CSCI3170 Introduction to Database Systems

Tutorial 10 – Final Exam Revision

DECOMPOSITION

Decomposition

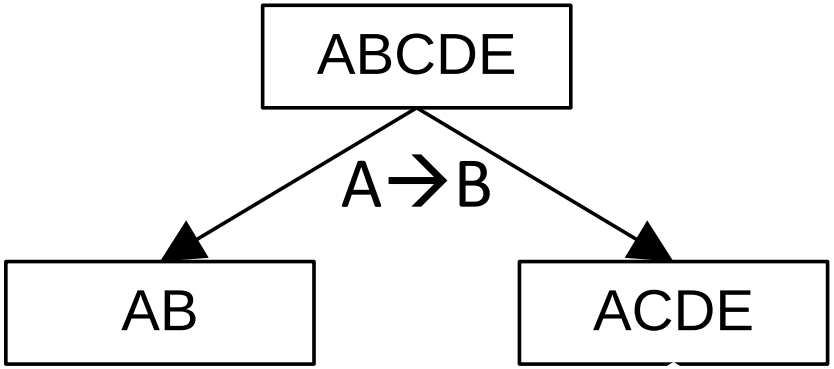
- $\{R_1, \ldots, R_n\}$ – a set of relation schemas
- $\{R_1, \ldots, R_n\}$ is a *decomposition* of R
  - if $R_1 \cup R_2 \cup \ldots \cup R_n = R$
- e.g.
  - R = (A, B, C)
  - R_1 = (A, B)
  - R_2 = (A, C)
- R_1 and R_2 is a decomposition of R

BCNF decomposition algorithm

Suppose R is not in BCNF, A is an attribute, and X → A is a FD that violates the BCNF condition.

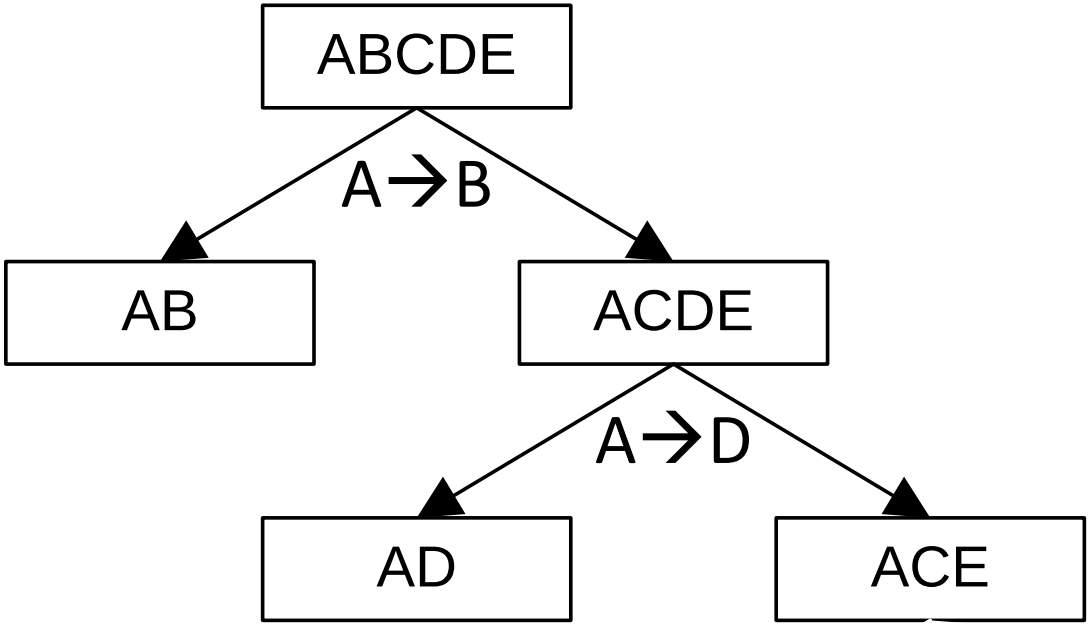
1. Remove A from R
2. Decompose R into XA and R-A
3. Repeat this process until all the relations become BCNF

Example



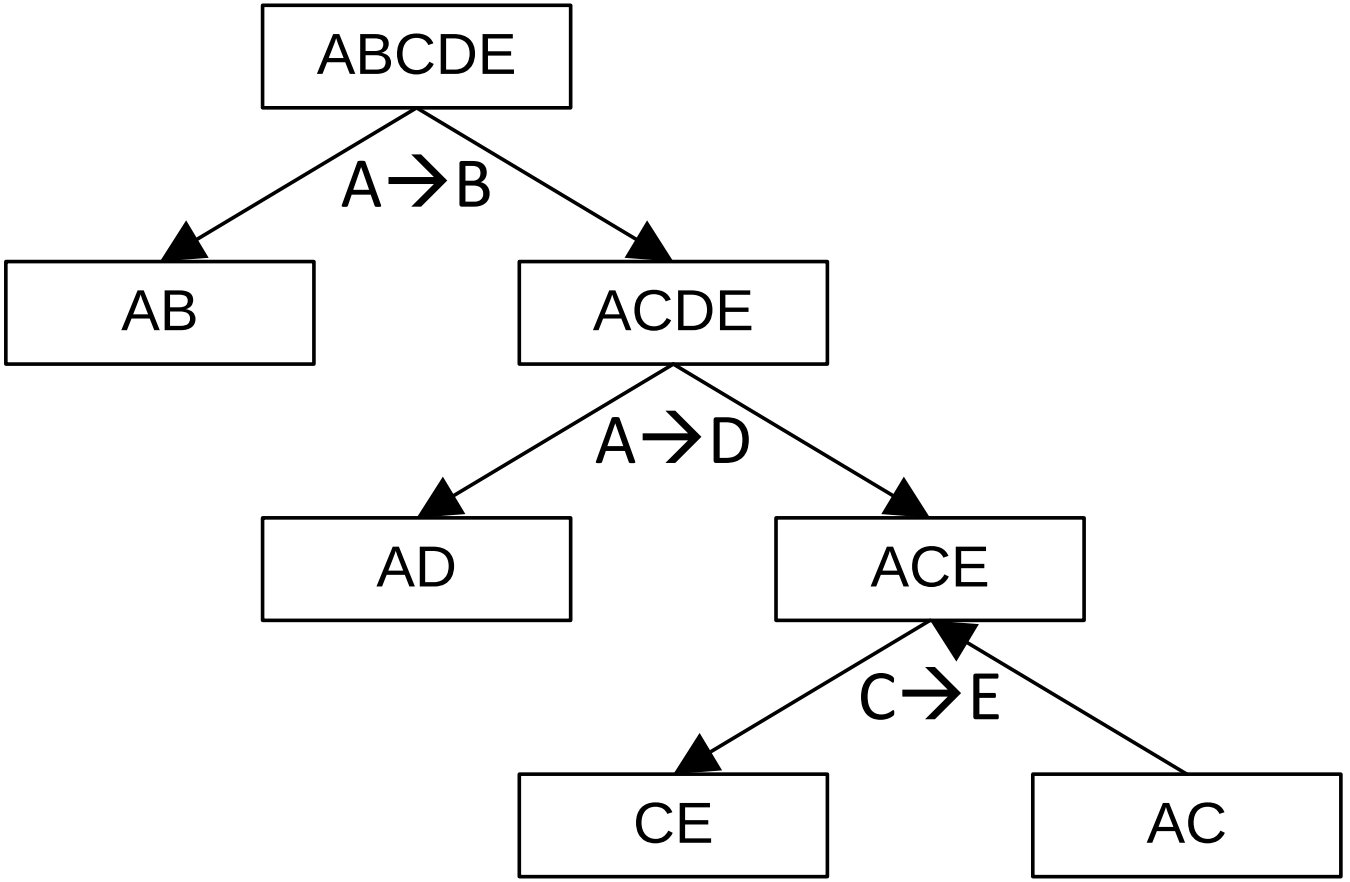
R = (A,B,C,D,E)
Key = AC
A → B

Example



R = (A,B,C,D,E)
Key = AC
$A \rightarrow B$
$A \rightarrow D$

Example



R = (A,B,C,D,E)
Key = AC
A → B
A → D
C → E

Canonical Cover

repeat
    Replace any $\alpha_1 \rightarrow \beta_1$ and $\alpha_1 \rightarrow \beta_2$ by $\alpha_1 \rightarrow \beta_1\beta_2$
    Delete any extraneous attribute from any $\alpha \rightarrow \beta$
until F does not change

Example

F = {E→A, E→B, A→BC, B→C}

- F_c = {**E→A, E→B**, A→BC, B→C}

  Combining **E→ A, E → B** into **E → AB**

Example

F = {E→A, E→B, A→BC, B→C}

- F_c = {E→A, E→B, A→BC, B→C}
- F_c = {E→AB, **A→BC, B→C**}

A→BC is extraneous
From **A→B** and **B→C**, we deduce **A→C** (transitivity)
From **A→B** and **A→C**, we deduce **A→BC** (union)

Example

F = {E→A, E→B, A→BC, B→C}

- F_c = {E→A, E→B, A→BC, B→C}
- F_c = {E→AB, A→BC, B→C}
- F_c = {**E→AB, A→B**, B→C}

E→AB is extraneous
From **E→A** and **A→B**, we deduce **E→A** (transitivity)
From **E→A** and **E→B**, we deduce **E→AB** (union)

Example

$F = \{E \rightarrow A, E \rightarrow B, A \rightarrow BC, B \rightarrow C\}$

- $F_c = \{E \rightarrow A, E \rightarrow B, A \rightarrow BC, B \rightarrow C\}$
- $F_c = \{E \rightarrow AB, A \rightarrow BC, B \rightarrow C\}$
- $F_c = \{E \rightarrow AB, A \rightarrow B, B \rightarrow C\}$
- $F_c = \{E \rightarrow A, A \rightarrow B, B \rightarrow C\}$

Final Result: $F_c = \{E \rightarrow A, A \rightarrow B, B \rightarrow C\}$

3NF decomposition algorithm

find a canonical cover F_c for F
result = { }
for each $\alpha \rightarrow \beta$ in F_c do
    if no schema in result contains $\alpha\beta$ then
        add schema $\alpha\beta$ to result
end for
if no schema in result contains a candidate key for R
   choose any candidate key α for R
   add schema α to result
end if

Example

- R = (A, B, C, D, E, F, G)
- F = { A → B, A → C, D → E, B → A, F → BG }
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

F_c	result
A → BC	
D → E	
B → A	
F → BG	

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

F_c	result
A → BC	ABC
D → E	
B → A	
F → BG	

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

F_c	result
A → BC	ABC
D → E	DE
B → A	
F → BG	

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

F_c	result
A → BC	ABC
D → E	DE
B → A	
F → BG	

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

F_c	result
A → BC	**AB**C
D → E	DE
B → A	
F → BG	

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

F_c	result
A → BC	ABC
D → E	DE
B → A	
F → BG	FBG

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = **DF**

F_c	result
A → BC	ABC
D → E	DE
B → A	
F → BG	FBG

Result = {ABC, DE, FBG}

Example

- R = (A, B, C, D, E, F, G)
- F_c = { A → BC, D → E, B → A, F → BG }
- Candidate key = DF

F_c	result
A → BC	ABC
D → E	DE
B → A	
F → BG	FBG

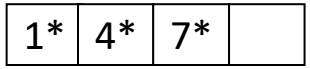
Result = {ABC, DE, FBG, DF}

B+ TREE

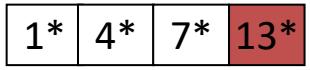
Insertion of B+ Tree

Order 2 B+ Tree
Root node: $1 \leq$ # elements ≤ 4
Non-root nodes: $2 \leq$ # elements ≤ 4

Original Tree

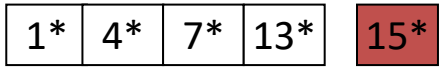


Insert 13



(No overflow)

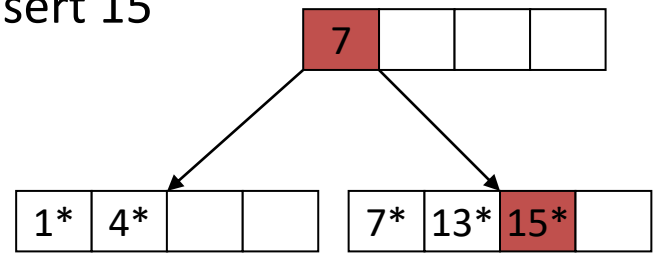
Insert 15



(Overflow)

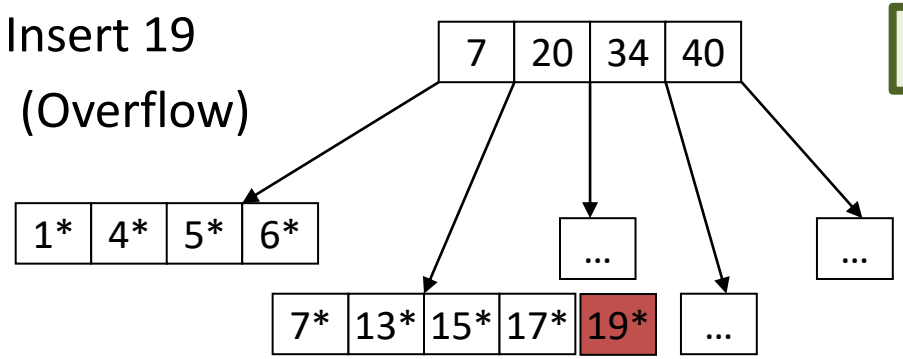
Leaf node overflow: split leaf node, **copy** middle **key** to the parent.

After Insert 15

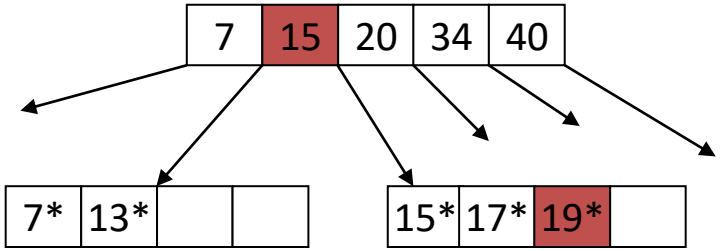


Tree grows

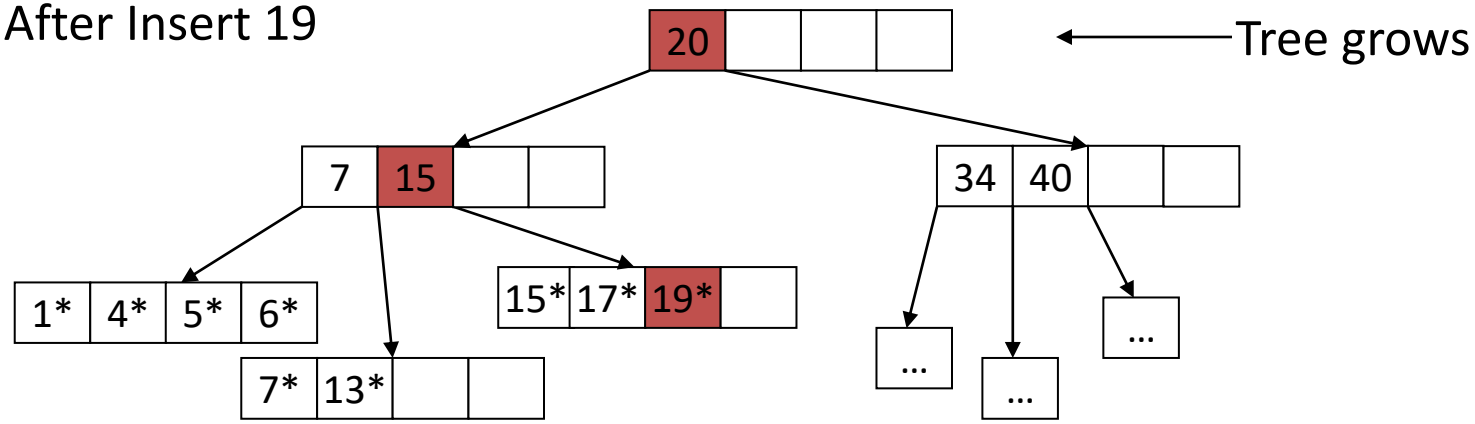
Insertion of B+ Tree



1. Leaf node overflow: split leaf node.

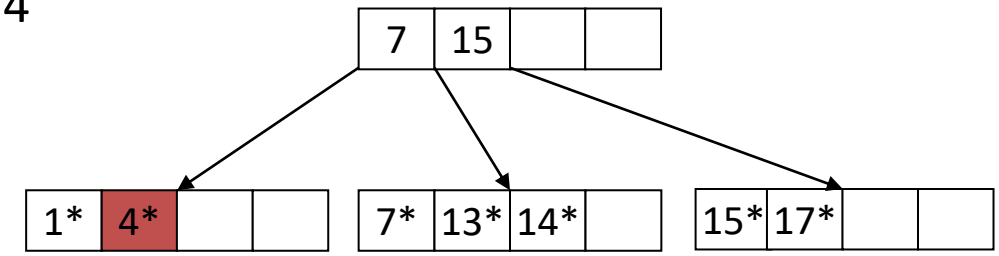


2. Non-leaf node overflow: split non-leaf node, **push** middle key up.



Deletion of B+ Tree

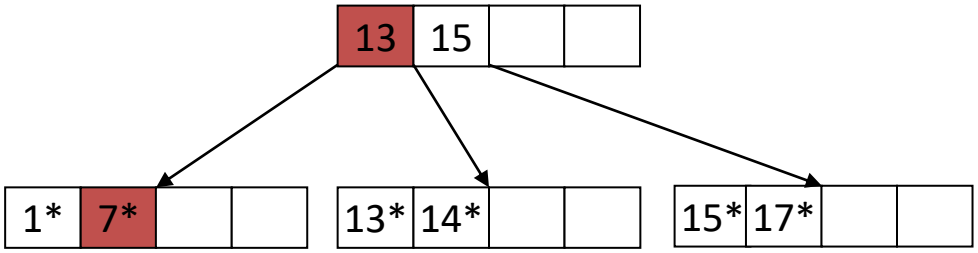
Delete 4



(Underflow)

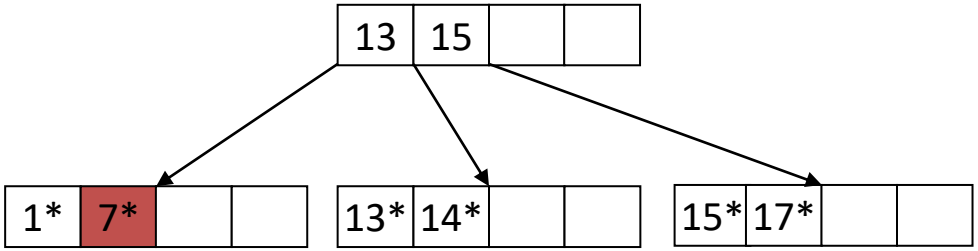
After delete 4, the page will underflow, need to borrow from sibling, update the parent.

After Delete 4



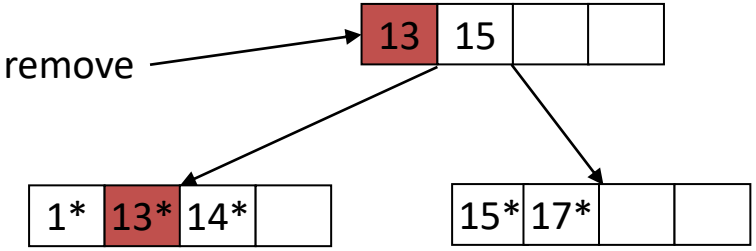
Deletion of B+ Tree

Delete 7

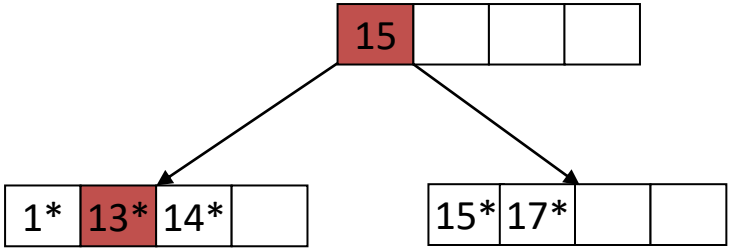


(Underflow)

After delete 7, the page will underflow, can't borrow from sibling, need to merge with sibling and update the parent.



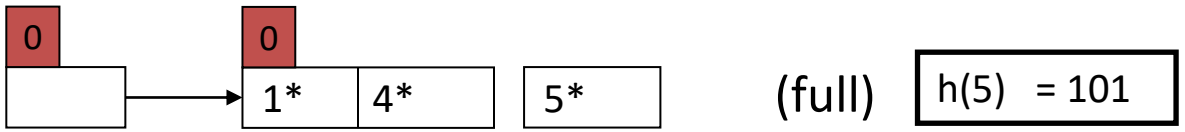
After Delete 7



HASHING

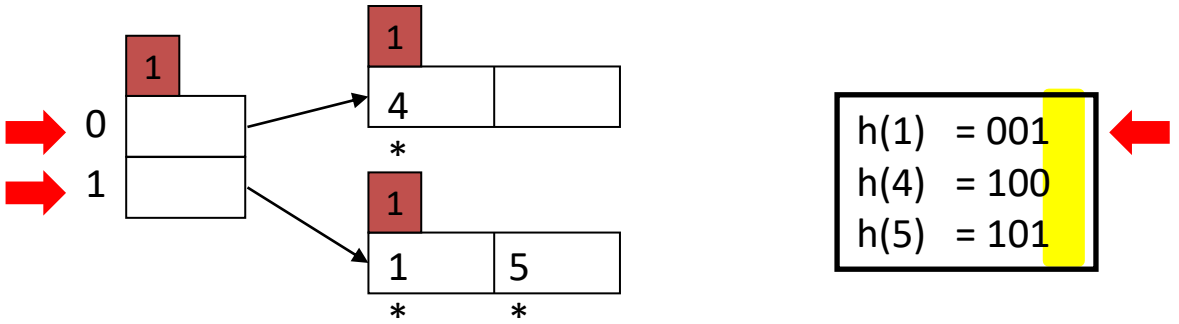
Insertion of Extensible Hashing

Insert 5:



If bucket with local depth = global depth, then double the directory and split the bucket.

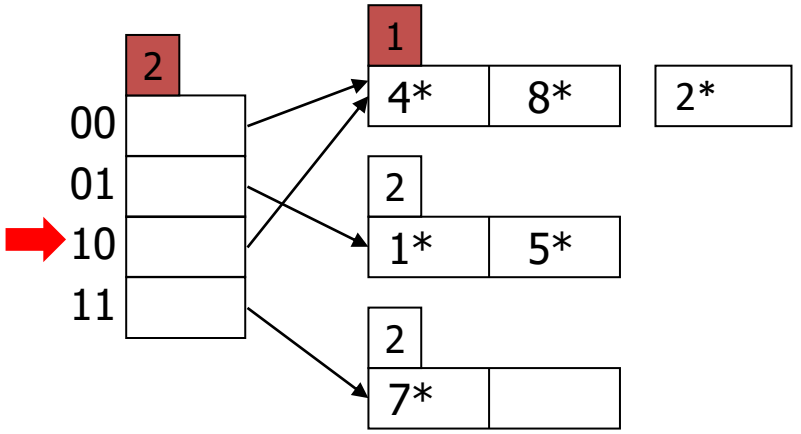
After insert 5:



Increase the global depth and local depth of the new buckets by 1.

Insertion of Extensible Hashing

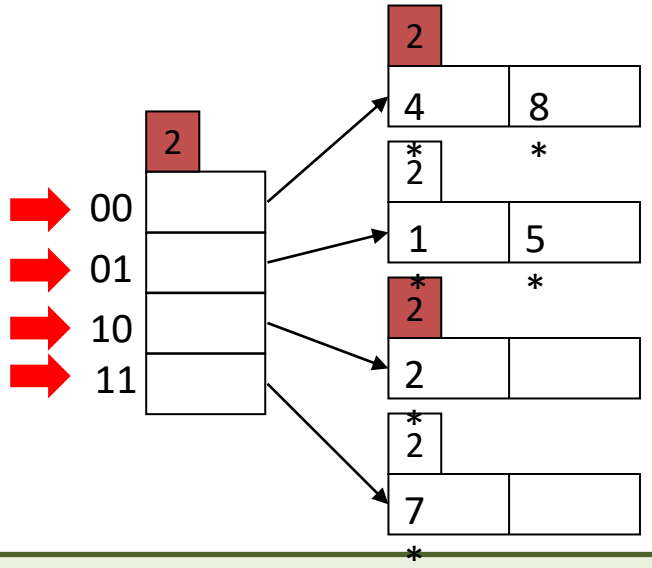
Insert 2:



h(2) = 010

If bucket with local depth < global depth, then split the bucket and update the pointers.

After insert 2:



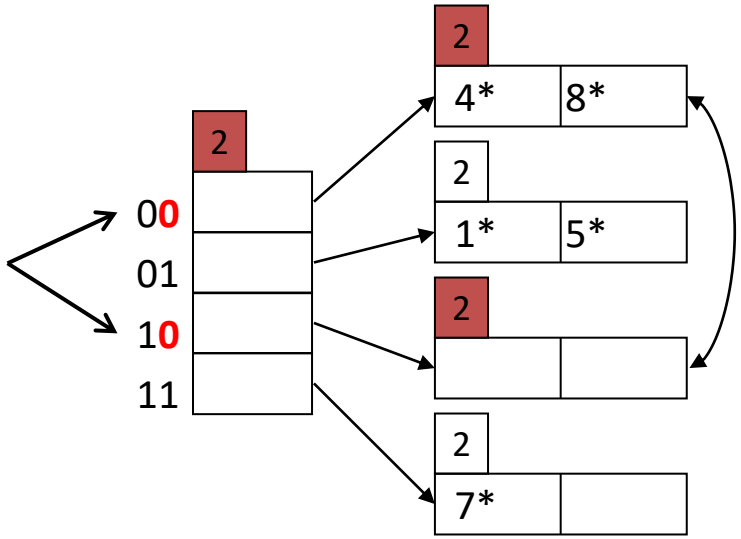
h(1) = 0001
h(2) = 0010
h(4) = 0100
h(5) = 0101
h(7) = 0111
h(8) = 1000

Increase the local depth of the new buckets by 1.

Deletion of Extensible Hashing

Delete 2:

Look at the last
(global depth-1) bits

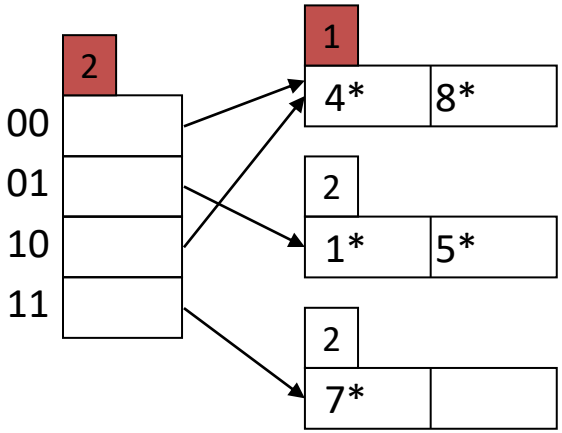


Merge them

(empty)

If the removal makes the bucket empty, then remove the bucket and update the pointer.

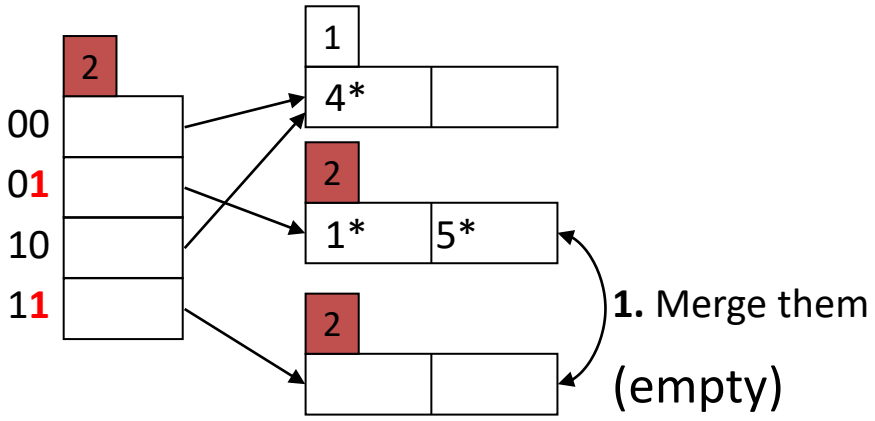
After delete 2:



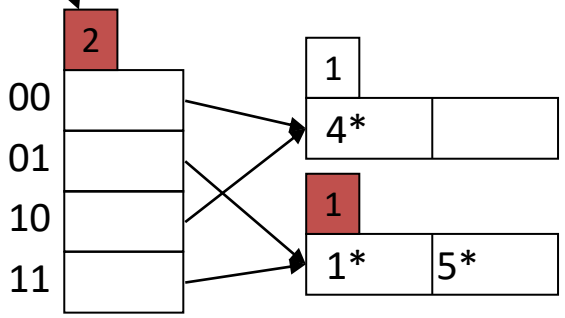
Decrease the local depth of the new bucket by 1.

Deletion of Extensible Hashing

Delete 7:

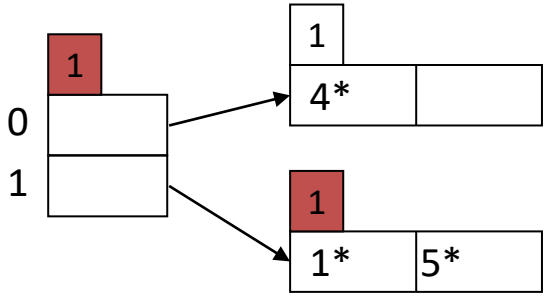


2. Halve the directory



If the mergence makes max(local depth of all buckets) < global depth, then halve the size of directory.

After delete 7:



Decrease the global depth of the new bucket by 1.

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QUERY PROCESSING

CSC3170A 2007-2008 1st Term – Q5

Suppose there are two relations for a car rental company:

Customers (cid: integer, cname: string, age: real)

Reserves (cid: integer, carNO: integer, day: date)

Assumptions:

Reserves: 100 tuples per page, 1000 pages. Totally 100 cars, uniform distribution.

Customers: 80 tuples per page, 500 pages.

The buffer size is 20 pages.

a) Assume ***cid* in Reserves is a foreign key** on **Customers**. Please estimate the size of **Customers ⋈ Reserves** in terms of number of tuples.

100 x 1000 = 100000

CSC3170A 2007-2008 1st Term – Q5

```
SELECT Distinct R.cid, R.carNO
FROM Reserves R
```

Suppose the query is executed in the following steps:

1. **Scan *R* and write *cid* and *carNO* of each tuple to a temporary file *T*.**
2. Sort ***T*** based on both *cid* and *carNO.*
3. Scan the sorted file, compare the adjacent tuples and discard duplicate tuples

b) Assume the size of ***T*** is 250 pages. Estimate the number of page accesses to process the above query. *Hint*: the number of page accesses to sort a file is $2 \times M \times (\lceil \log_{B-1} M/B \rceil + 1)$.

1000 + 250 = 1250 I/Os

CSC3170A 2007-2008 1st Term – Q5

```
SELECT Distinct R.cid, R.carNO
FROM Reserves R
```

Suppose the query is executed in the following steps:

1. Scan ***R*** and write *cid* and *carNO* of each tuple to a temporary file ***T***.
2. **Sort *T* based on both *cid* and *carNO.***
3. Scan the sorted file, compare the adjacent tuples and discard duplicate tuples

b) Assume the size of ***T*** is 250 pages. Estimate the number of page accesses to process the above query. *Hint*: the number of page accesses to sort a file is $2 \times M \times (\lceil \log_{B-1} M/B \rceil + 1)$.

$$2 \times 250 \times (\lceil \log_{20-1} 250/20 \rceil + 1) = 1000 \text{ I/Os}$$

CSC3170A 2007-2008 1st Term – Q5

```
SELECT Distinct R.cid, R.carNO
FROM Reserves R
```

Suppose the query is executed in the following steps:

1. Scan ***R*** and write *cid* and *carNO* of each tuple to a temporary file ***T***.
2. Sort ***T*** based on both *cid* and *carNO.*
3. **Scan the sorted file, compare the adjacent tuples and discard duplicate tuples**

b) Assume the size of ***T*** is 250 pages. Estimate the number of page accesses to process the above query. *Hint*: the number of page accesses to sort a file is $2 \times M \times (\lceil \log_{B-1} M/B \rceil + 1)$.

250 I/Os

CSC3170A 2007-2008 1st Term – Q5

```
SELECT Distinct R.cid, R.carNO
FROM Reserves R
```

Suppose the query is executed in the following steps:

1. Scan ***R*** and write *cid* and *carNO* of each tuple to a temporary file ***T***.
2. Sort ***T*** based on both *cid* and *carNO.*
3. Scan the sorted file, compare the adjacent tuples and discard duplicate tuples

b) Assume the size of ***T*** is 250 pages. Estimate the number of page accesses to process the above query. *Hint*: the number of page accesses to sort a file is $2 \times M \times (\lceil \log_{B-1} M/B \rceil + 1)$.

1250 + 1000 + 250 = 2500 I/Os

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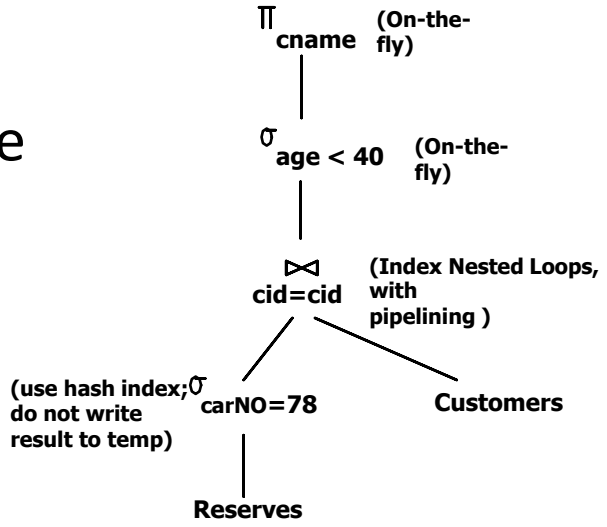
Assume there is clustered hash index on *carNO* of ***Reserves,*** and hash index on *cid* of ***Customers***. Consider the following query:

```
SELECT  C.cname
FROM  Reserves R, Customers C
WHERE  R.cid=C.cid AND R.carNO=78 AND C.age<40
```

c) Please estimate the number of page accesses for the query. Assume that there is no overflow bucket and the directories of both the hash structures are in the main memory.



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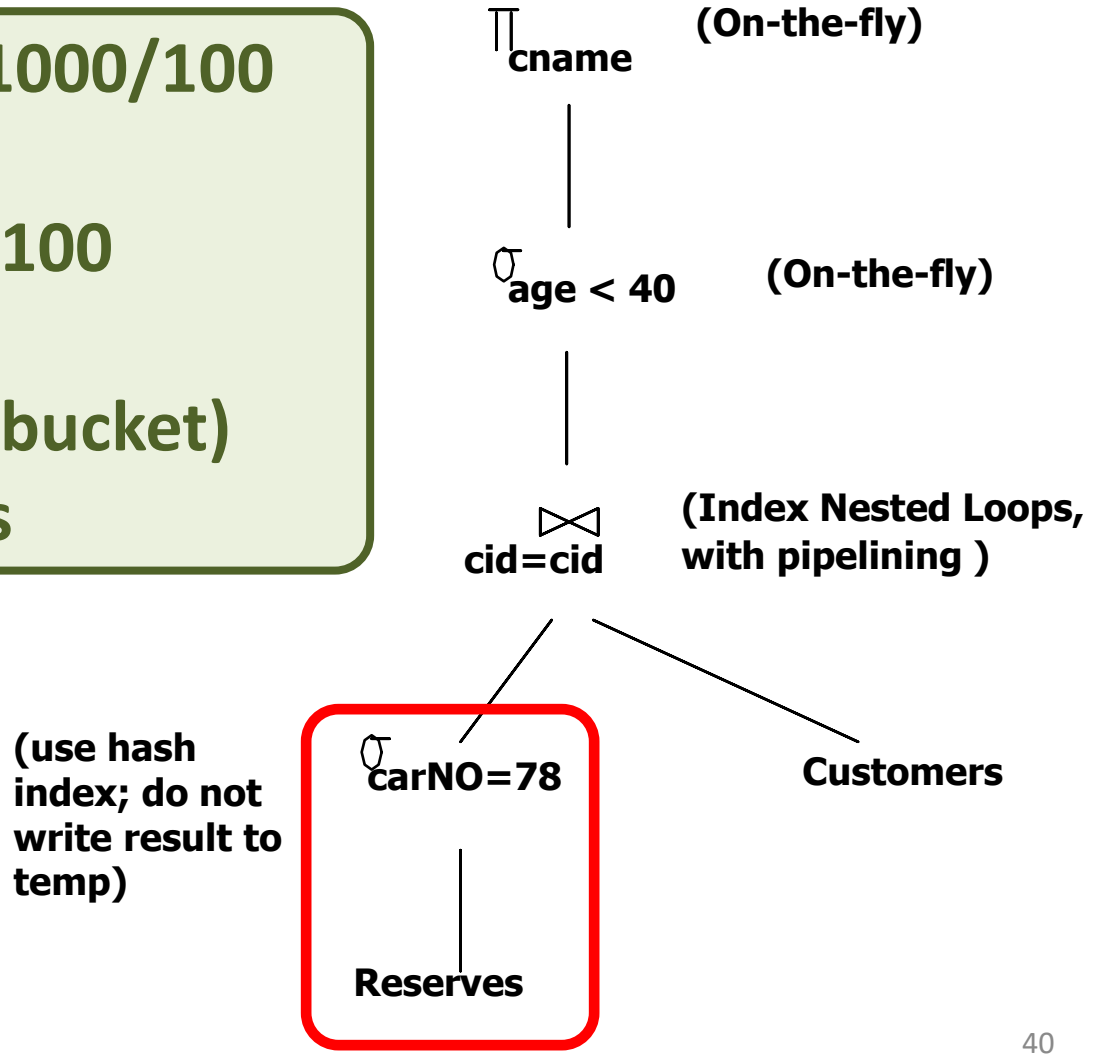
No. of tuples = 100x1000/100
= 1000
No. of pages = 1000/100
= 10
Page access = 10 + 1(bucket)
= 11 I/Os



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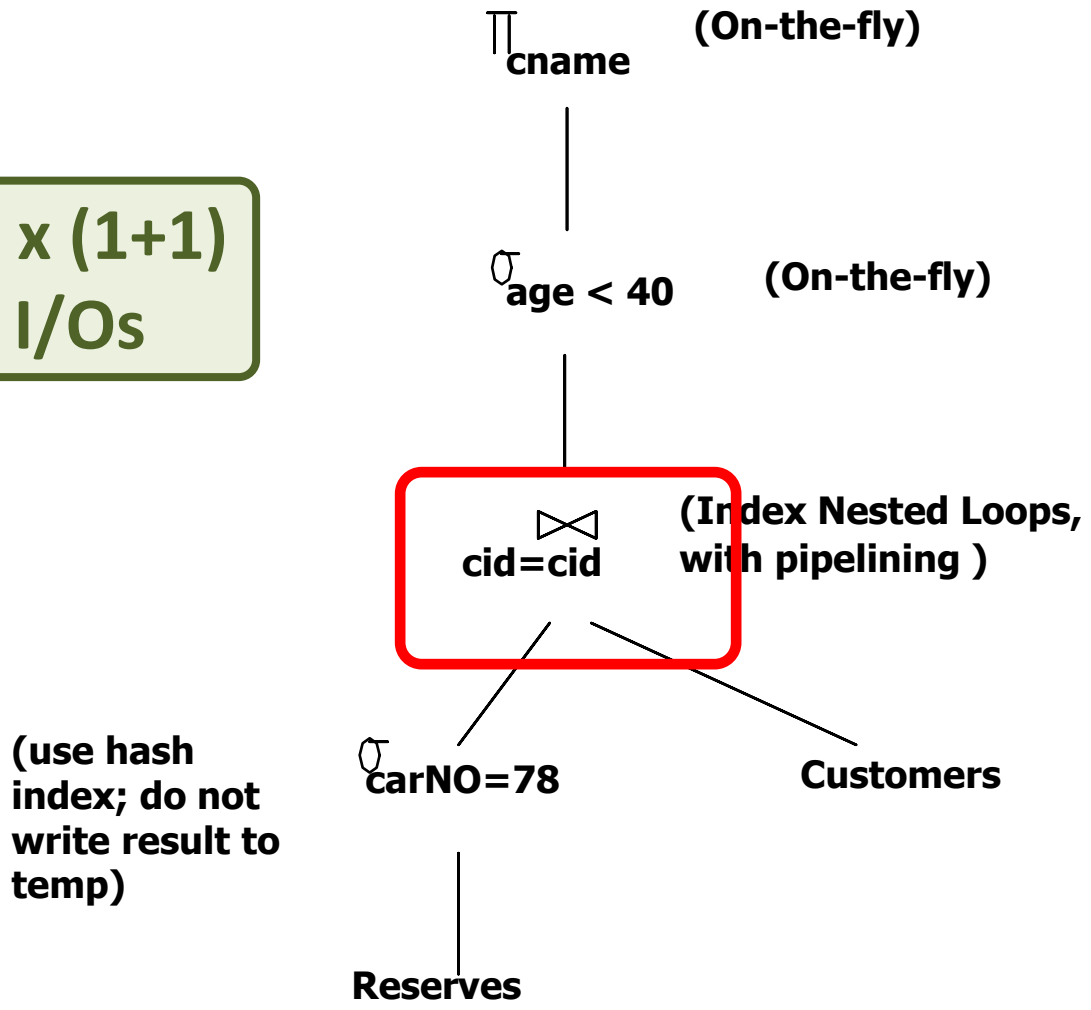
Page access = 1000 x (1+1)
= 2000 I/Os



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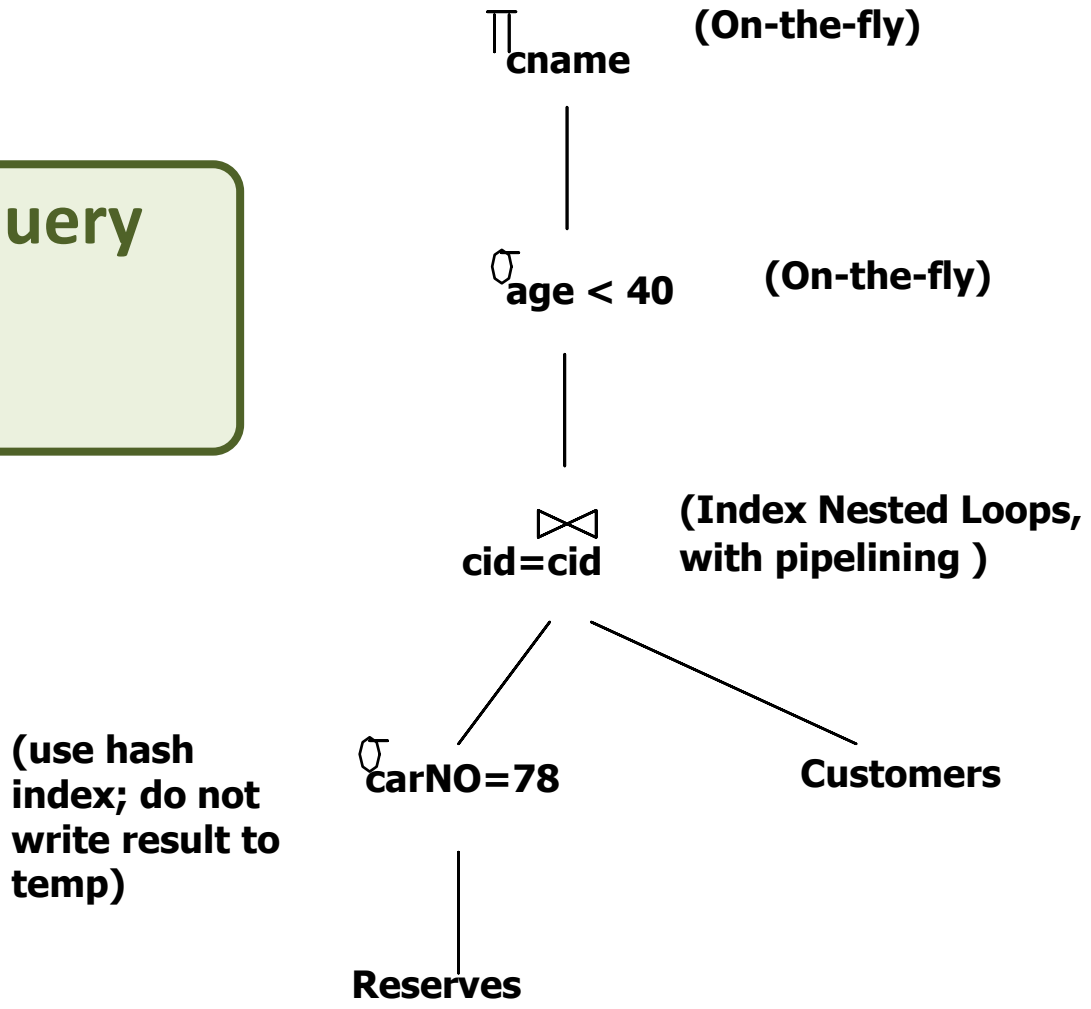
Total cost of the query
= 11 + 2000
= 2011



CONCURRENCY CONTROL

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$w_3[a]$ $r_2[a]$ $w_1[a]$ $w_2[a]$

(a) Please state all the ***read-from*** relations.

T_2 reads a from T_3

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$w_3[a]\ r_2[a]\ w_1[a]\ \mathbf{w_2[a]}$

(b) Please state which transaction executes the ***final write*** operation on ***a***.

T_2 issues the final write on ***a***

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$w_3[a]\ r_2[a]\ w_1[a]\ w_2[a]$

(b) Is the history **view serializable**? Why? Please state the **serialization order** if it is view serializable.

Yes. The history has the same read from relation and same final write operation as $\mathbf{T_1\ T_3\ T_2}$

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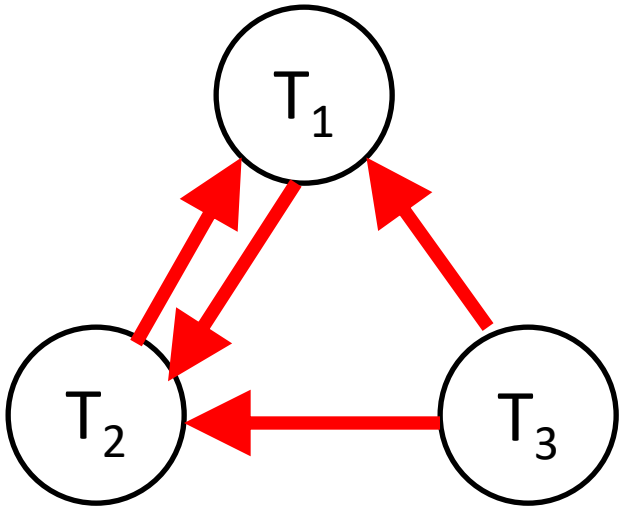
$w_3[a]\ r_2[a]\ \mathbf{w_1[a]\ w_2[a]}$

(d) Draw the serialization graph of the above history.



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$w_3[a]\ r_2[a]\ w_1[a]\ w_2[a]$

(e) Is the history **conflict serializable**? Why? Please state the serialization order if it is conflict serializable.

No, because there is a cycle in the serialization graph.