Workshop on Transactional Memory 2012

Towards Fair Transaction Scheduling with Competing QoS Requirements

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Context
Soft Real Time Applications

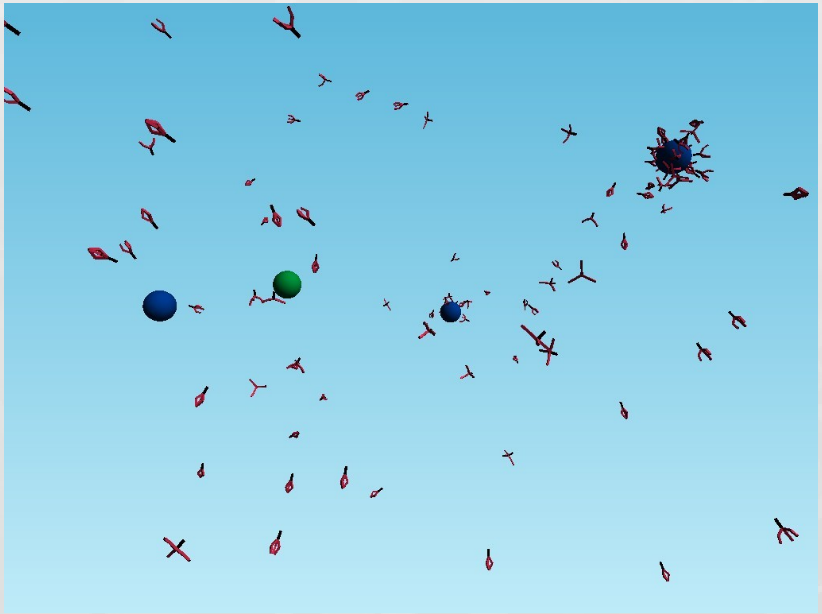
- Performance is not measured by raw throughput, but perceived responsiveness.
  - Service Level Agreement (SLA)
  - Quality of Service (QoS)
    - Measured as a % of *key events* completed within a given time (*deadline*).
    - e.g.: QoS(95,500) → 95% complete under 500ms
- Missed deadlines do not terminate the application
  - But perceived performance degrades
  - Results in user “frustration”

Context
Soft Real Time Applications

- Bulk of user applications falls in this category
  - Multimedia playback (video/audio rendering)
    - Failed deadlines lead frames skipped
    - Leads to choppy video/audio
  - Interactive applications (latency to input)
    - Temporarily “frozen” application
    - Increases user input error rates
  - Gaming (latency to input)
    - High latency handicaps players
    - Has a direct effect on fairness

Context
Soft RT Applications (Examples)

- Swarm
  - OpenGL rendering application [U. of Rochester]
  - One thread renders the scene
  - Others update the world state
  - QoS translates into output *framerate*

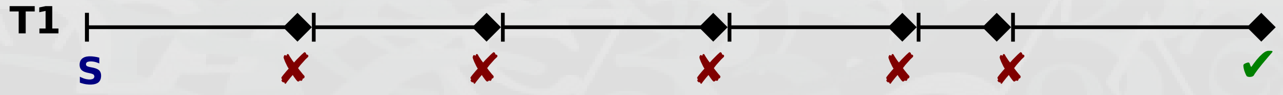


Context
Soft RT Applications (Examples)

- Synquake
  - Benchmark based on Quake [U. of Toronto]
  - Interactive application based on an online game
  - QoS measures action response time (*lag*)
    - Actions have their own scope / data access patterns

Context
Transactional Memory Suitability

- TM is a good candidate for these applications
  - Few actual conflicts
  - Locks often cover more objects than needed
  - ✔ TM can provide better scalability
- However, there are no time guarantees
  - ✗ Transactions retry until the block executes successfully
  - ✗ Durations are unbounded



Design
Our Proposal

- How can TM be adapted to meet QoS requirements?
  - Previous work is on irrevocable transactions
    - ✔ Prioritizes a transaction → ensures commit
    - ✗ Limits parallelism
    - ✗ Penalizes throughput even when unneeded
  - Our approach is state based
    - Use different execution modes with varying scalable/predictable tradeoffs
    - Switch among them according to time to deadline

STM
(default optimistic behavior)

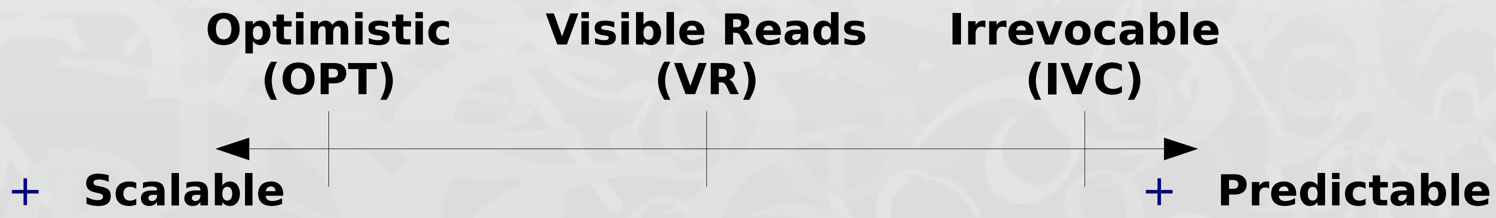
\+ **Scalable**
− **Predictable**

STM
(in irrevocable mode)

− **Scalable**
\+ **Predictable**

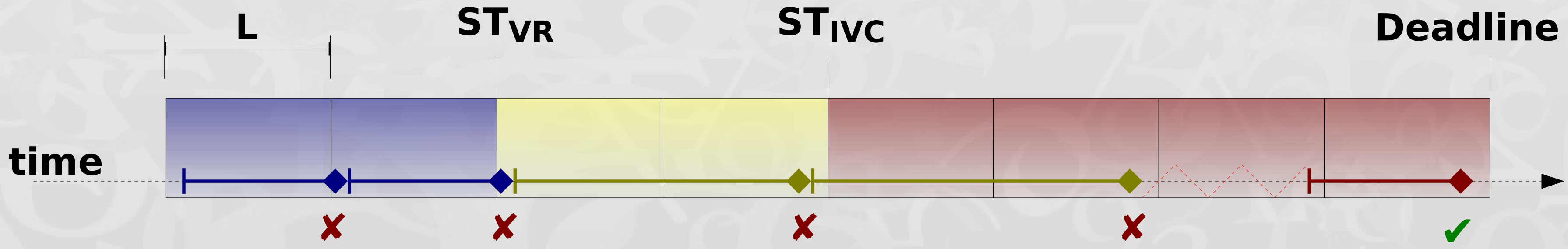
Design
Execution Modes

- Optimistic (Invisible Reads)
  - ✔ Highest throughput
  - ✗ Conflict detection is often delayed
- Visible Reads
  - ✔ Allows earlier conflict detection
  - ✗ Slower execution
- Irrevocable
  - ✔ Ensures commit
  - ✗ Serializes execution



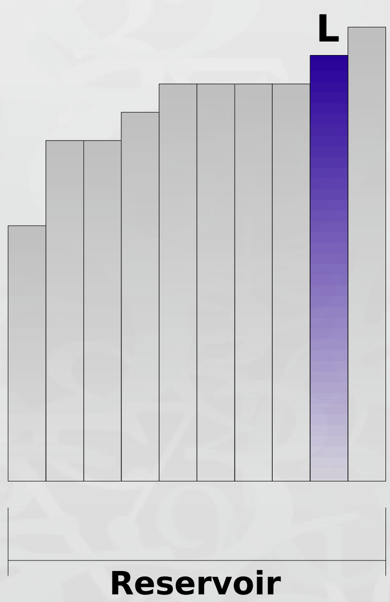
Design
Switching Modes

- Decision taken at abort/retry
- Estimate required time to complete in other modes:
  - L = estimated length in Optimistic
  - Visible Reads = 2 x L
  - Irrevocable = 2 x L
- Switch times:
  - ST_{VR} = 6 x L
  - ST_{IVC} = 4 x L



Design
Time Measuring

- Sample past execution times
  - Use Vitter's Reservoir algorithm
  - Provides representative distribution of durations
  - QoS as a percentile + Sorted reservoir → Expected execution time **L** to use

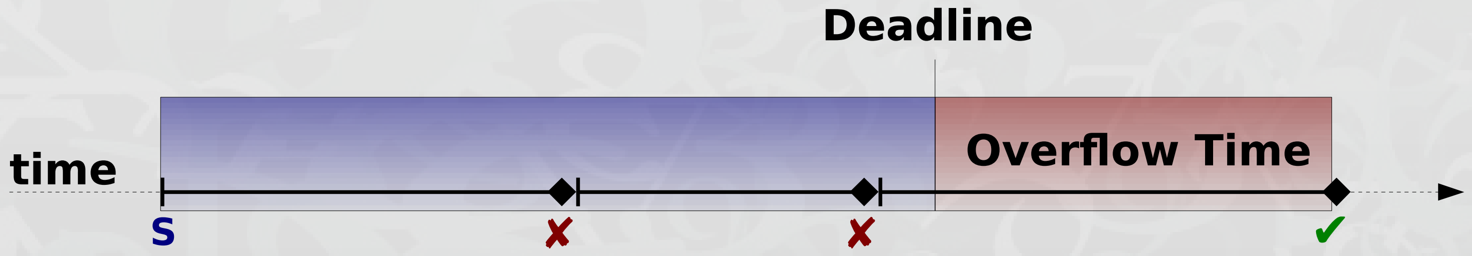


Design
Concurrent Deadlines

- Meeting QoS can be impossible with simultaneous deadlines
  - Using irrevocable ensures one TX meets its deadline
  - Others are delayed
- Secondary goal to meeting QoS: balancing deadlines
  - Even distribution of missed deadlines → *fairness*
    - No thread performs overall better than others
    - All missed deadlines within a thread fail “equally bad”

Design
Measuring Fairness

- Measure by Hit-rate
  - Percentage of deadlines met
  - Stable hit-rate → no thread has an advantage over than others
- Measure by Overflow
  - Amount of time by which deadline was missed
  - Stable overflow → missed deadlines are not “worse” in some cases than others



Design
Contention Managers

- Basic CMs:
  - Suicide (lowest overhead)
  - Deadline Aware (priority to deadline)
- Concurrent Deadlines CMs:
  - Basic (priority to closest to deadline)
  - Fair (priority to lower average hit rate)
  - Cycles (priority to most average overflow time)
  - Compound (if deadline not missed use basic, otherwise cycles)

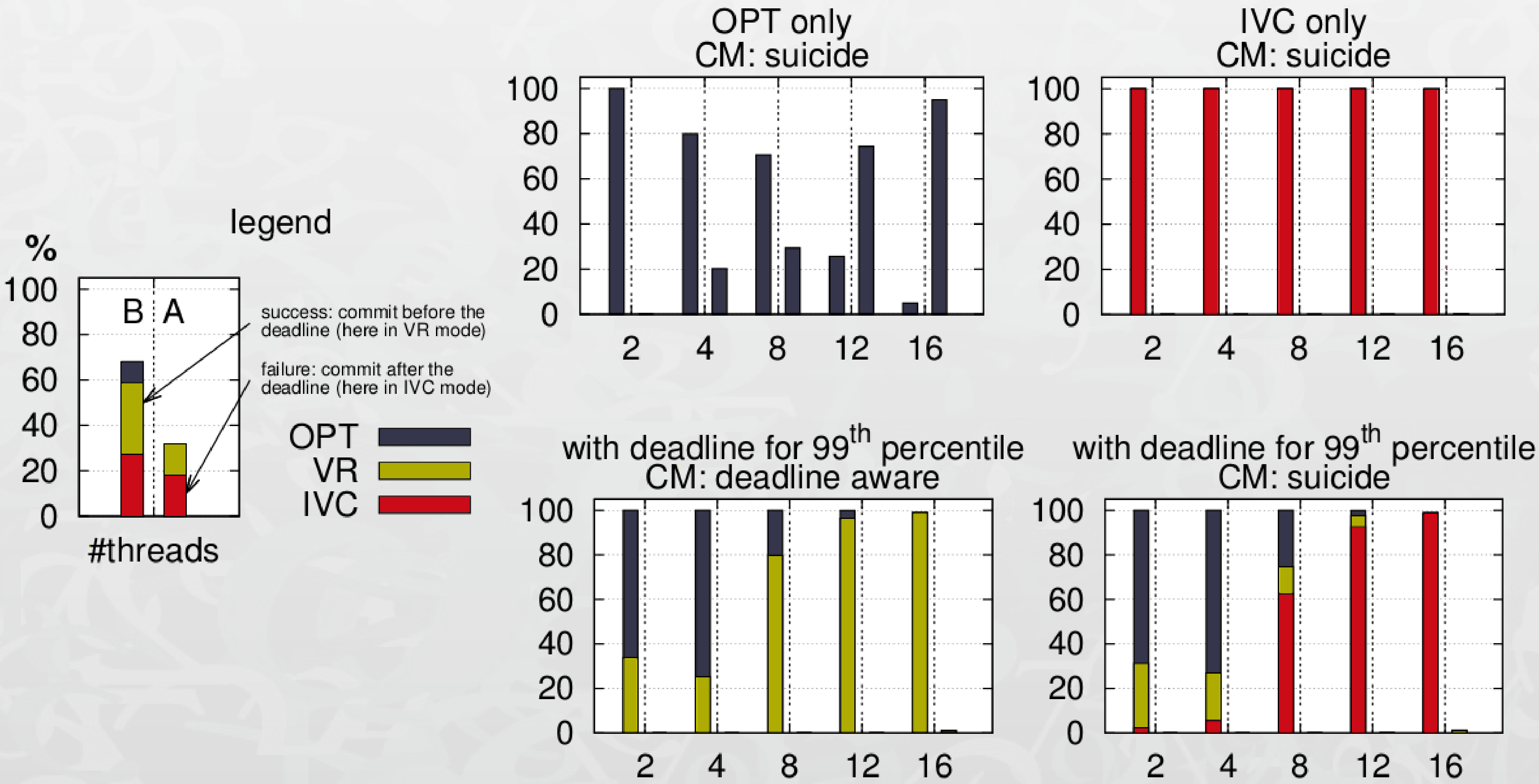
Design
Irrevocable Queue

- Default IVC implementation is insufficient for concurrent deadlines
- Has no queue, no ordering (spin-lock based)
  - Using a synchronized queue threads enter irrevocable using a “highest priority first” order
  - Priority can be determined:
    - Time of deadline (time stamp)
    - Current overflow time average

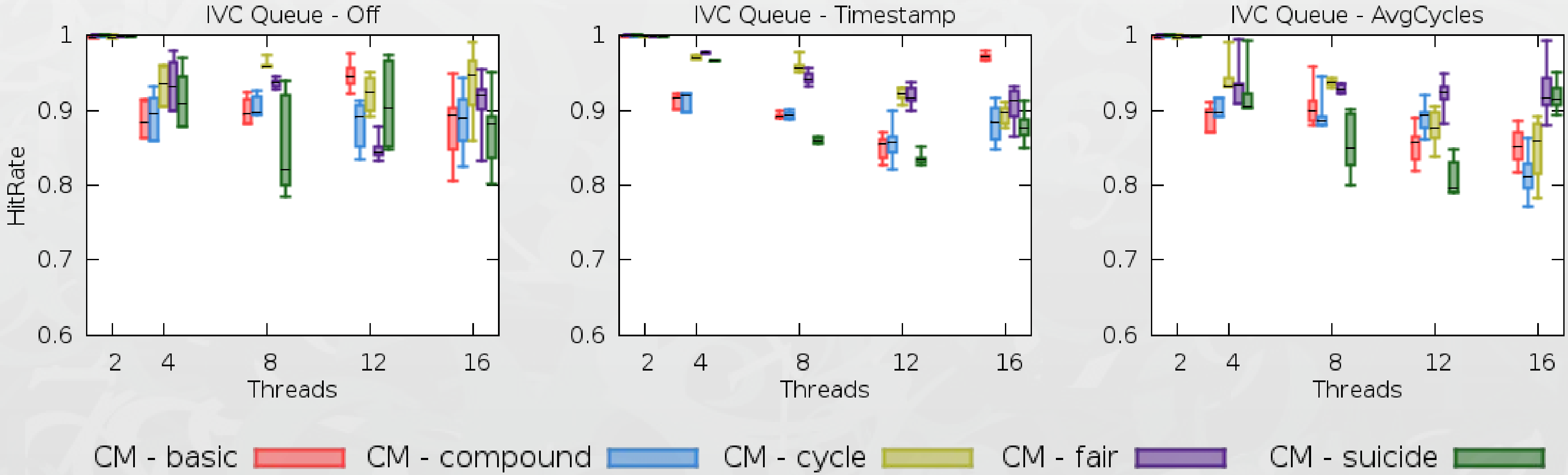
Experimental Results
Setup

- TinySTM
- Linux Kernel 2.6.34 SMP 64bit
- AMD Opteron Server
  - Four 2.3 GHz quad-core CPUs (16 cores)
  - 8GB RAM
- Swarm
  - Deadline: 30 fps
  - QoS 99%
- SynQuake
  - Deadline specified for the *attack* action
  - QoS 99%

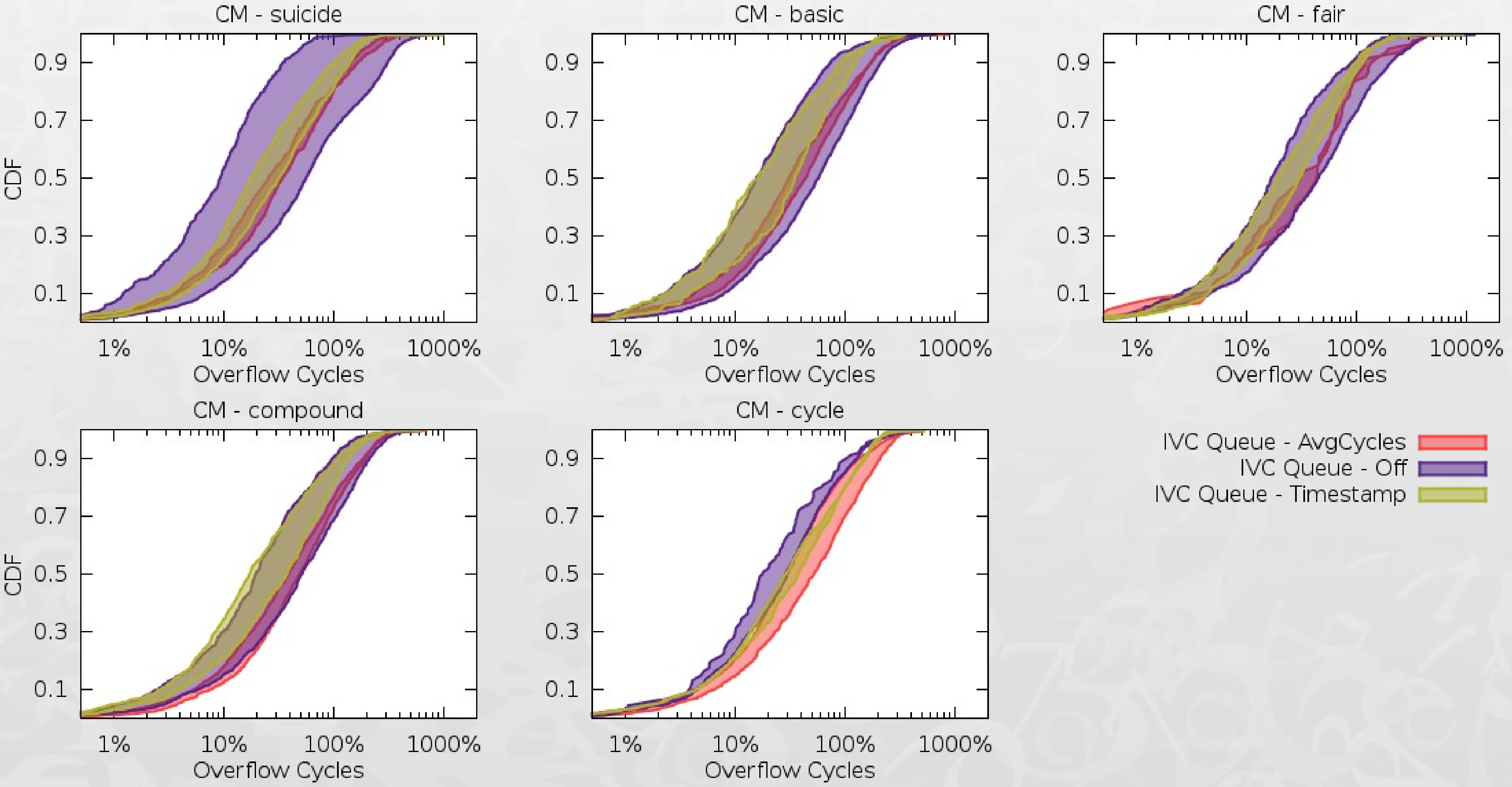
Experimental Results
Single Deadlines (Swarm)



Experimental Results
Concurrent Deadlines (SynQuake)



Experimental Results
Synquake – Overflow distributions

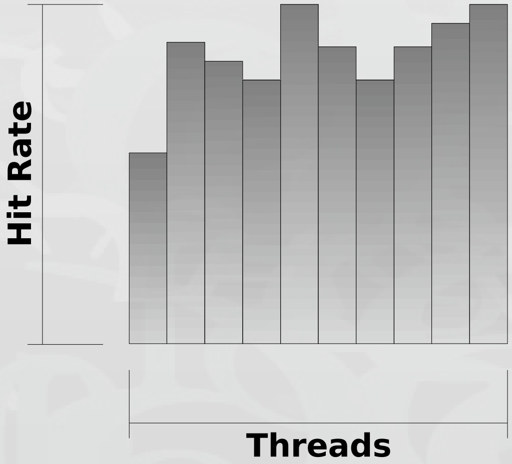


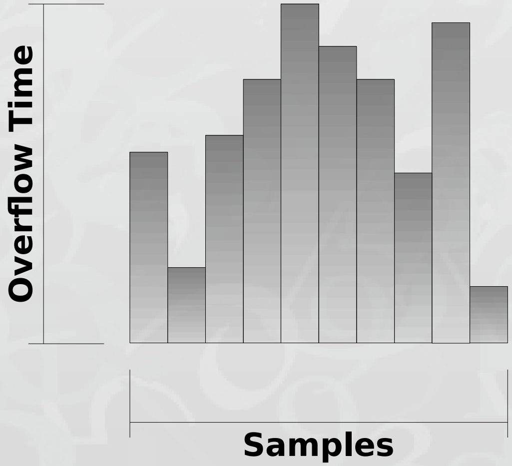
Conclusions

- Single deadlines can be met most of the time
  - With results equivalent to irrevocable
    - But with much lower contention
- Concurrent deadlines have widely varying results
  - CM Cycles has the most stable output and good hit-rate
  - Time stamp based queue improves overall results slightly more than overflow time
  - CM Cycles + Time stamp Queue gives overall best result
  - There is not necessarily a forced tradeoff between hit-rate and fairness

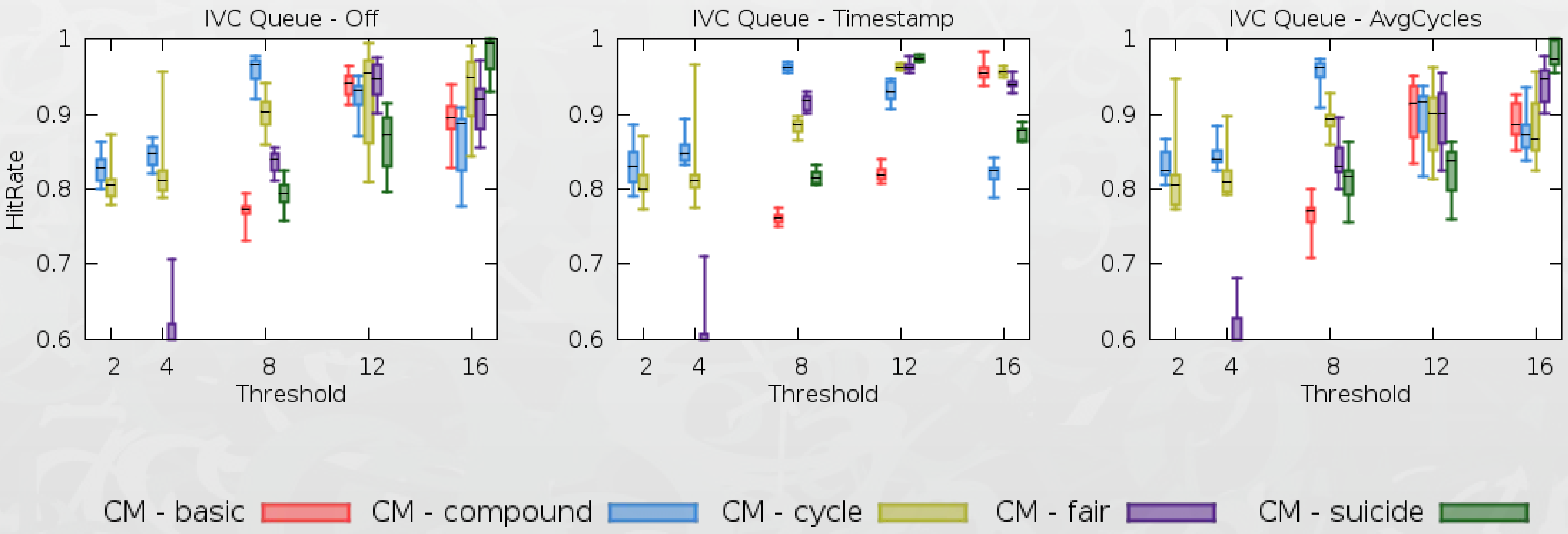
Design
Measuring Fairness

- Measured between threads or within threads
  - Between: per-thread results should have low variance
  - Within: overflow times should have low variance
- Selected two approaches to simplify:
  - Hit-Rate variance between threads
  - Overflow variance within threads





Experimental Results
Synquake – Hit Rate (Threshold 8)



Experimental Results
Synquake – Overflows (Threshold 8)