Data-intensive Computing Systems

Query Optimization (Cost-based optimization)

Shivnath Babu

Query Optimization Problem

Pick the best plan from the space of physical plans

Cost-Based Optimization

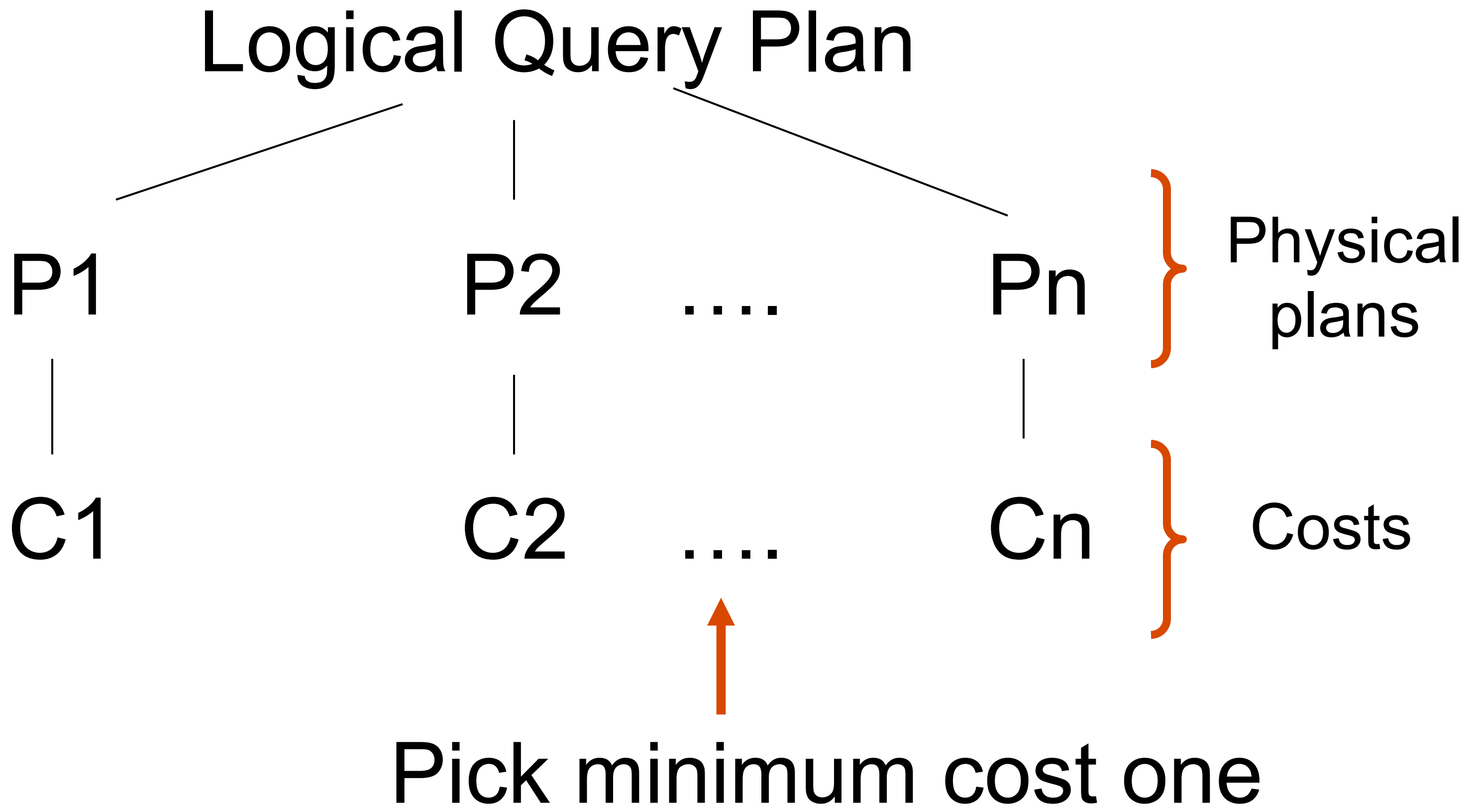
- Prune the space of plans using heuristics
- Estimate cost for remaining plans
  - Be smart about how you iterate through plans
- Pick the plan with least cost

Focus on queries with joins

Heuristics for pruning plan space

- Predicates as early as possible
- Avoid plans with cross products
- Only left-deep join trees

Physical Plan Selection



Review of Notation

- T (R) : Number of tuples in R
- B (R) : Number of blocks in R

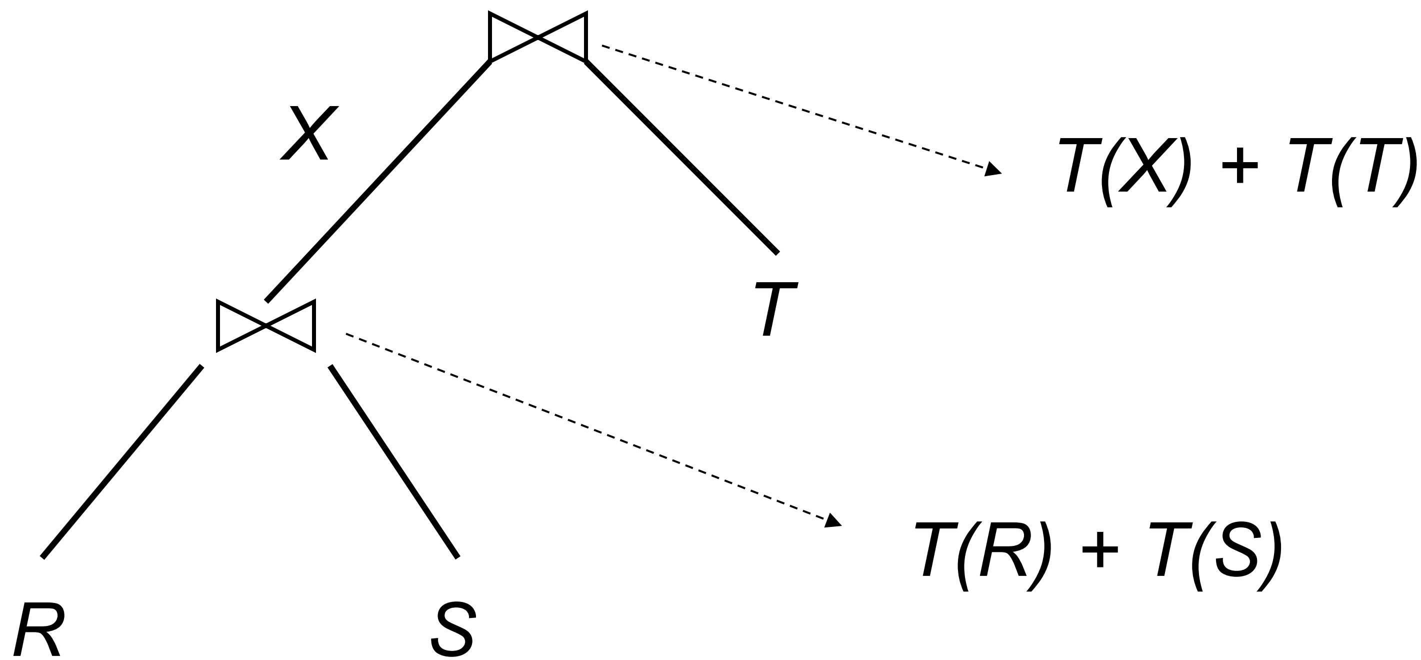
Simple Cost Model

$$\text{Cost}(R \bowtie S) = T(R) + T(S)$$

All other operators have 0 cost

Note: The simple cost model used for illustration only

Cost Model Example



Total Cost: $T(R) + T(S) + T(T) + T(X)$

Selinger Algorithm

- *Dynamic Programming* based
- Dynamic Programming:
  - General algorithmic paradigm
  - Exploits "principle of optimality"
  - Useful reading:
    - Chapter 16, Introduction to Algorithms, Cormen, Leiserson, Rivest

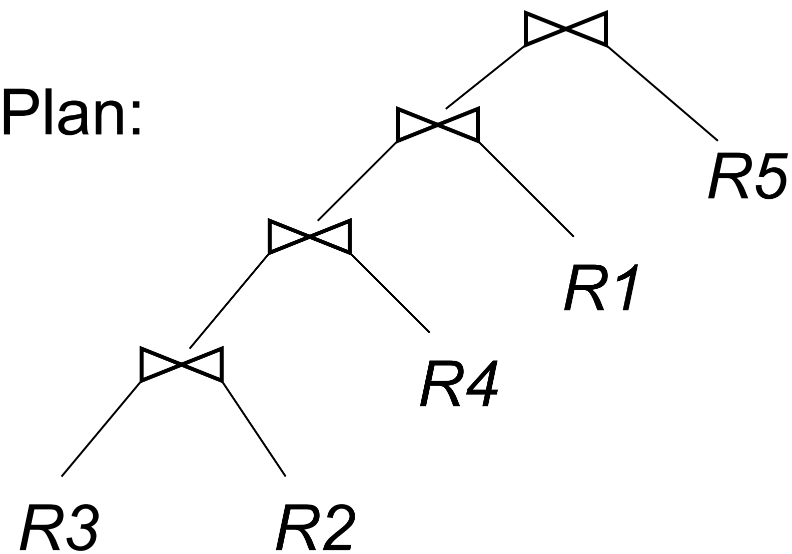
Principle of Optimality

Optimal for “whole” made up from optimal for “parts”

Principle of Optimality

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

Optimal Plan:



Principle of Optimality

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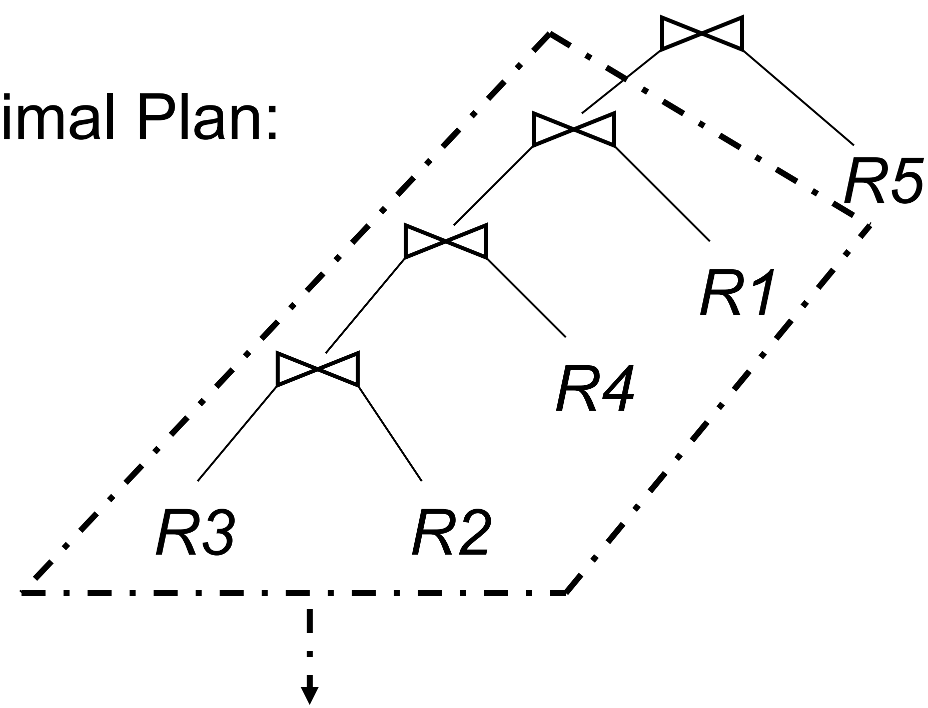
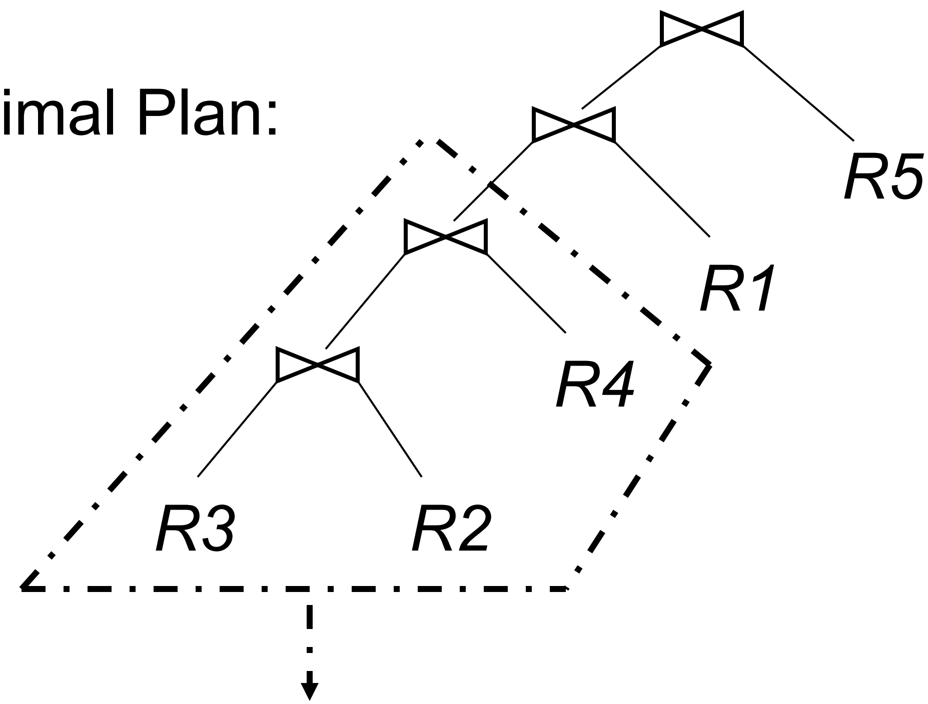


Optimal plan for joining *R3, R2, R4, R1*

Principle of Optimality

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

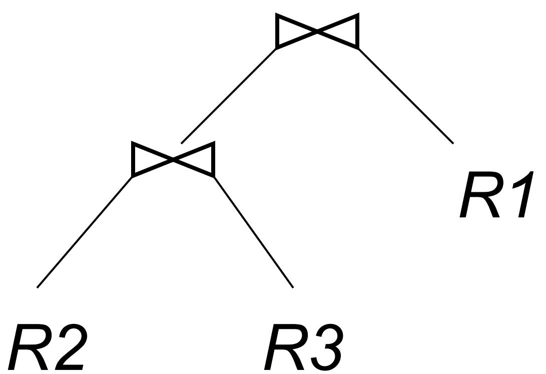
Optimal Plan:



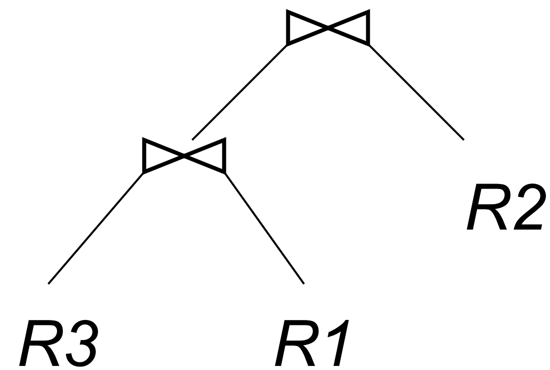
Optimal plan for joining *R3, R2, R4*

Exploiting Principle of Optimality

Query: $R1 \bowtie R2 \bowtie \quad \dots \quad \bowtie Rn$

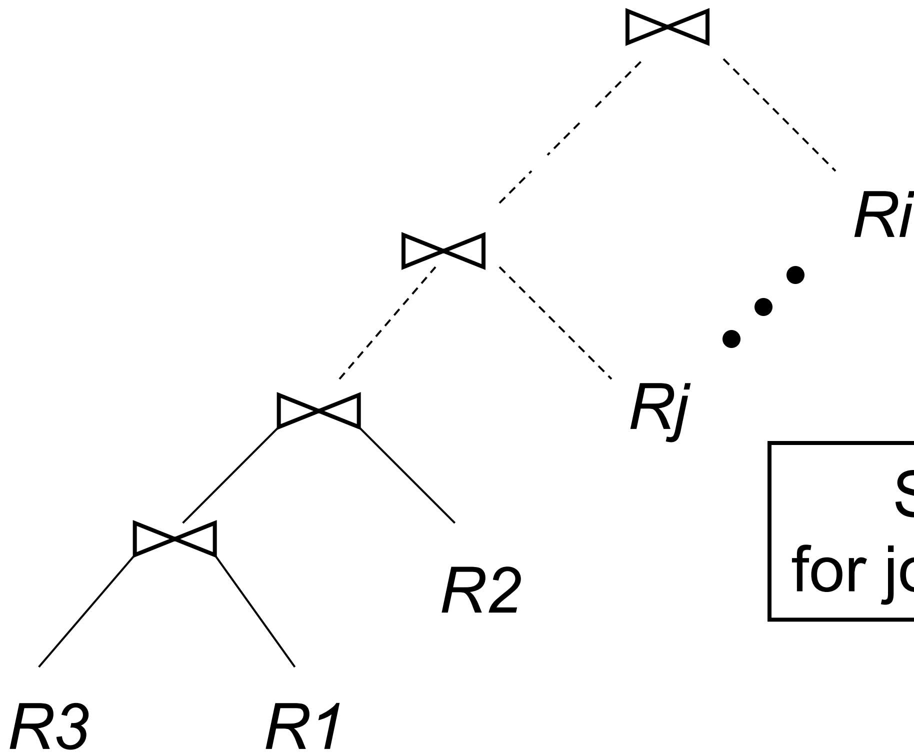


Optimal
for joining *R1, R2, R3*



Sub-Optimal
for joining *R1, R2, R3*

Exploiting Principle of Optimality

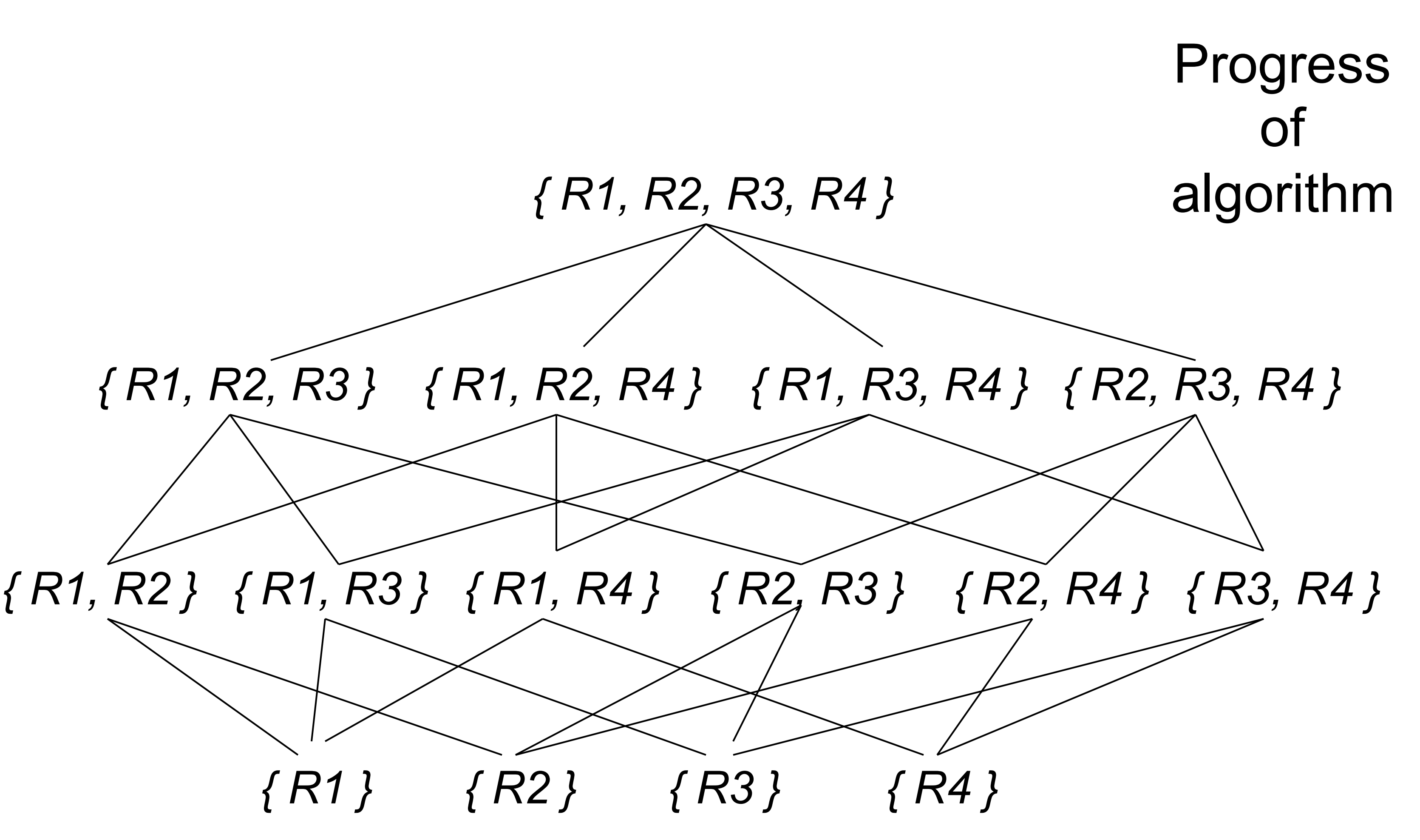


Sub-Optimal
for joining R1,…,Rn

A sub-optimal sub-plan cannot lead to an optimal plan

Selinger Algorithm:

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$



Notation

OPT ({ *R1, R2, R3* }):

Cost of optimal plan to join *R1,R2,R3*

T ({ *R1, R2, R3* }):

Number of tuples in $R1 \bowtie R2 \bowtie R3$

Selinger Algorithm:

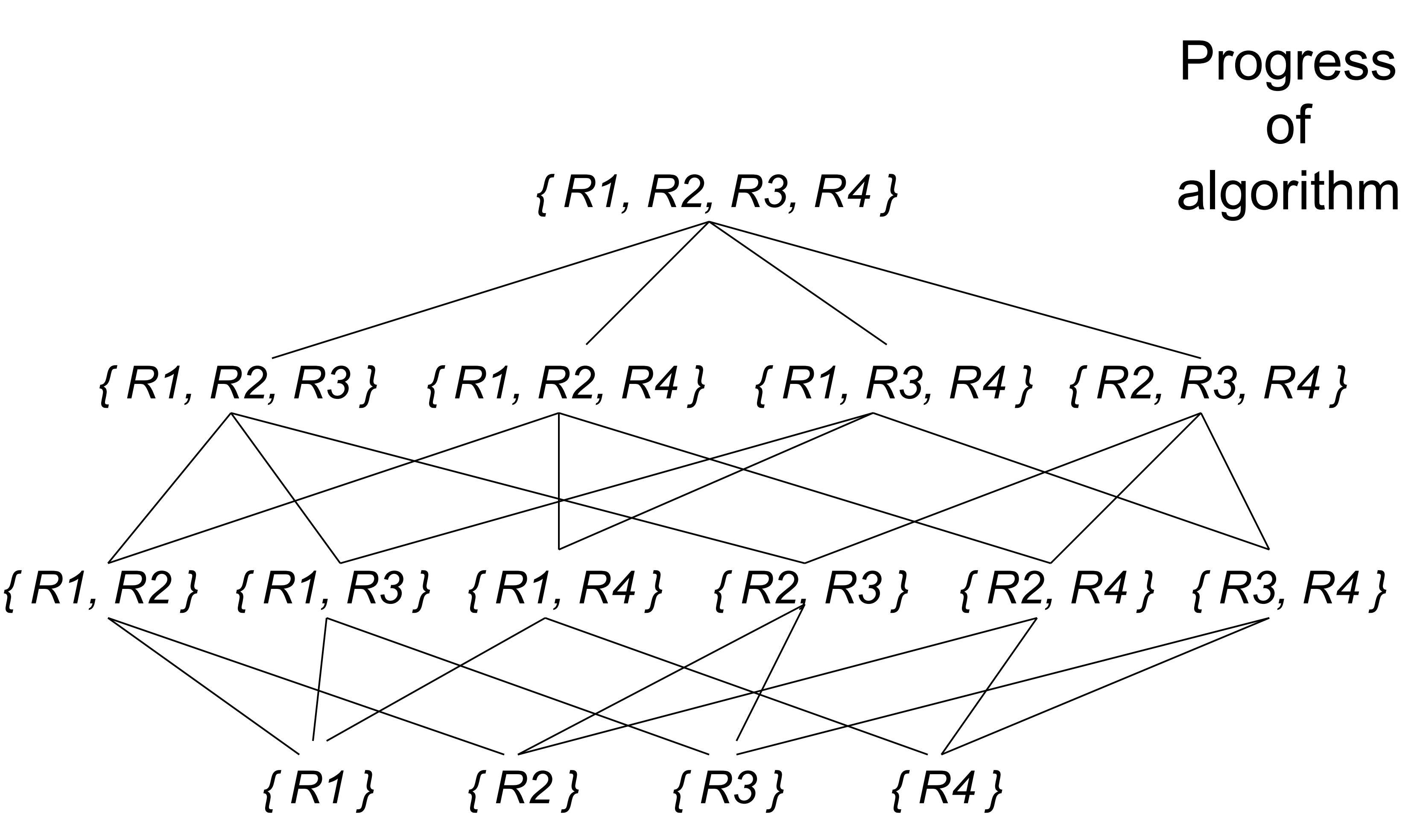
OPT ({ R1, R2, R3 }):

$$
\text{Min} \begin{cases} \text{OPT}(\{R1, R2\}) + T(\{R1, R2\}) + T(R3) \\ \text{OPT}(\{R2, R3\}) + T(\{R2, R3\}) + T(R1) \\ \text{OPT}(\{R1, R3\}) + T(\{R1, R3\}) + T(R2) \end{cases}
$$

Note: Valid only for the simple cost model

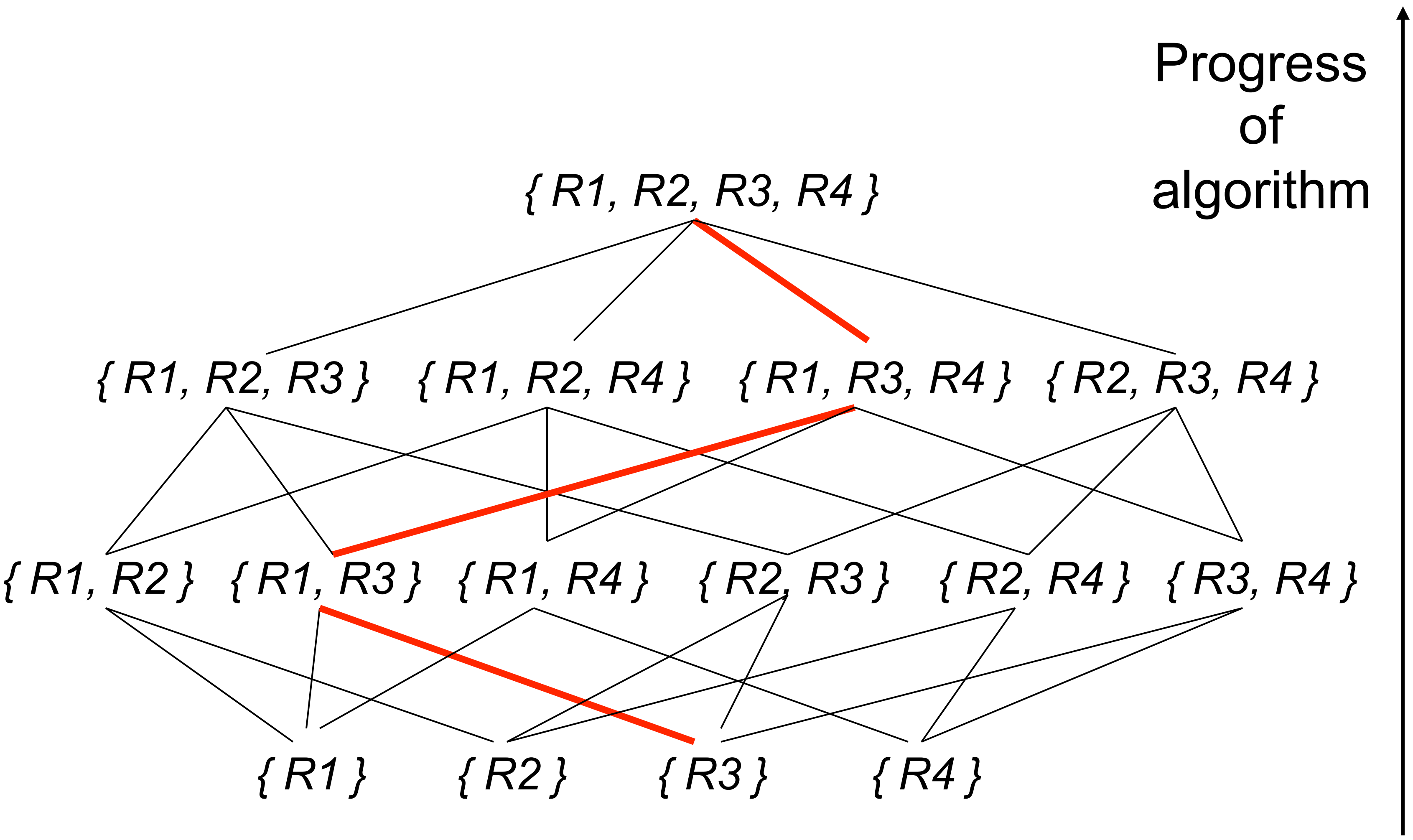
Selinger Algorithm:

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$



Selinger Algorithm:

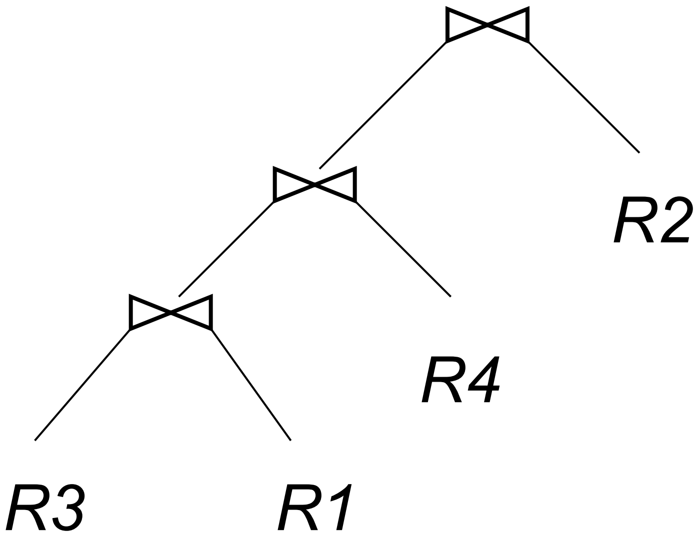
Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$



Selinger Algorithm:

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4$

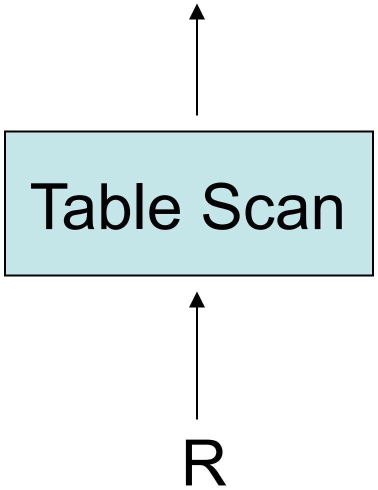
Optimal plan:



More Complex Cost Model

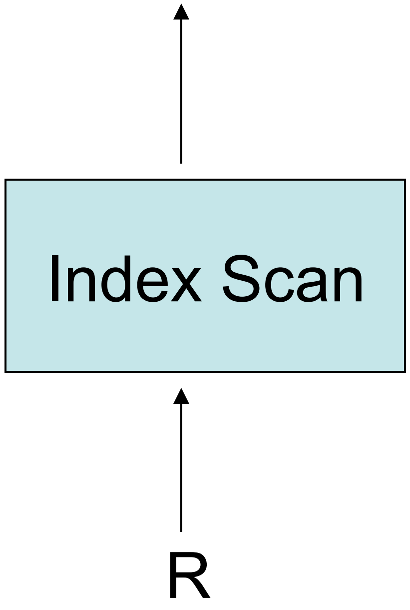
- DB System:
  - Two join algorithms:
    - Tuple-based nested loop join
    - Sort-Merge join
  - Two access methods
    - Table Scan
    - Index Scan (all indexes are in memory)
  - Plans pipelined as much as possible
- Cost: Number of disk I/O s

Cost of Table Scan



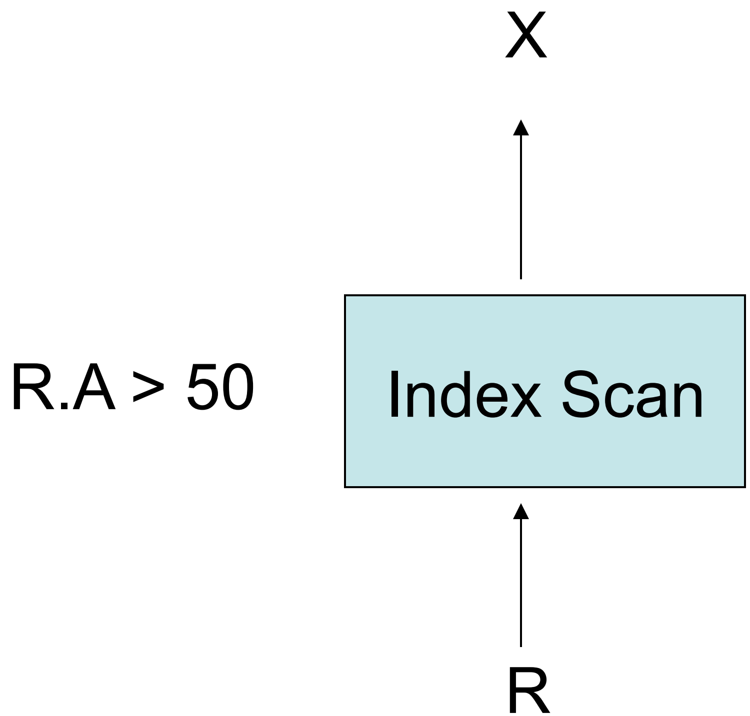
Cost: B (R)

Cost of Clustered Index Scan



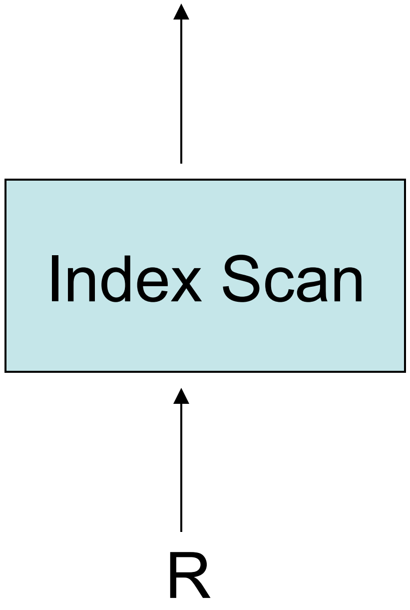
Cost: B (R)

Cost of Clustered Index Scan



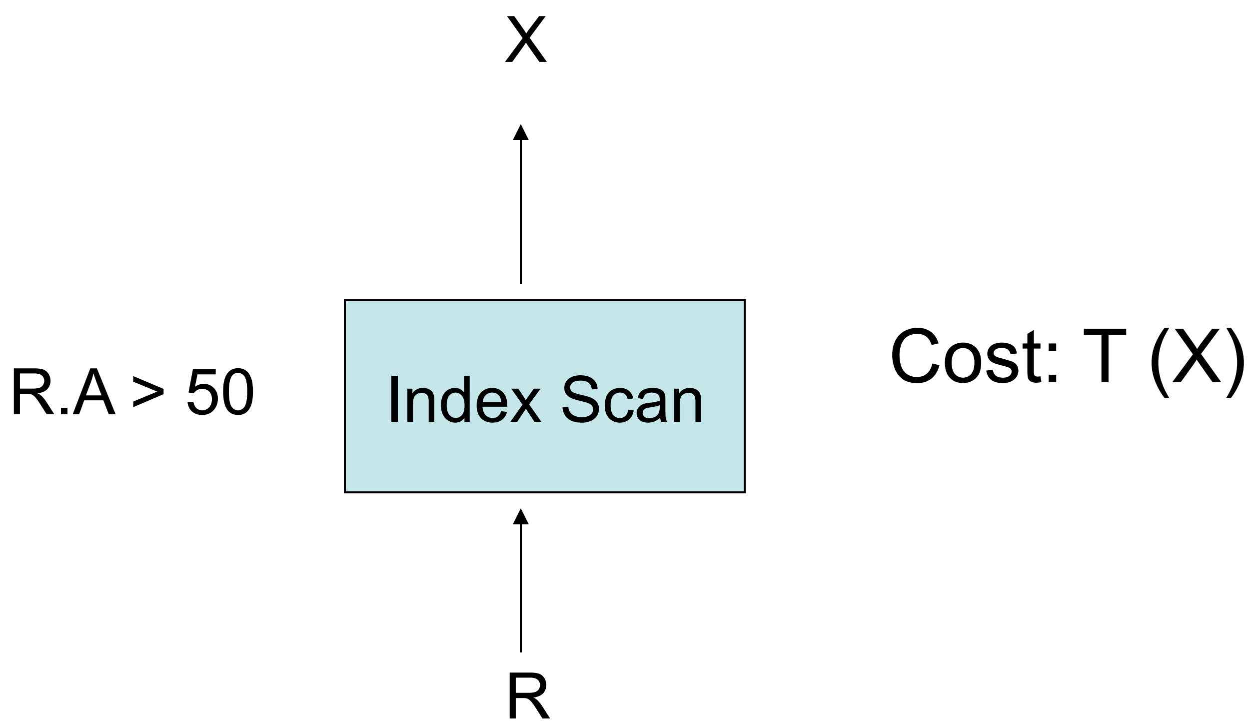
Cost: B (X)

Cost of Non-Clustered Index Scan

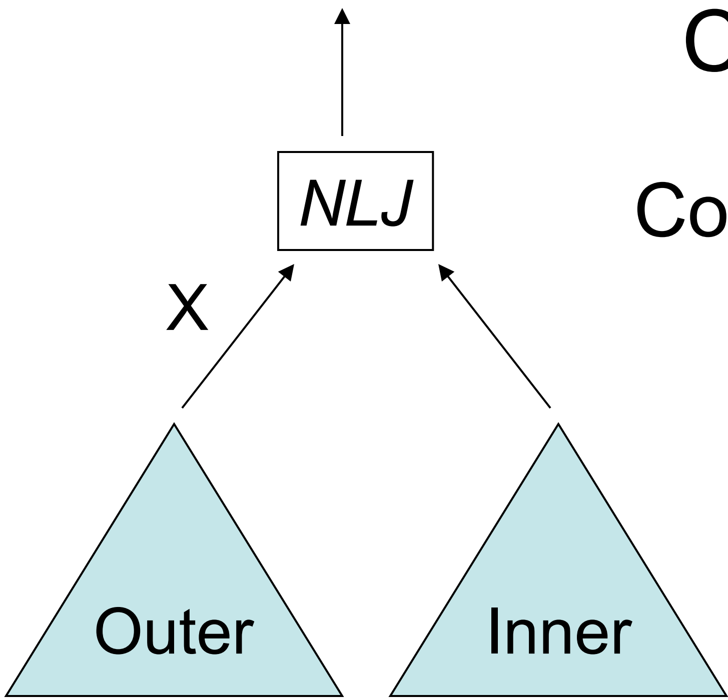


Cost: T (R)

Cost of Non-Clustered Index Scan



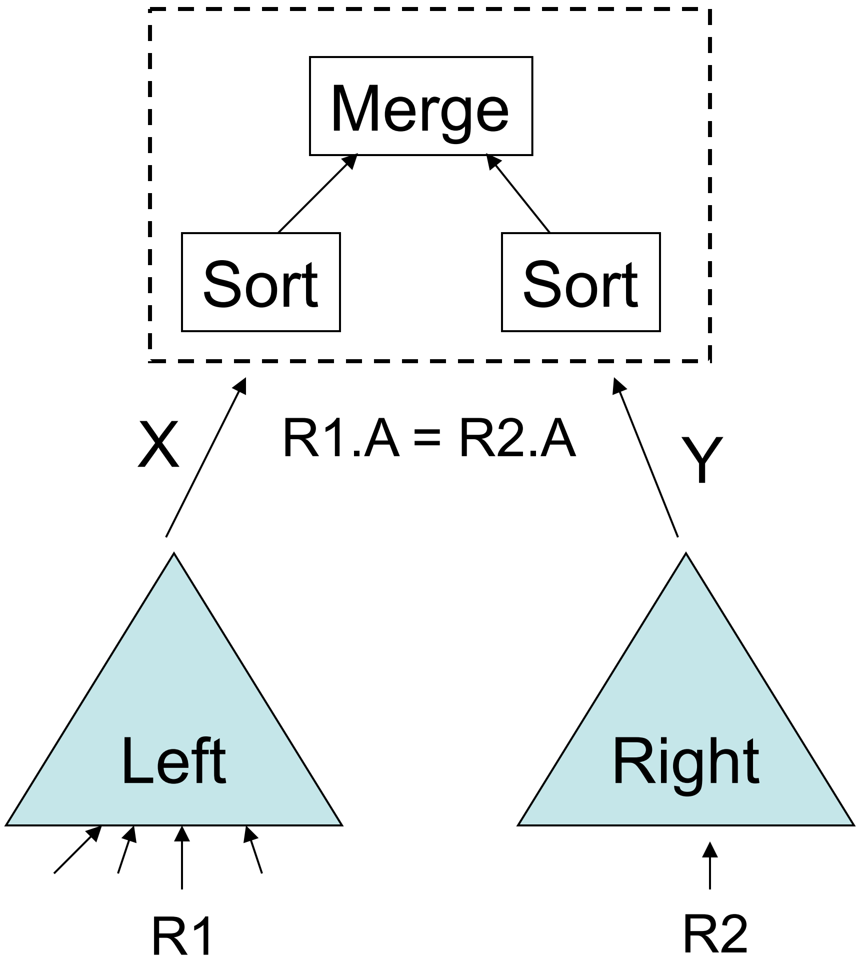
Cost of Tuple-Based NLJ



Cost for **entire** plan:

Cost (Outer) + T(X) x Cost (Inner)

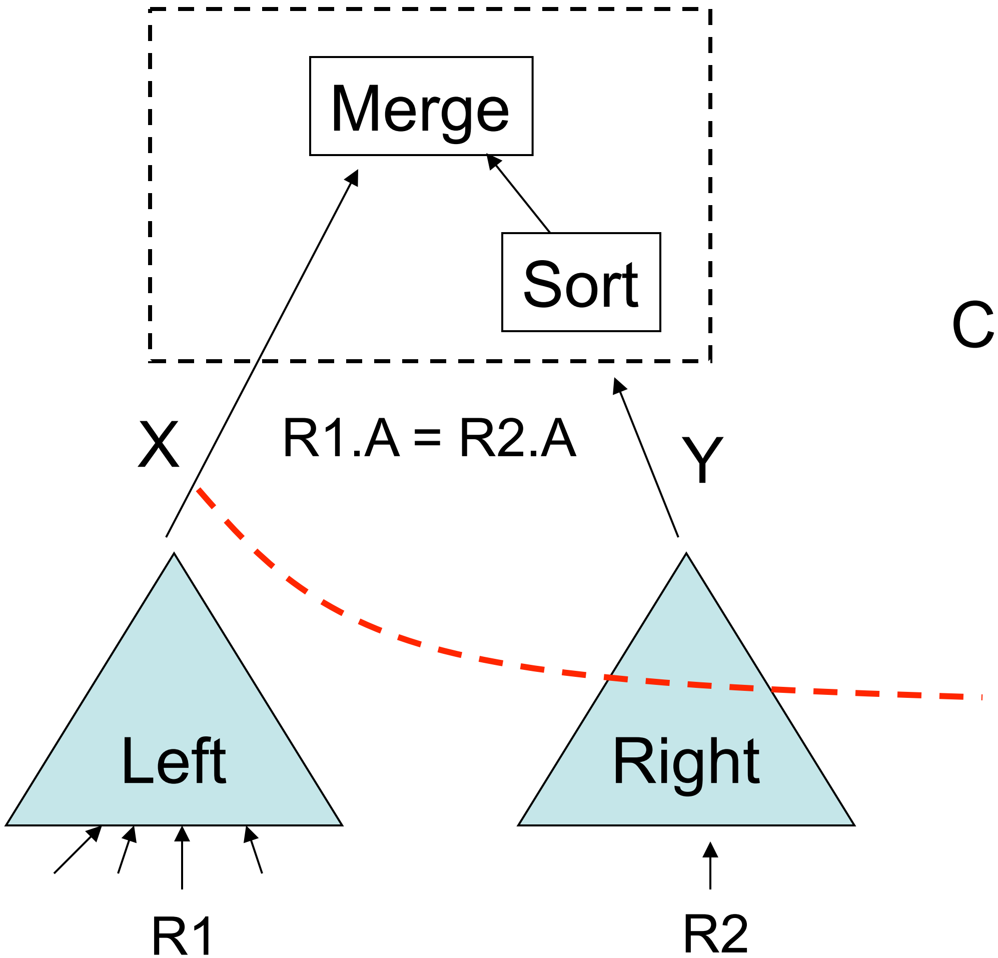
Cost of Sort-Merge Join



Cost for **entire** plan:

Cost (Right) + Cost (Left) +
2 (B (X) + B (Y))

Cost of Sort-Merge Join



Cost for **entire** plan:

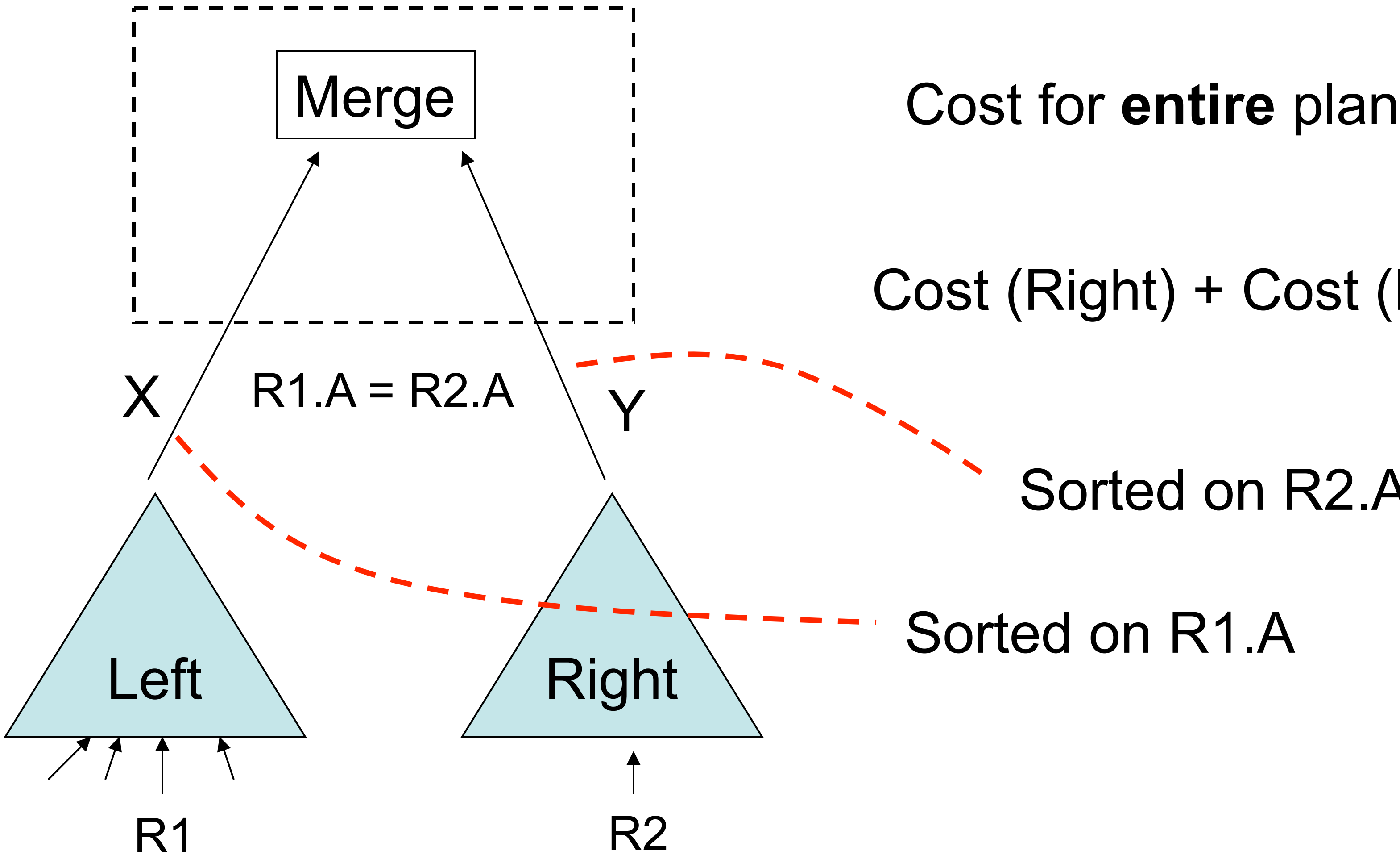
Cost (Right) + Cost (Left) +
2 B (Y)

Sorted on R1.A

Cost of Sort-Merge Join

Cost for **entire** plan:

Cost (Right) + Cost (Left)



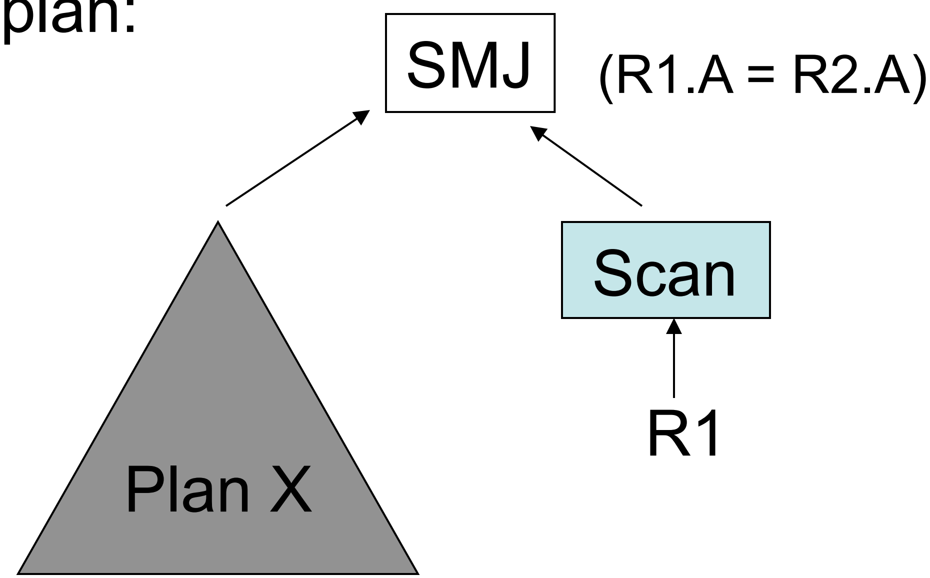
Cost of Sort-Merge Join

Bottom Line: Cost depends on sorted-ness of inputs

Principle of Optimality?

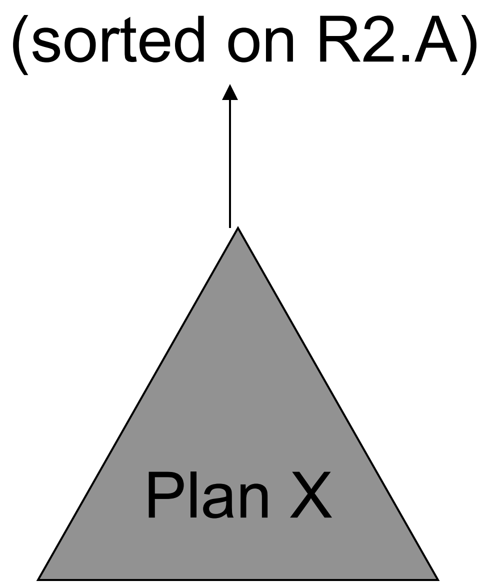
Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

Optimal plan:

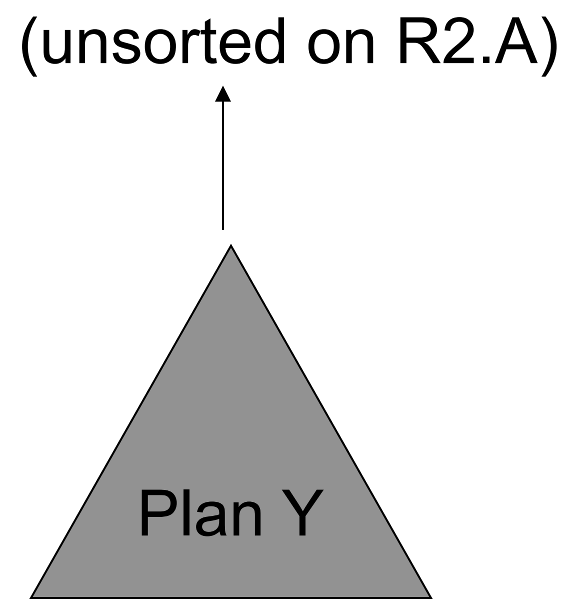


Is Plan X the optimal plan for joining R2,R3,R4,R5?

Violation of Principle of Optimality



Suboptimal plan for joining
R2,R3,R4,R5

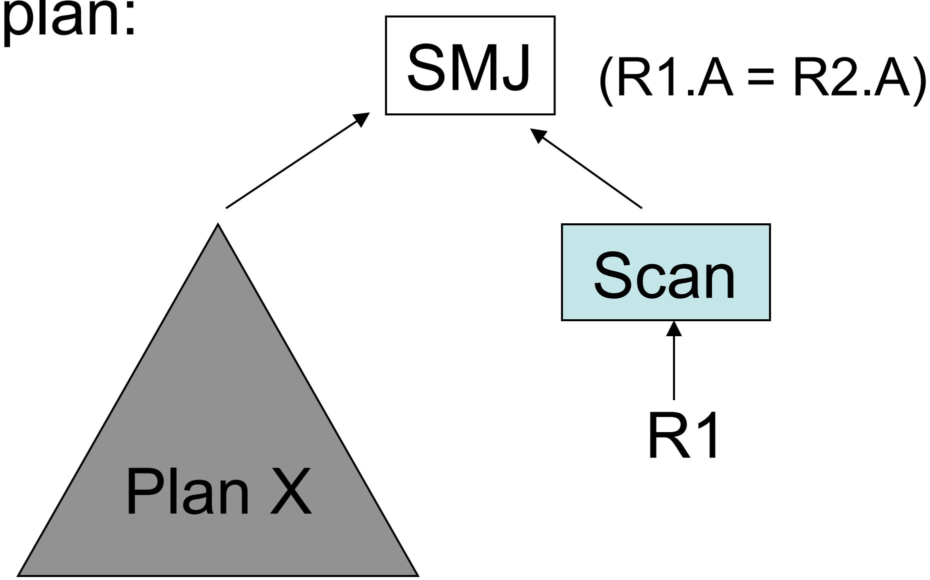


Optimal plan for joining
R2,R3,R4,R4

Principle of Optimality?

Query: $R1 \bowtie R2 \bowtie R3 \bowtie R4 \bowtie R5$

Optimal plan:



Can we assert anything about plan X?

Weaker Principle of Optimality

If plan X produces output sorted on R2.A then plan X is the **optimal plan** for joining R2,R3,R4,R5 that produces output sorted on R2.A

If plan X produces output unsorted on R2.A then plan X is the **optimal plan** for joining R2, R3, R4, R5

Interesting Order

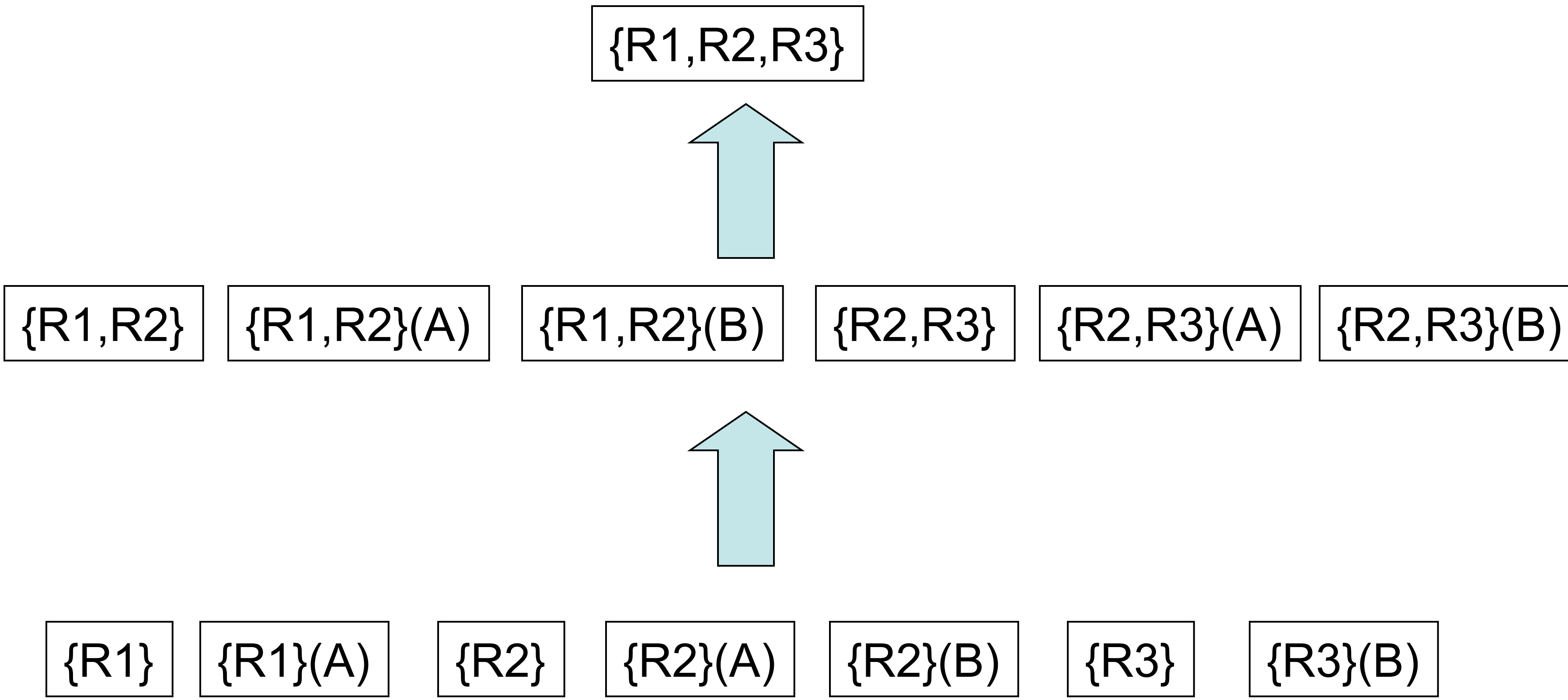
- An attribute is an **interesting order** if:
  - participates in a join predicate
  - Occurs in the Group By clause
  - Occurs in the Order By clause

Interesting Order: Example

Select *
From R1(A,B), R2(A,B), R3(B,C)
Where R1.A = R2.A and R2.B = R3.B

Interesting Orders: R1.A, R2.A, R2.B, R3.B

Modified Selinger Algorithm



Notation

{R1,R2} (C)

Optimal way of joining R1, R2 so that output is sorted on attribute R2.C

Modified Selinger Algorithm