MichiganEngineering

Persistency Programming 101

Why and What of memory persistency

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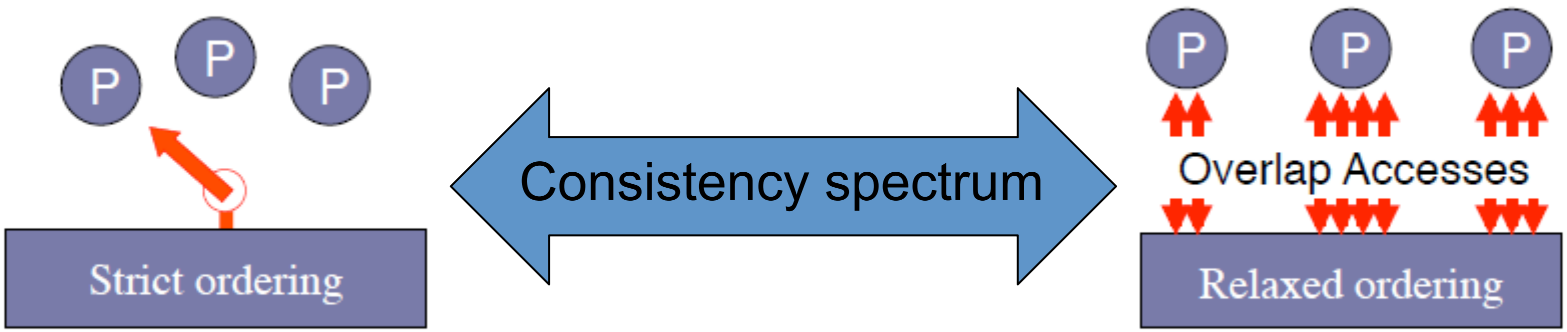
Executive summary

- NVMs → in-memory, recoverable data structs
- Require ordering of NVM writes (persists)
- Consistency models do not order persists
- Memory persistency [ISCA '14]
  - Consistency models for NVM
- This talk:
  - Motivate memory persistency
  - Summarize persistency models

Background - Memory consistency

- Contract b/w hardware and software on store visibility (implementation independent)
- May be strict (SC) or relaxed (RMO)

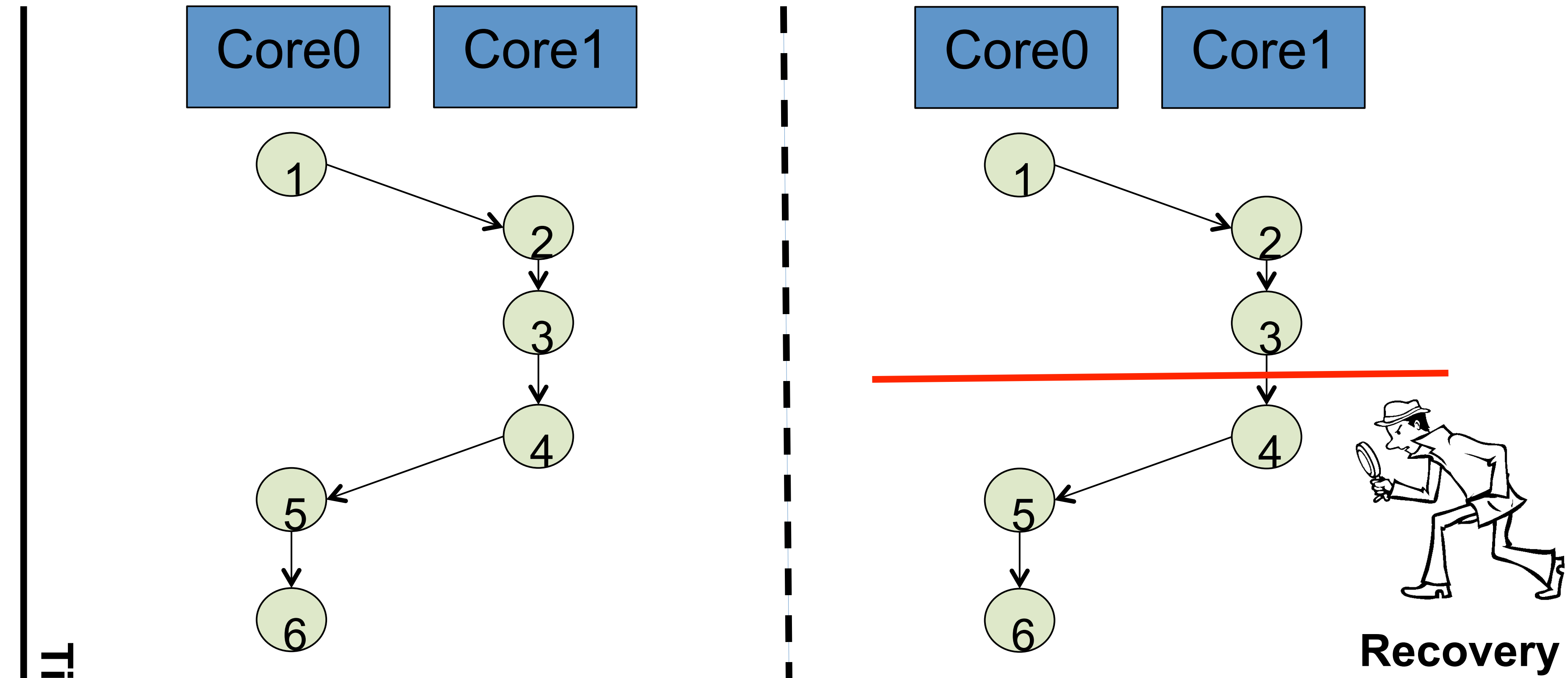


- Does not apply to persists

Need persistency models to order persists

Future system abstraction

Memory events (stores/loads)



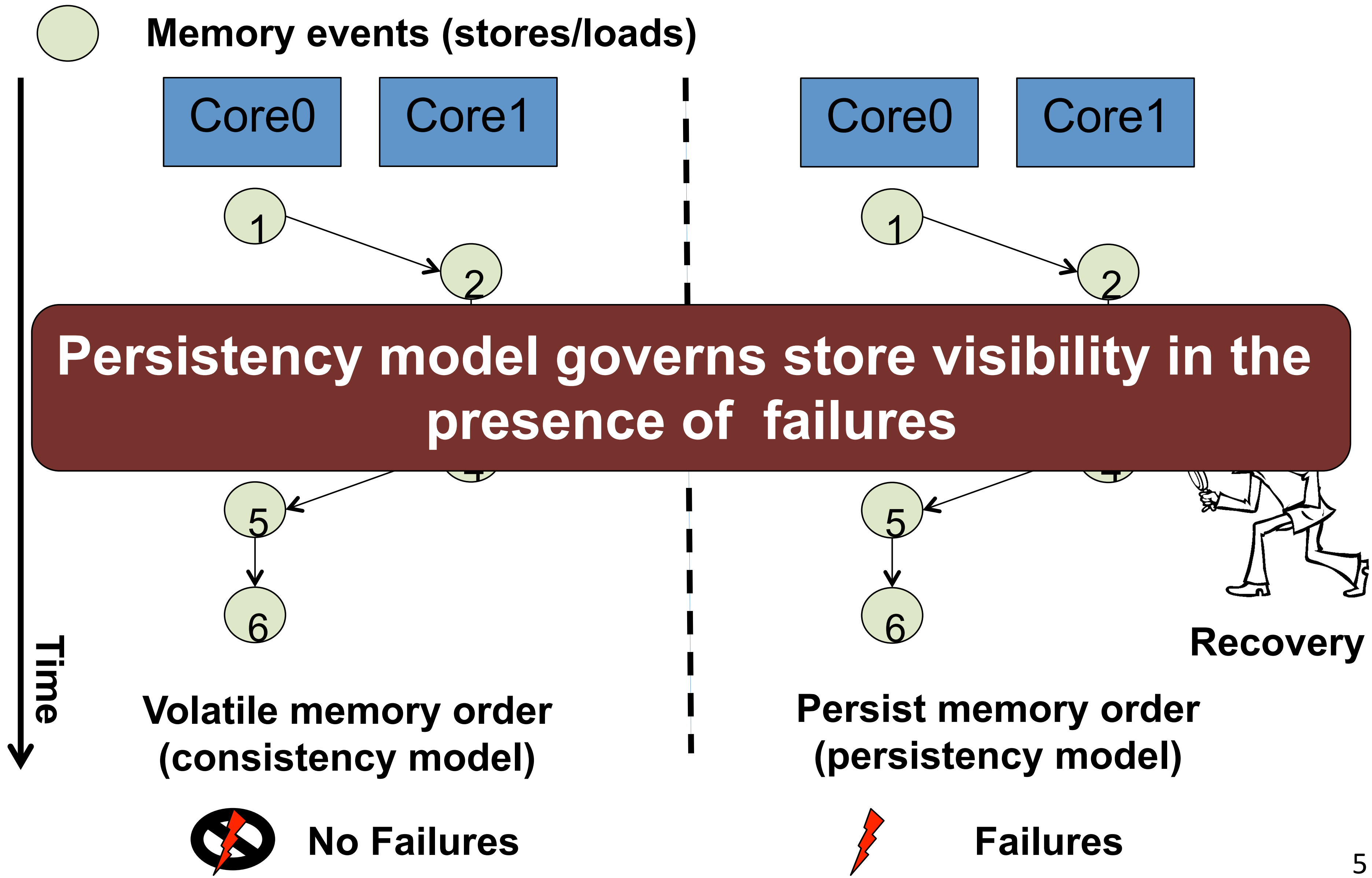
Volatile memory order (consistency model)

Persist memory order (persistency model)

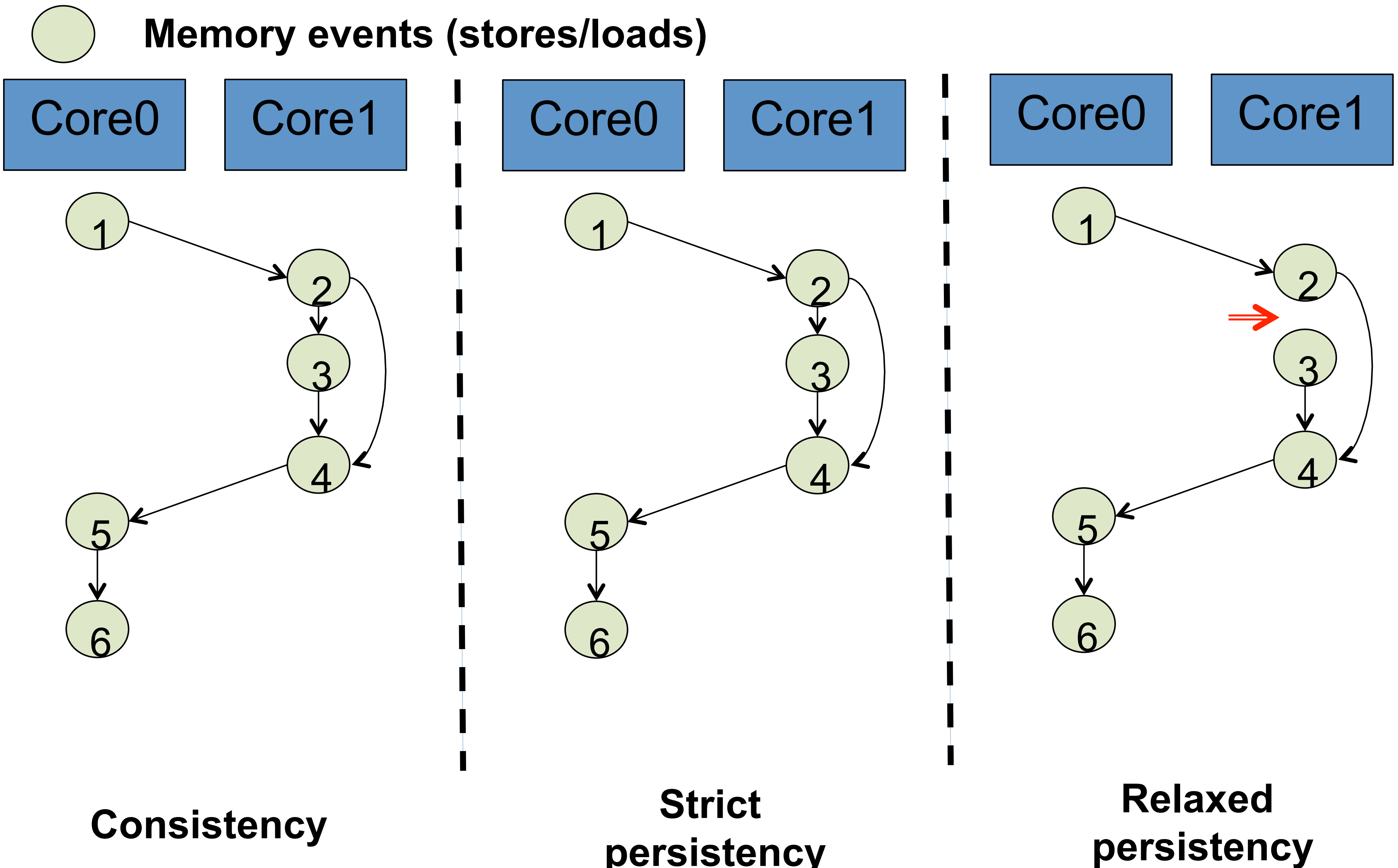
No Failures

Failures

Future system abstraction



Types of persistency models



Strict vs relaxed persistency

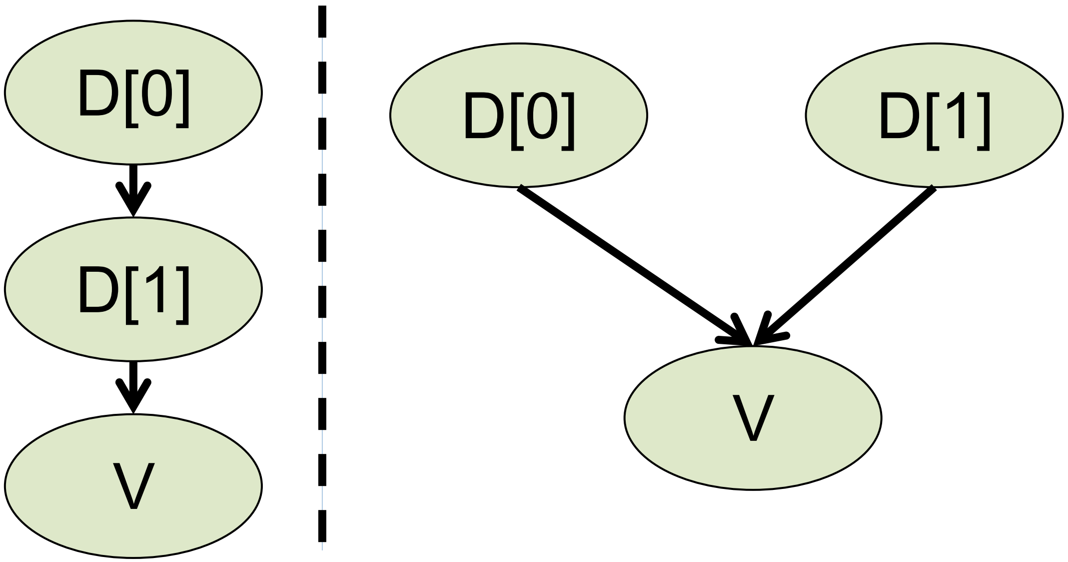
- Strict persistency
  - Consistency model = persistency model
  - Expensive (cost of persist > cost of store)
- Relaxed persistency
  - Separate consistency and persistency models
  - Reduces persist memory order constraints
  - Might require more robust recovery software
  - Failures are infrequent → recovery overhead OK

Relaxed persistency models → ↑ performance

How do persists affect performance?

- Persists form a directed acyclic graph (DAG)
  - Critical path limits overall performance

1: persist Qe.data[0] = x
2: persist Qe.data[1] = y
3: persist Qe.valid = true



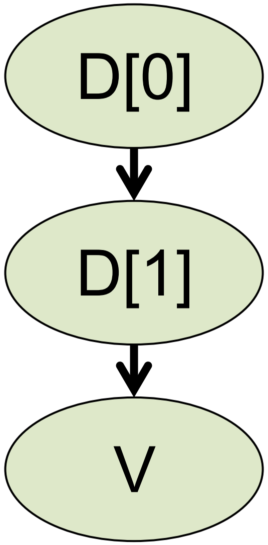
Models should allow expression of minimal constraints

Strict persistency

- Consistency model = persistency model
- Relaxed consistency → ↑persist concurrency

Strict persistency with SC

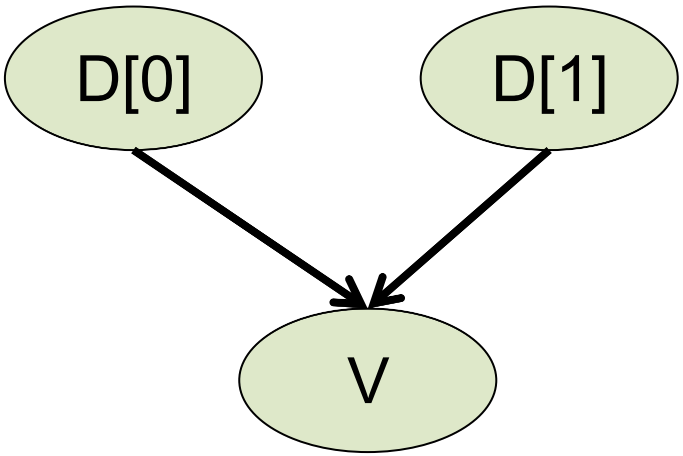
1. lock (volatile mutex)
2. persist Qe.data[0] = x
3. persist Qe.data[1] = y
4. persist Qe.valid = true
5. unlock



- Program order → store order → persist order
- No annotations required
- Suboptimal persist critical paths

Strict persistency with RMO

1. lock (volatile mutex)
2. barrier
3. persist Qe.data[0] = x
4. persist Qe.data[1] = y
5. barrier
6. persist Qe.valid = true
7. barrier
8. unlock



- Barriers for synchronization and recovery
- Annotation burden on the programmer
- Affects volatile perf

Strict persistency with RMO

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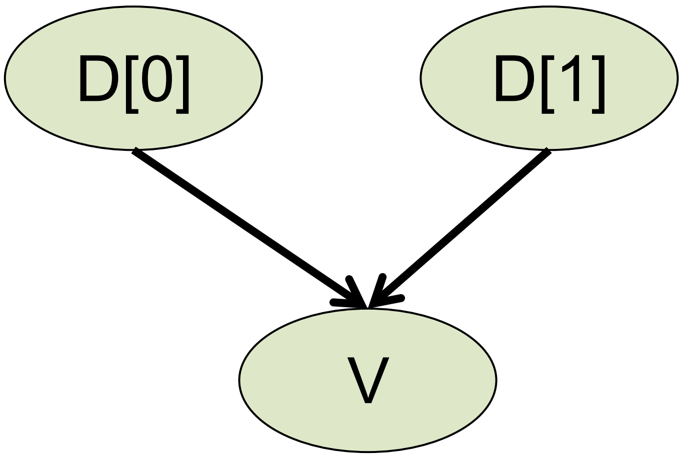


- Barriers for synchronization and recovery
- Annotation burden on the programmer
- Affects volatile perf

Relaxed persistency models

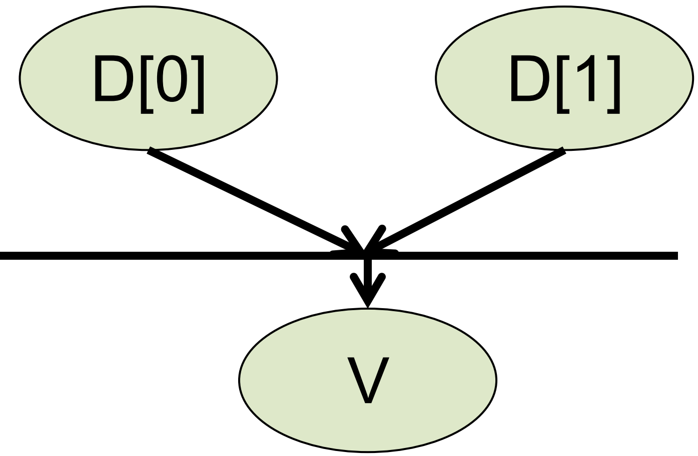
- Decouple consistency and persistency models
- Expose additional persist concurrency
  - Important for conservative consistency models
- Will use SC as underlying consistency model

Epoch persistency

1. lock (volatile mutex)
2. persist Qe.data[0] = x
3. persist Qe.data[1] = y
4. persist barrier
5. persist Qe.valid = true
6. unlock

Epoch 1

Epoch 2

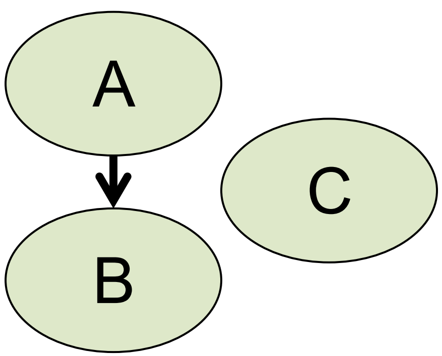


- Persist barriers divide program into epochs
  - Inspired from BPFS [SOSP '09]
  - Persists within epoch concurrent
  - Persists from successive epochs ordered
  - Store visibility still dictated by program order

Epoch persistency drawback

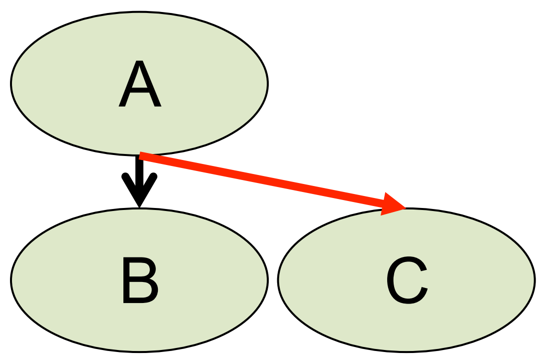
Ideal

persist A
persist B
persist C



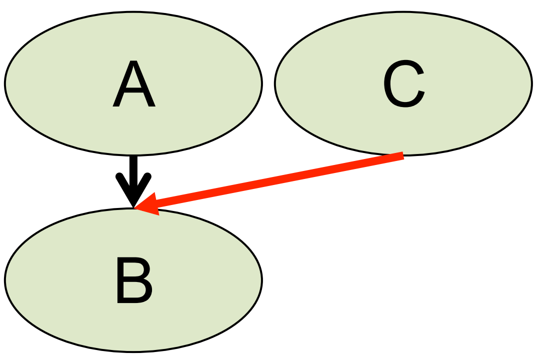
DAG-1

persist A	persist A
persist barrier	persist barrier
persist B	persist C
persist C	persist B



DAG-2

persist A	persist C
persist C	persist A
persist barrier	persist barrier
persist B	persist B

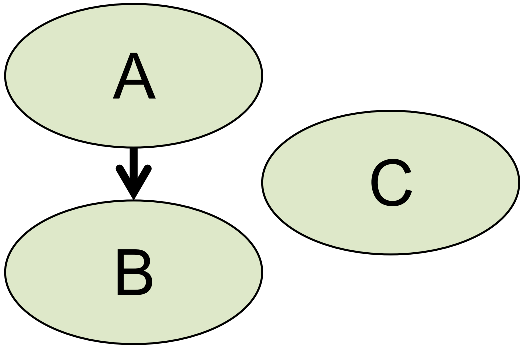


Cannot express minimal constraints

Strand persistency

- Divide thread's execution into strands
  - A strand can be abstracted as a logical thread
- Persists on different strands are concurrent
- New memory event *newStrand*
  - Persist barriers order persists within a strand

persist A
persist barrier
persist B
newStrand
persist C



Can enforce only the necessary constraints

Ordering persists across threads

- Conflicting accesses establish persist order
  - Two accesses to same address, at least one store
  - Persist order must match volatile order
  - Could be to volatile/non-volatile addresses
  - *Strong persist atomicity*

Strong persist atomicity example

Thread - 1	Thread - 2
lock X (volatile mutex)	
persist barrier	
persist A	
persist barrier	
unlock X	lock X
	persist barrier
	persist B
	persist barrier
	unlock X

Persist order

Conflicting accesses

Time

Conclusions

- Strict persistency
  - Unifies consistency and persistency model
- Epoch persistency
  - Persists within epoch concurrent, epochs ordered
- Strand persistency
  - Allows enforcing only minimal constraints
- Strong persist atomicity
  - Allows ordering persists across threads/strands

Thank You!

Questions?