6.033 Spring 2017

Lecture #16

- **Atomicity via Write-ahead logging**

goal: build reliable systems from unreliable components

the abstraction that makes that easier is

transactions, which provide **atomicity** and **isolation**, while not hindering **performance**

atomicity ⟶ **shadow copies** (simple, poor performance)

isolation ⟶ **?**

eventually, we also want transaction-based systems to be **distributed**: to run across multiple machines

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the abstraction that makes that easier is

transactions, which provide **atomicity** and **isolation**, while not hindering **performance**

atomicity ⟶ **shadow copies** (simple, poor performance) or **logs** (better performance, a bit more complex)

isolation ⟶ **?**

eventually, we also want transaction-based systems to be **distributed**: to run across multiple machines

using shadow copies to abort on error

```
transfer(bankfile, account_a, account_b, amount):
  bank = read_accounts(bankfile)
  bank[account_a] = bank[account_a] - amount
  bank[account_b] = bank[account_b] + amount
  if bank[account_a] < 0:
    print "Not enough funds"
  else:
    write_accounts("tmp_bankfile")
    rename(tmp_bankfile, bankfile)
```

with transaction syntax

```
transfer(account_a, account_b, amount):
  begin
  write(account_a, read(account_a) - amount)
  write(account_b, read(account_b) + amount)
  if read(account_a) < 0: // not enough funds
    abort
else:
  commit
```

```
begin     // T1
A = 100
B = 50
commit    // A=100; B=50

begin     // T2
A = A-20
B = B+20
commit    // A=80; B=70

begin     // T3
A = A+30
crash! 💥
```

problem: after crash, `A=110`, but `T3` never committed

we need a way to revert to A's previous committed value

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```
begin    // T1
A = 100
B = 50
commit   // A=100; B=50
```

```
begin    // T2
A = A-20
B = B+20
commit   // A=80; B=70
```

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begin    // T3
A = A+30
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read(log, var):
  commits = {}
  // scan backwards
  for record r in log[len(log) - 1] .. log[0]:
  // keep track of commits
  if r.type == commit:
    commits.add(r.tid)
  // find var's last committed value
  if r.type == update and
     r.tid in commits and
     r.var == var:
      return r.new_value
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performance?

problem: reads are slow

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cell storage | A 110 | | B 70 |

read(var):

```
  return cell_read(var)
```

write(var, value):

```
  log.append(current_tid, update, var, read(var), value)
  cell_write(var, value)
```

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      cell_write(r.var, r.old_val) // undo
```

TID	T1	T1	T1	T2	T2	T2	T3
	UPDATE	UPDATE	COMMIT	UPDATE	UPDATE	COMMIT	UPDATE
OLD	A=0	B=0		A=100	B=50		A=80
NEW	A=100	B=50		A=80	B=70		A=110

cell storage | A 80 | | B 70 | commits = {T2, T1}

```
recover(log):
  commits = {}
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performance?

problem: read performance is now great, but writes got (a little bit) slower and recovery got (a lot) slower

TID	T1	T1	T1	T2	T2	T2	T3
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```
read(var):
  if var in cache:
    return cache[var]
  else:
    // may evict others from cache to cell storage
    cache[var] = cell_read(var)
    return cache[var]

write(var, value):
  log.append(current_tid, update, var, read(var), value)
  cache[var] = value
```

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	UPDATE	UPDATE	COMMIT	UPDATE	UPDATE	COMMIT	UPDATE
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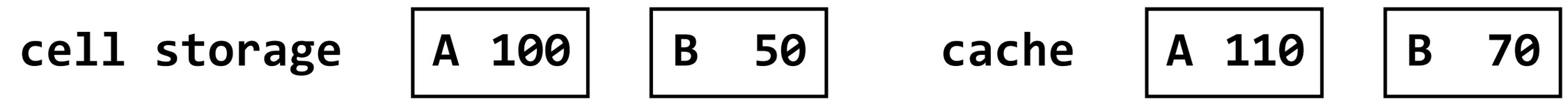

suppose we flushed the cache after T1 committed,
but have not flushed it since then

TID	T1	T1	T1	T2	T2	T2	T3
	UPDATE	UPDATE	COMMIT	UPDATE	UPDATE	COMMIT	UPDATE
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```

all other updates were committed; **B**'s value won't ever be changed

TID	T1	T1	T1	T2	T2	T2	T3
	UPDATE	UPDATE	COMMIT	UPDATE	UPDATE	COMMIT	UPDATE
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    cell_write(r.var, r.old_val) // undo
for record r in log[0] .. log[len(log)-1]:
  if r.type == update and r.tid in commits:
    cell_write(r.var, r.new_value) // redo
```

TID	T1	T1	T1	T2	T2	T2	T3
	UPDATE	UPDATE	COMMIT	UPDATE	UPDATE	COMMIT	UPDATE
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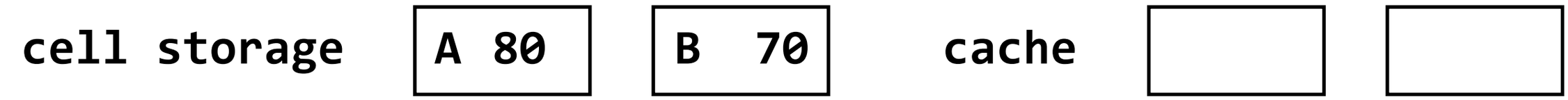

performance?

problem: recovery is still slow

TID	T1	T1	T1	T2	T2	T2	T3
	UPDATE	UPDATE	COMMIT	UPDATE	UPDATE	COMMIT	UPDATE
OLD	A=0	B=0		A=100	B=50		A=80
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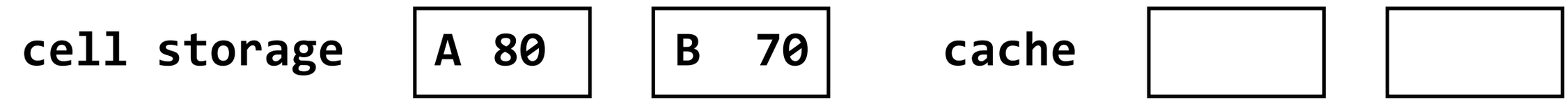

performance?

solution: write checkpoints and truncate the log

- **(Write-ahead) logs** provide **atomicity** with better performance than shadow copies. The primary benefit is making small appends for each update, rather than copying and entire file over for every change.

- **Cell storage** is used with the log to improve read-performance, and **caches** and **truncation** can be used to improve write- and recovery-performance.