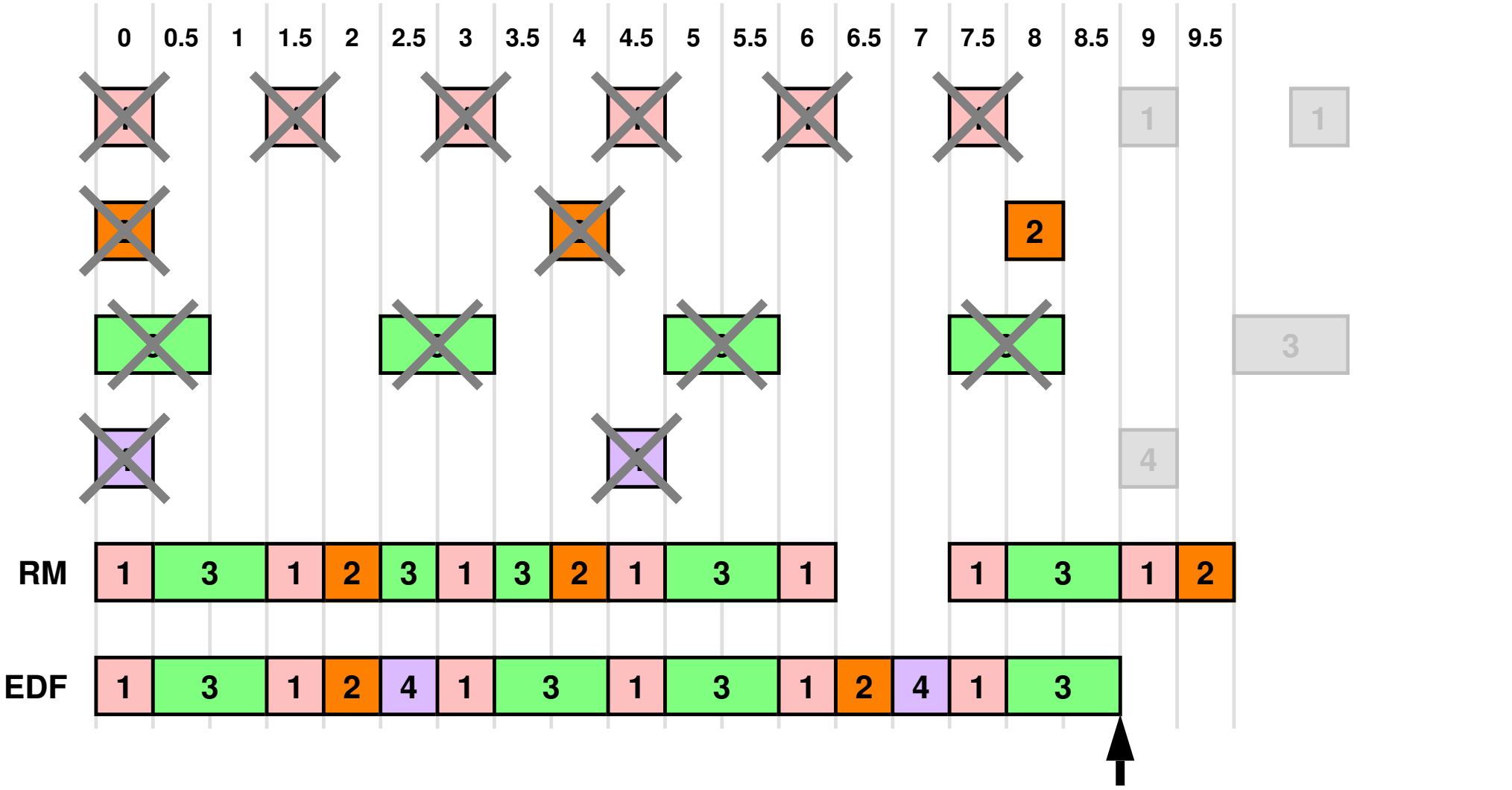

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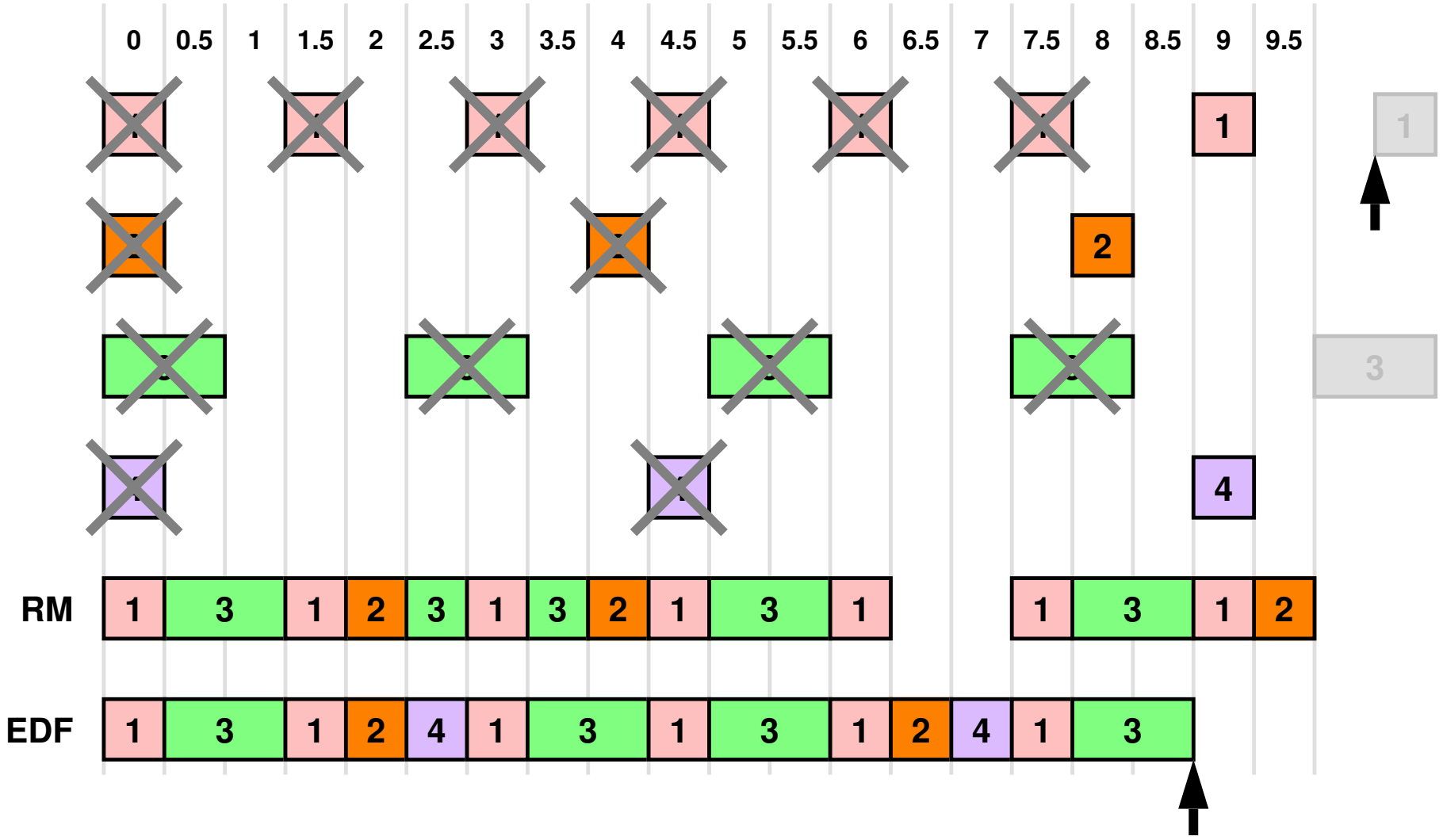

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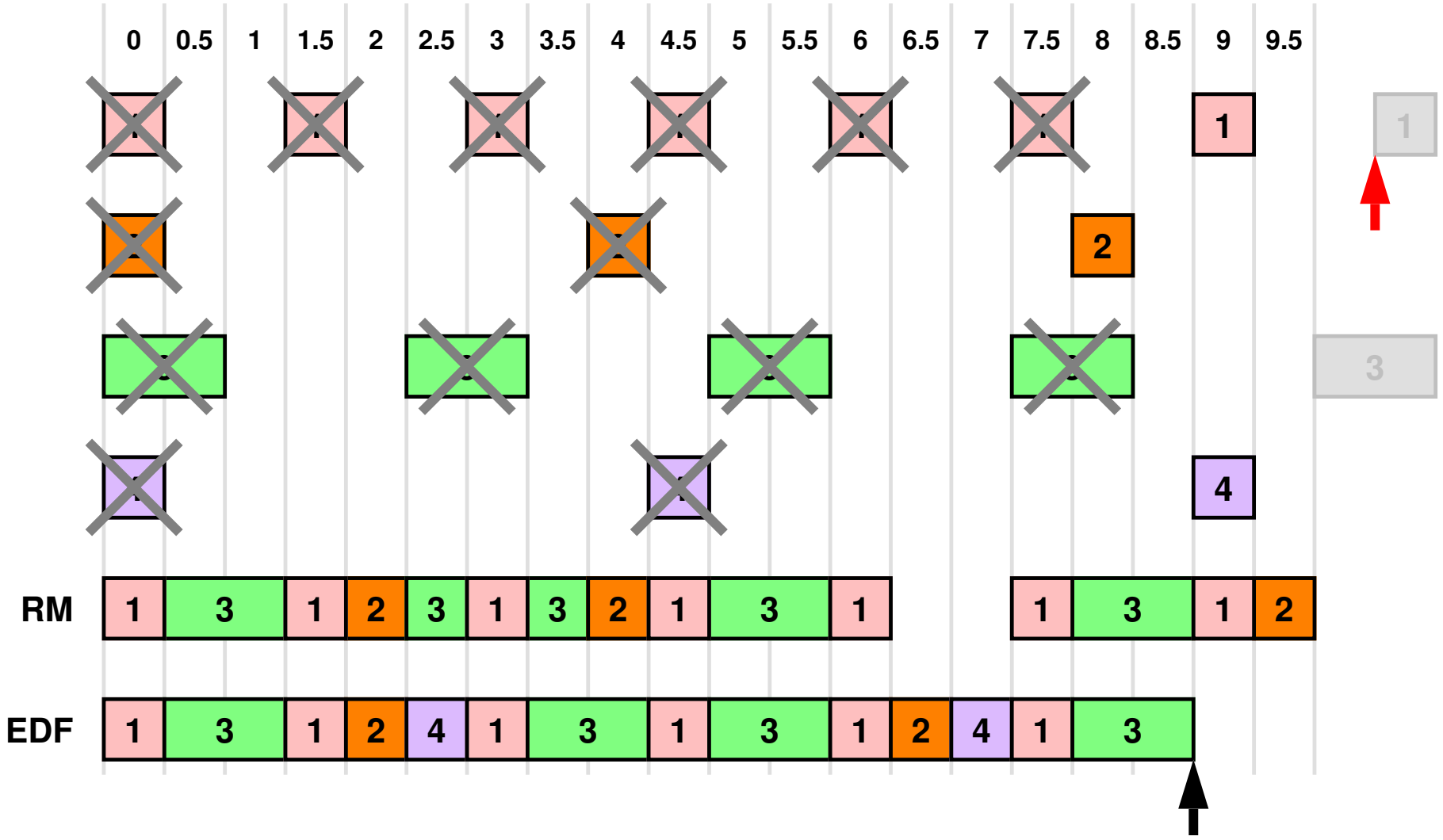

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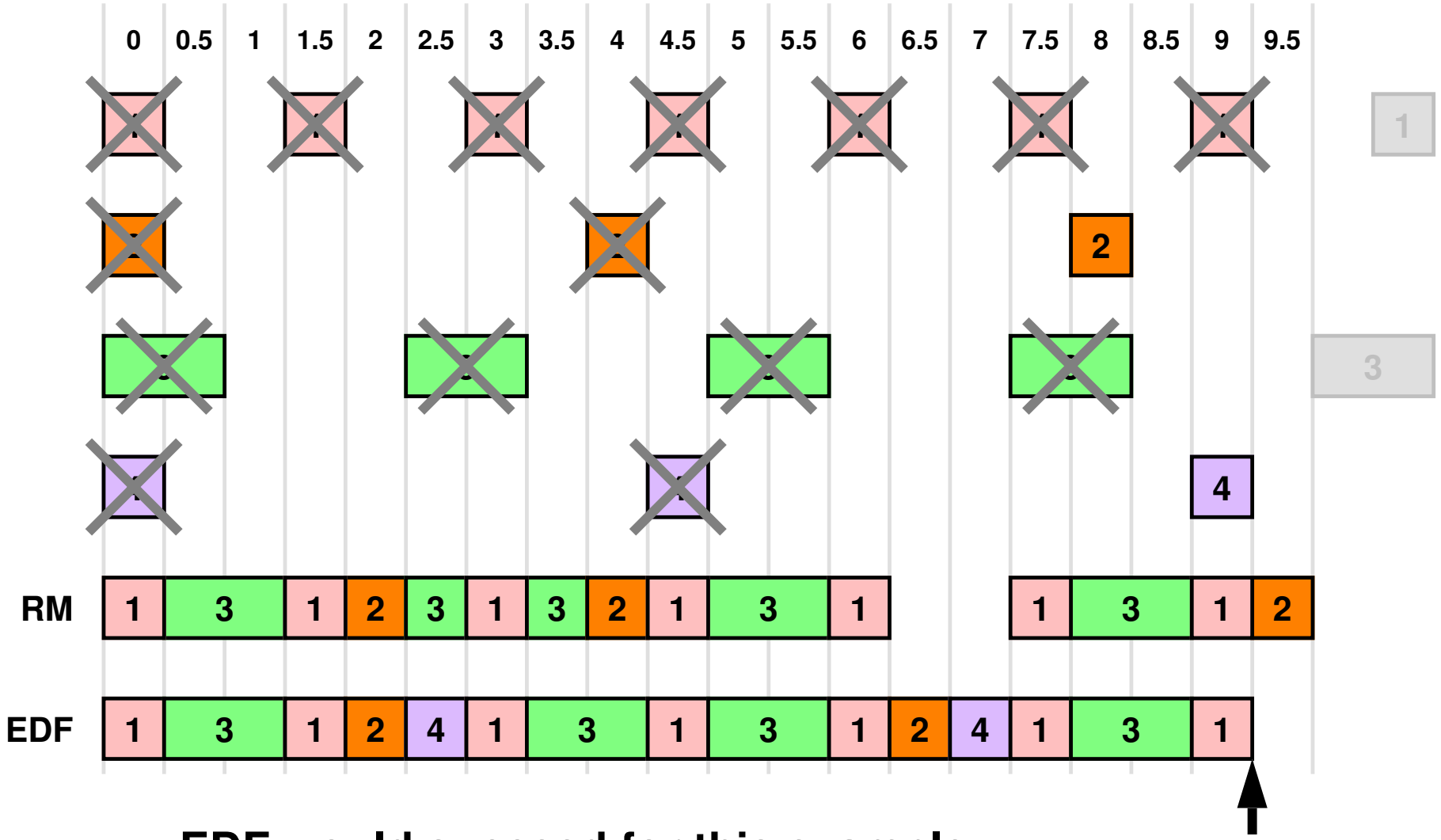
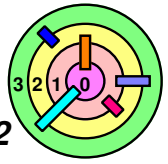
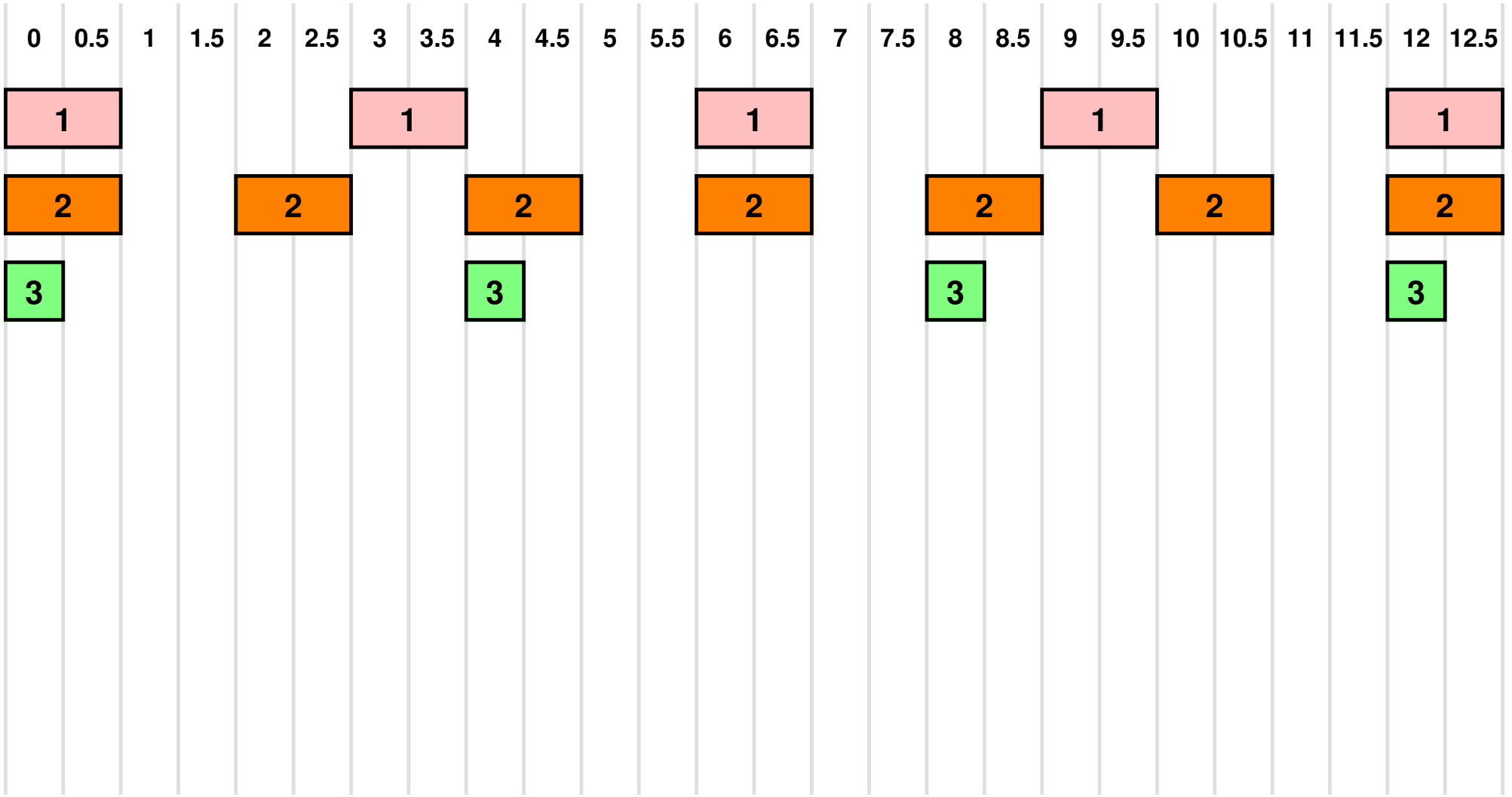


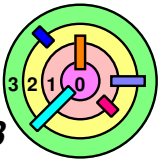
- EDF would succeed for this example
  - need to simulate till time = 180 to be certain



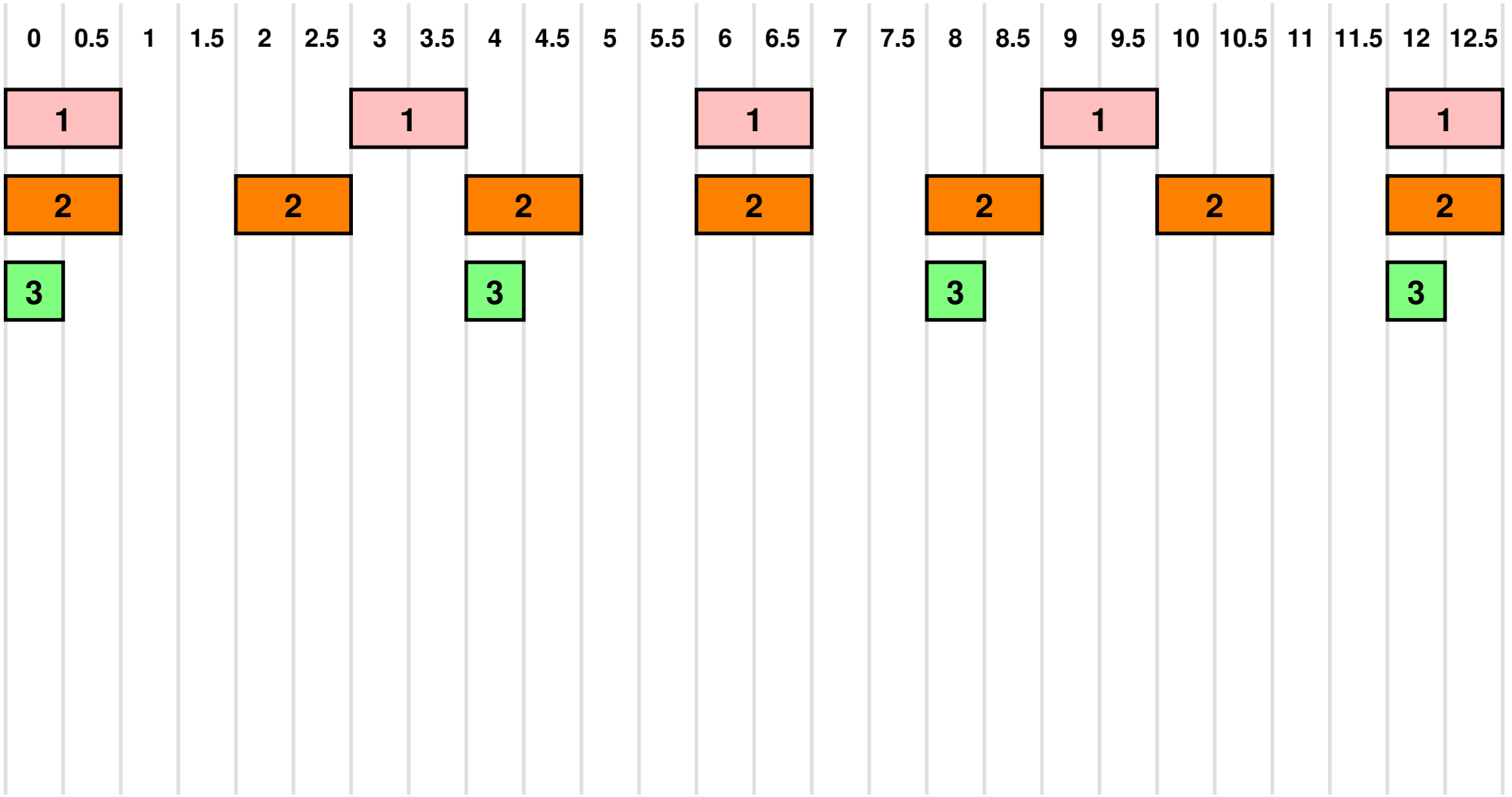
Phase Problems



- if jobs do not start in-phase, rate-monotonic scheduling still may work



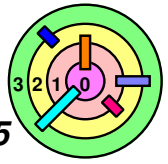
Phase Problems



see "extra slides" at the end

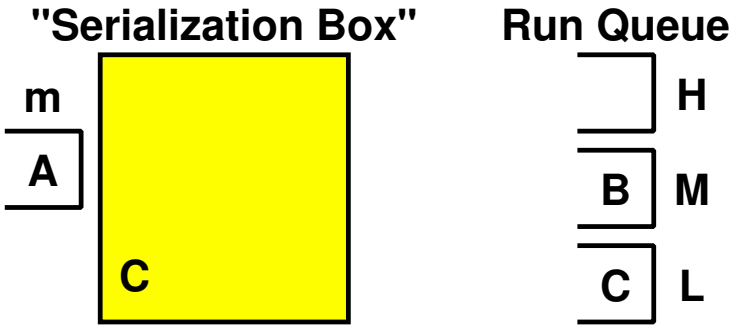
5.3 Scheduling

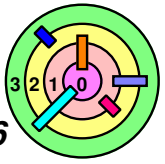
- Goals
- Scheduling Algorithms
- *Implementation Issues*
- Case Studies



Priority Problem

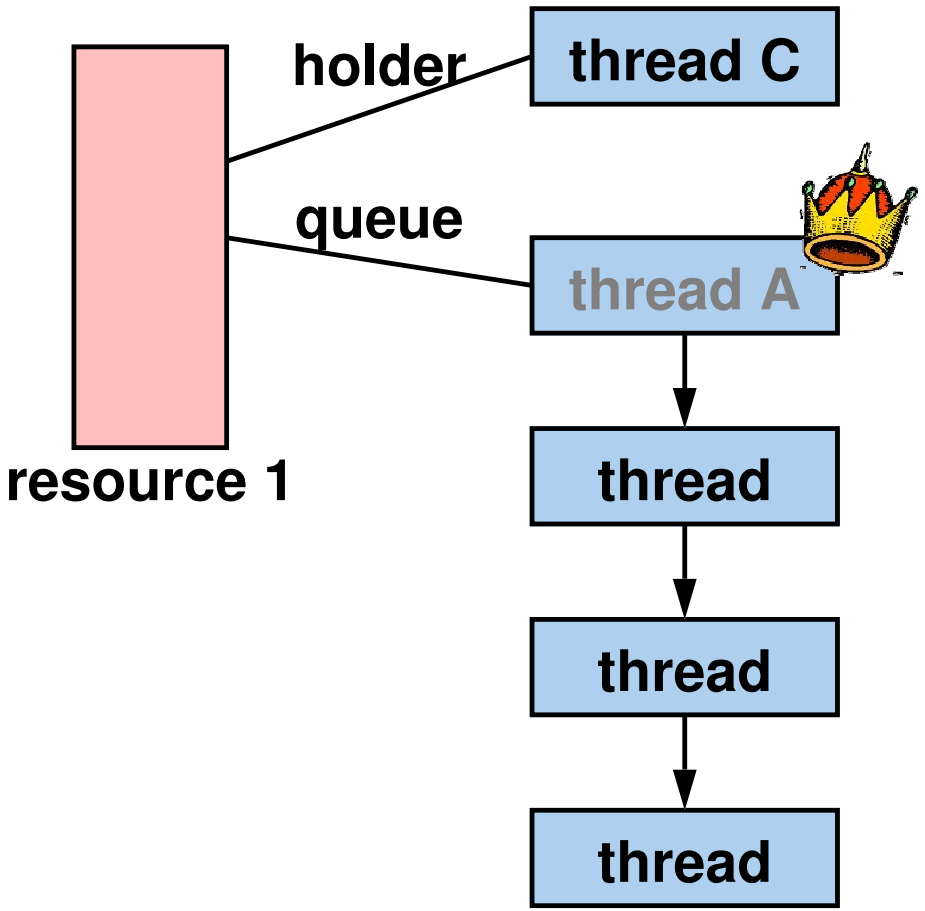
- High-priority thread A blocks on mutex 1
- Low-priority thread C holds mutex 1
- Thread C cannot run because medium-priority thread B is running
- A is effectively waiting at C's priority
  - *priority inversion*





Priority Inheritance

- While A is waiting for resource held by C, it gives C its priority



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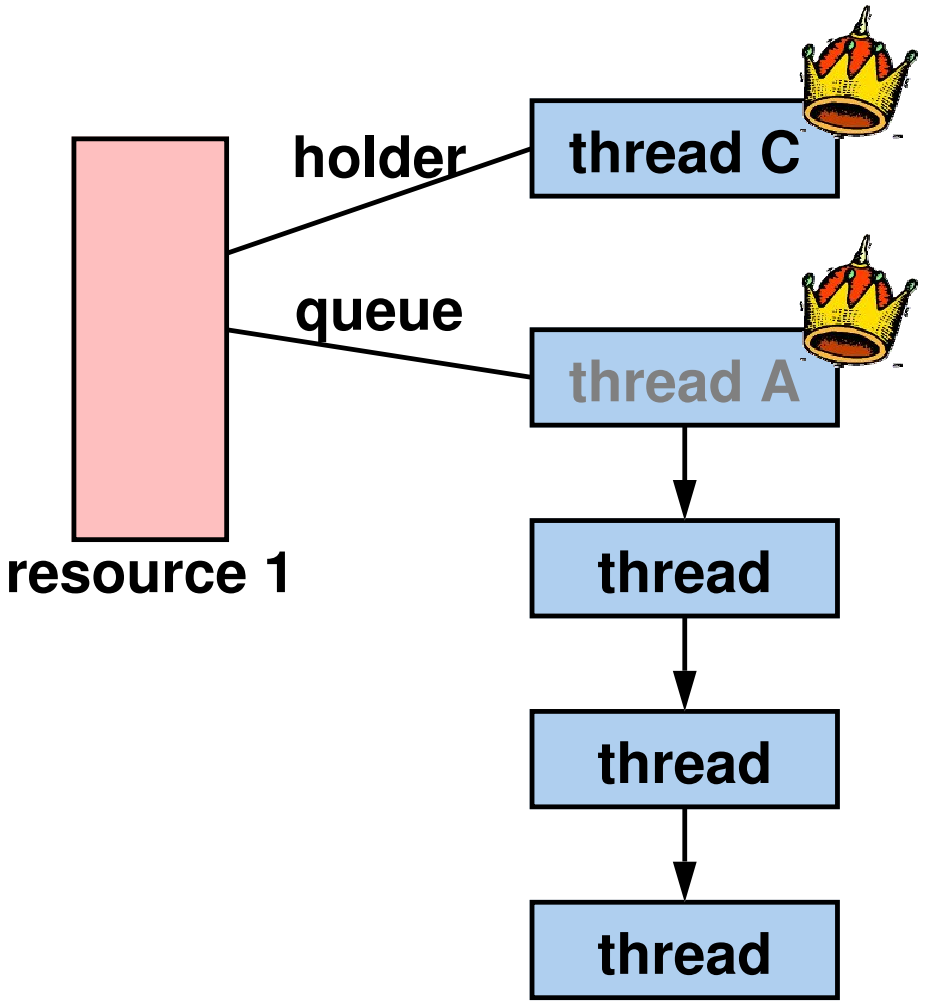
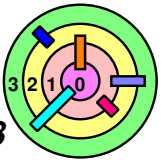
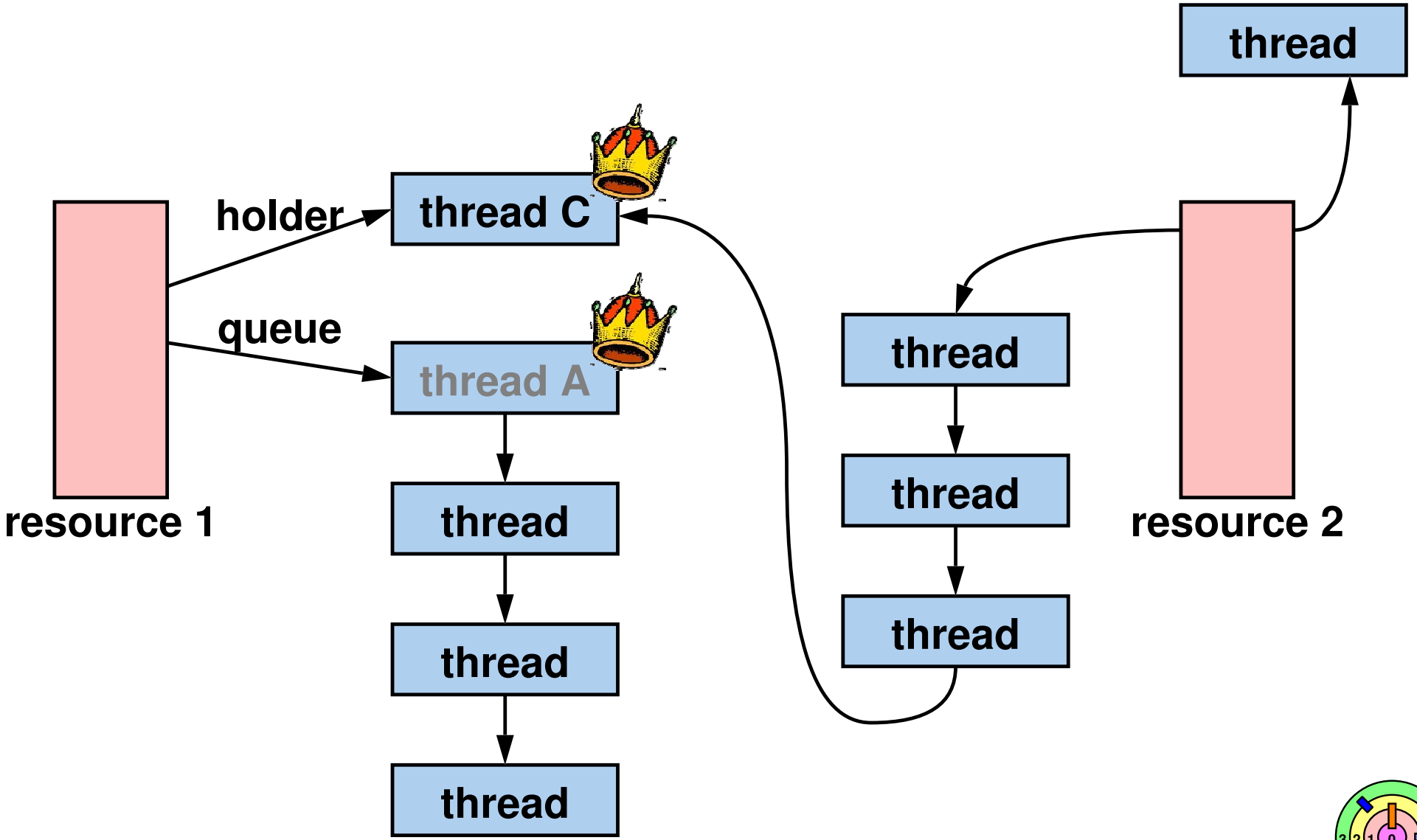




Cacading Inheritance



Cacading Inheritance