Formal Specification and Optimization of ETL Scenarios

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Motivation

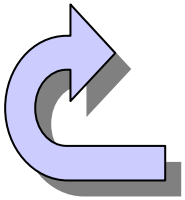
- ETL and Data Cleaning tools cost – the standard figures
  - **30%** of effort and expenses in the budget of the DW
  - **55%** of the total costs of DW runtime
  - **80%** of the development time in a DW project
- ETL market: a multi-million market
- ETL tools will not be replaced by other tools in near future
- ETL tools in the market
  - software packages
  - in-house development
- No standard, no common model

Problems

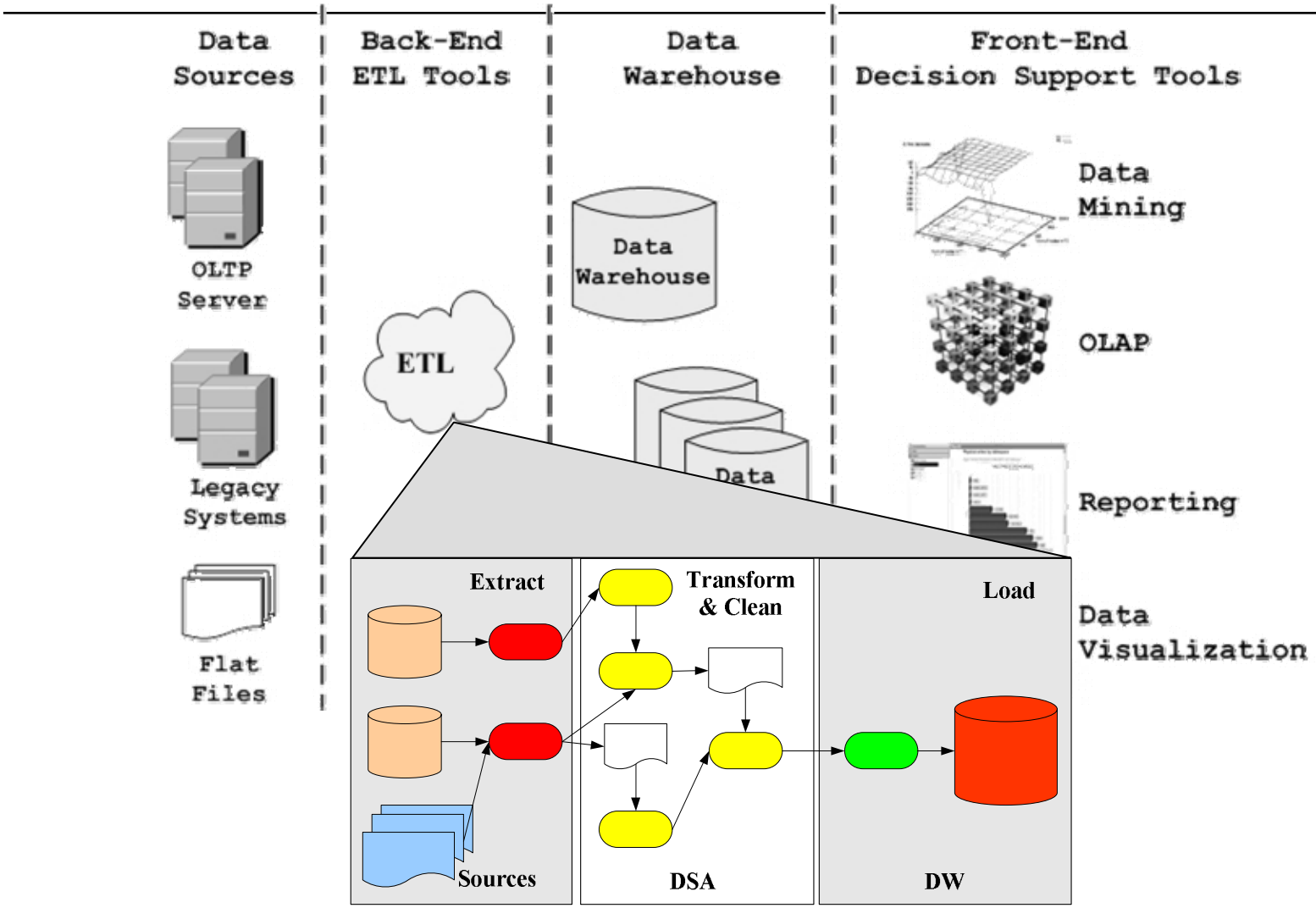
- The key factors underlying the main problems of ETL processes are:
  - **vastness** of the data volumes
  - **quality problems**, since data is not always clean and has to be cleansed
  - **performance**, since the whole process has to take place within a specific time window
  - **evolution** of the sources and the data warehouse can eventually lead, even to daily maintenance operations

But is it a “hot” problem?

- Some practitioners find that it may be obsolete
  - (*Is ETL Becoming Obsolete? - a Sunopsis White Paper*, http://www.sunopsis.com/corporate/us/forms/whitepaper.htm?I)
- Very few papers from academia
  - Even DOLAP has 2-3 papers in its history
  - Some interesting statistics!
- Do you agree?



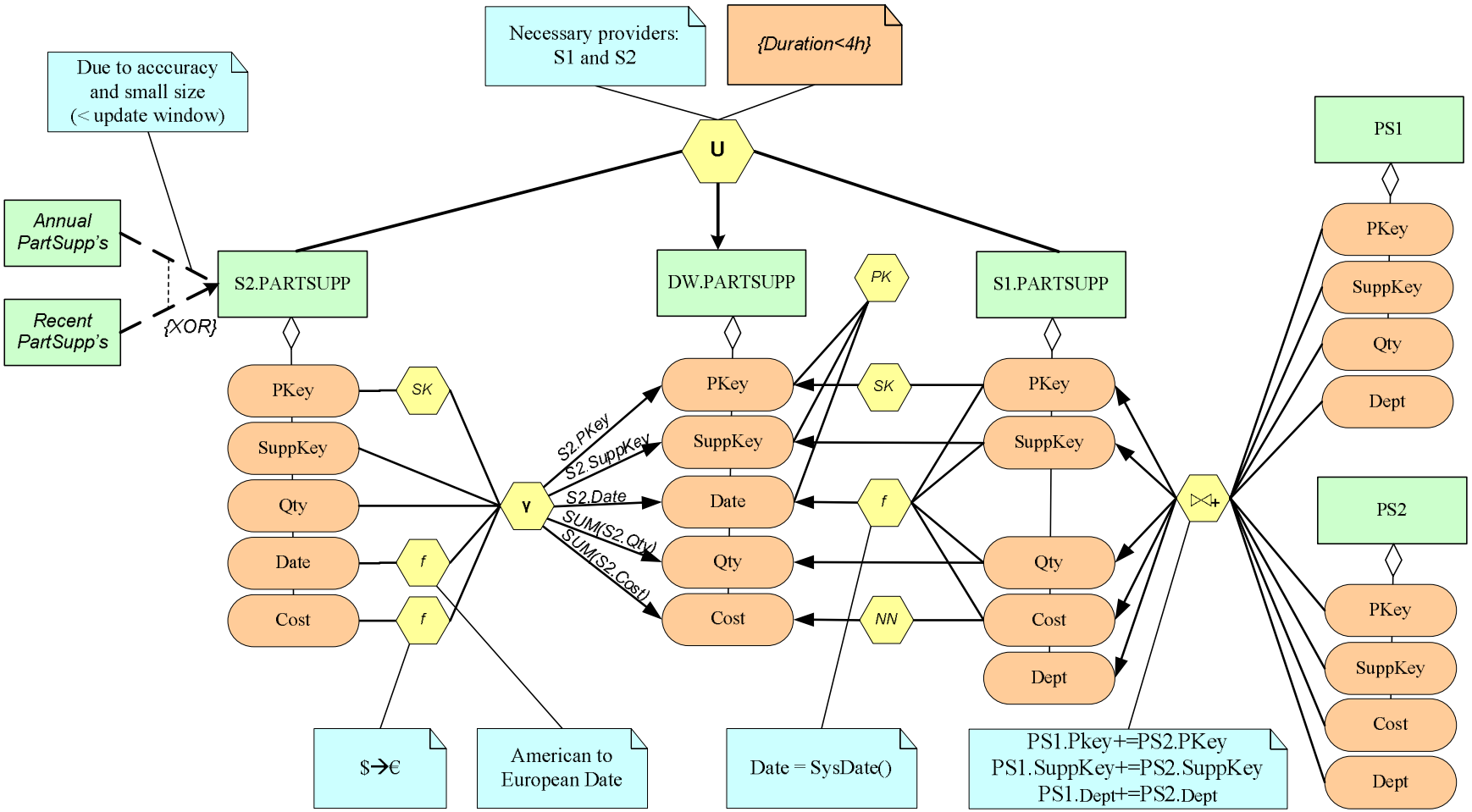
Extract-Transform-Load (ETL)



Modeling Work – Why?

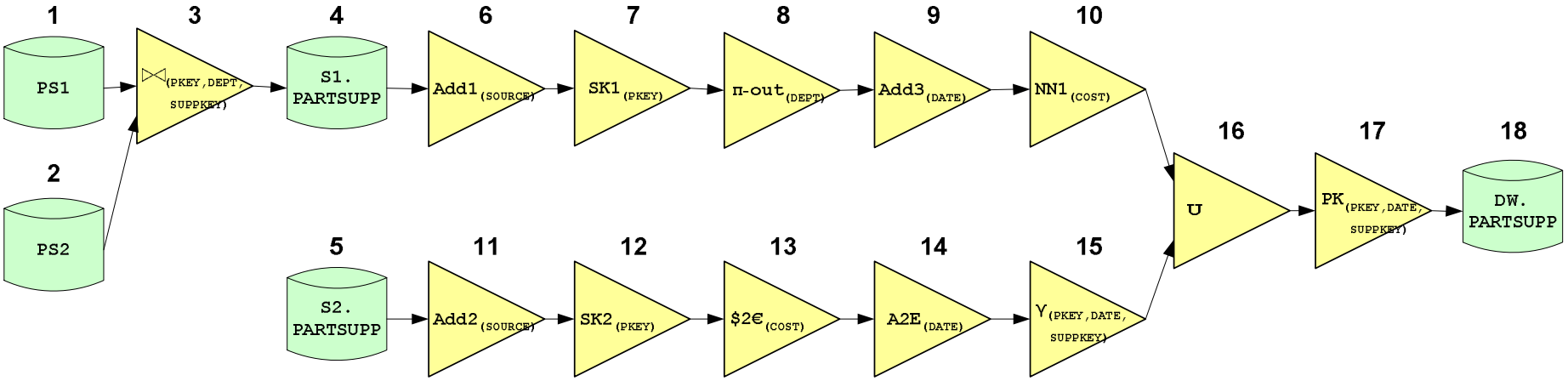
- Conceptual
  - we need a simple model, sufficient for the early stages of the data warehouse design; we need to be able to model what our sources “talk” about
- Logical
  - we need to model a workflow that offers formal and semantically founded concepts to capture the characteristics of an ETL process
- Execution
  - we need to find a good execution strategy for ETL processes, not in an ad-hoc way

Conceptual Model [DOLAP 02]



Logical Model - Architecture Graph [CAiSE 03]

Example



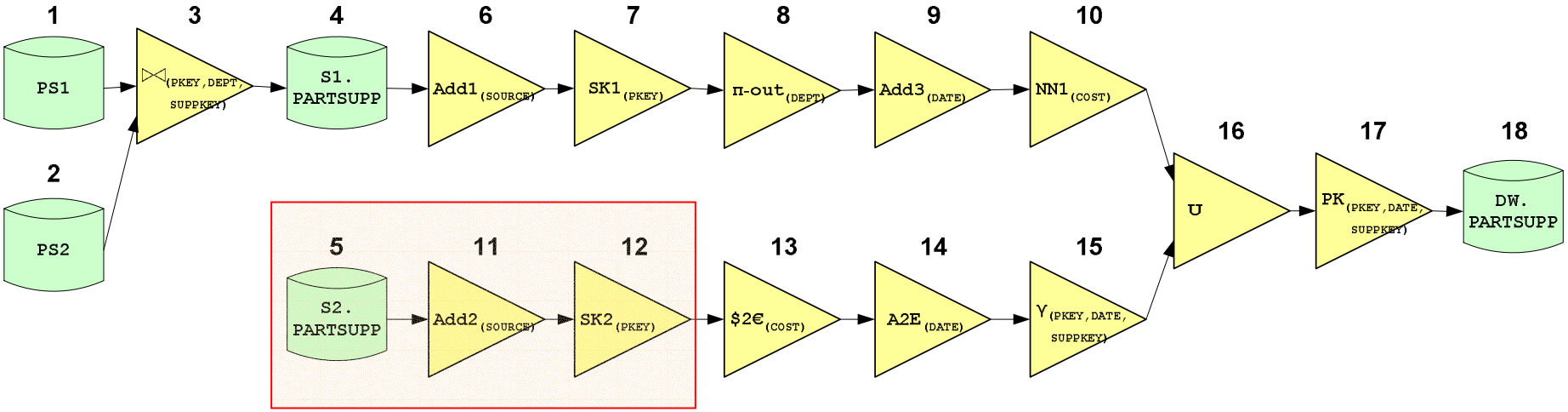

```
PS1(PKEY,SUPPKEY,DEPT,QTY)
PS2(PKEY,SUPPKEY,DEPT,COST)

S1.PARTSUPP(PKEY,SUPPKEY,DEPT,QTY,COST)
S2.PARTSUPP(PKEY,SUPPKEY,DATE,QTY,COST)

DW.PARTSUPP(PKEY,SUPPKEY,DATE,QTY,COST)
```

Architecture Graph

Example



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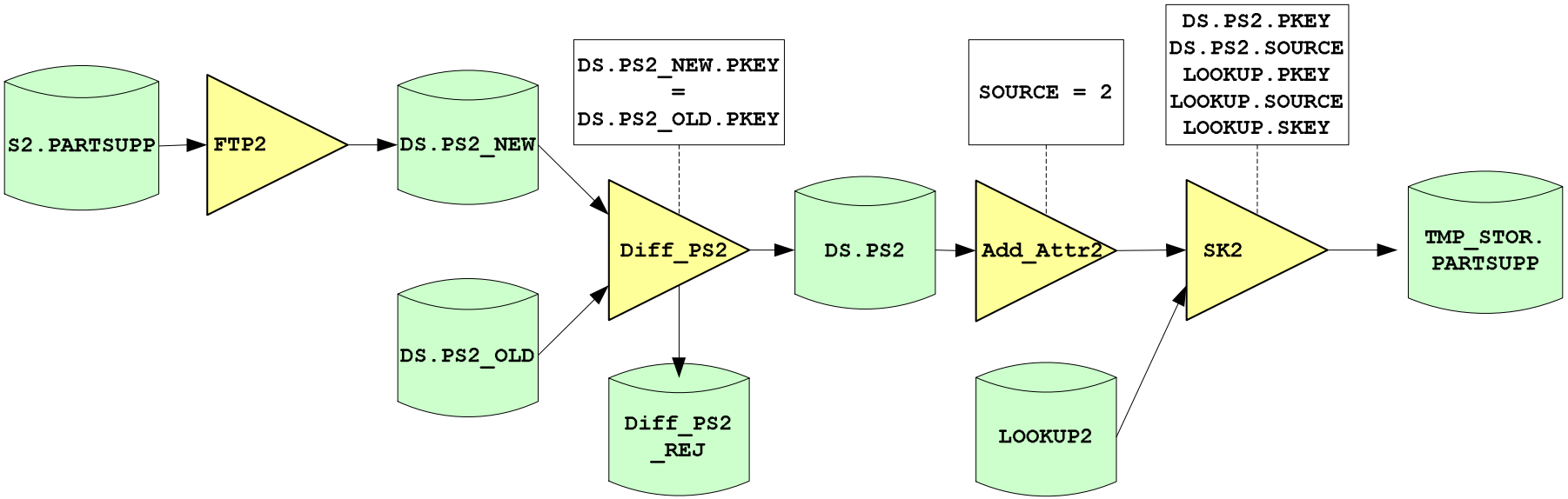
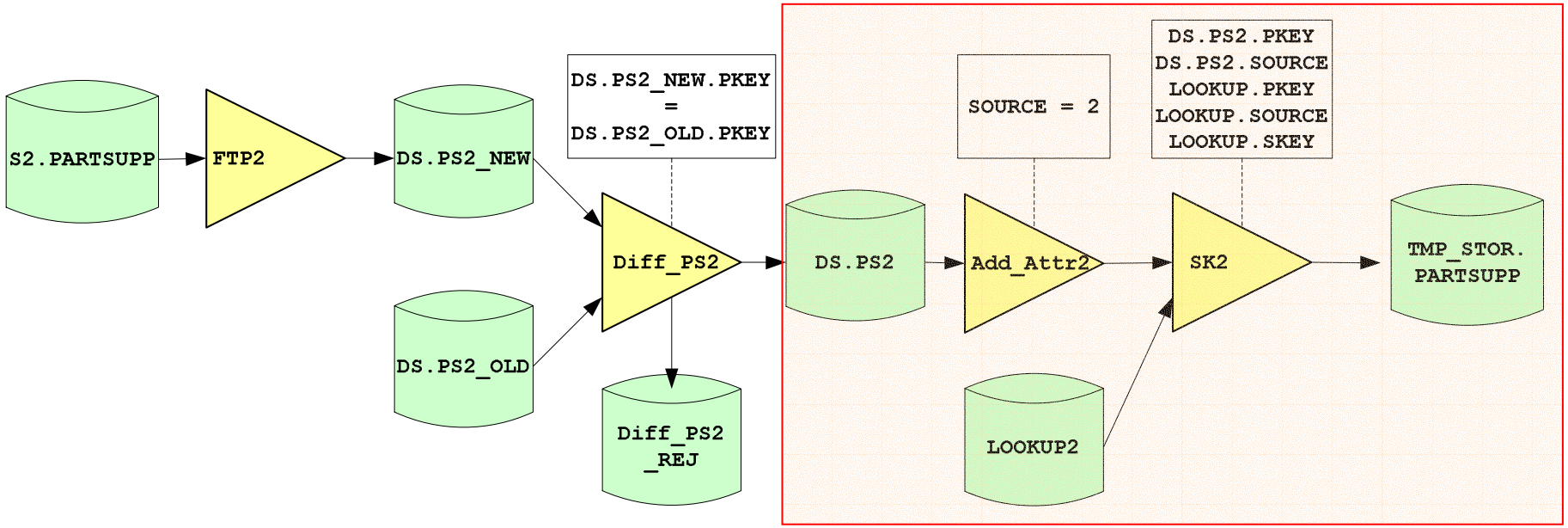
Architecture Graph

Example



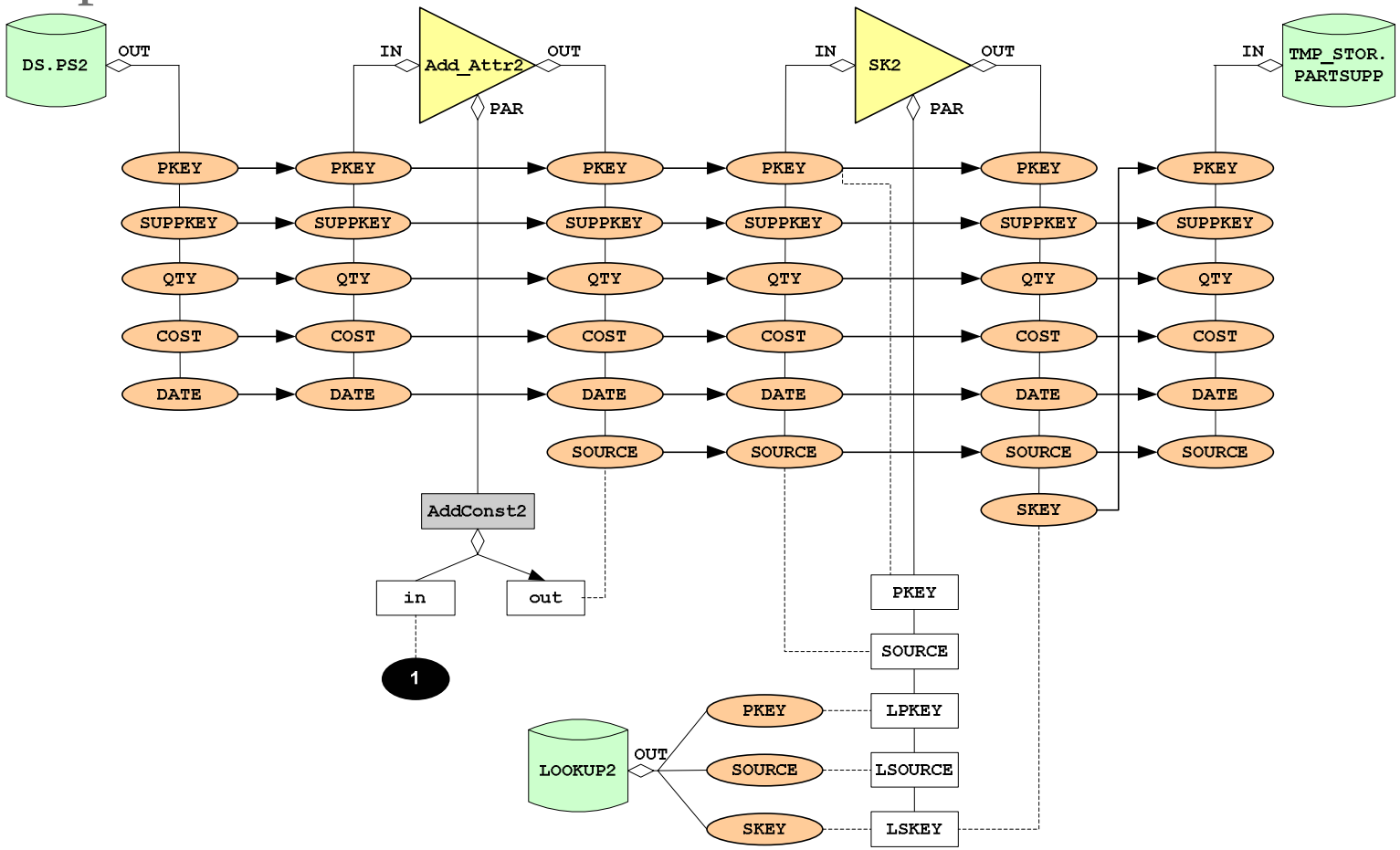
Architecture Graph

Example



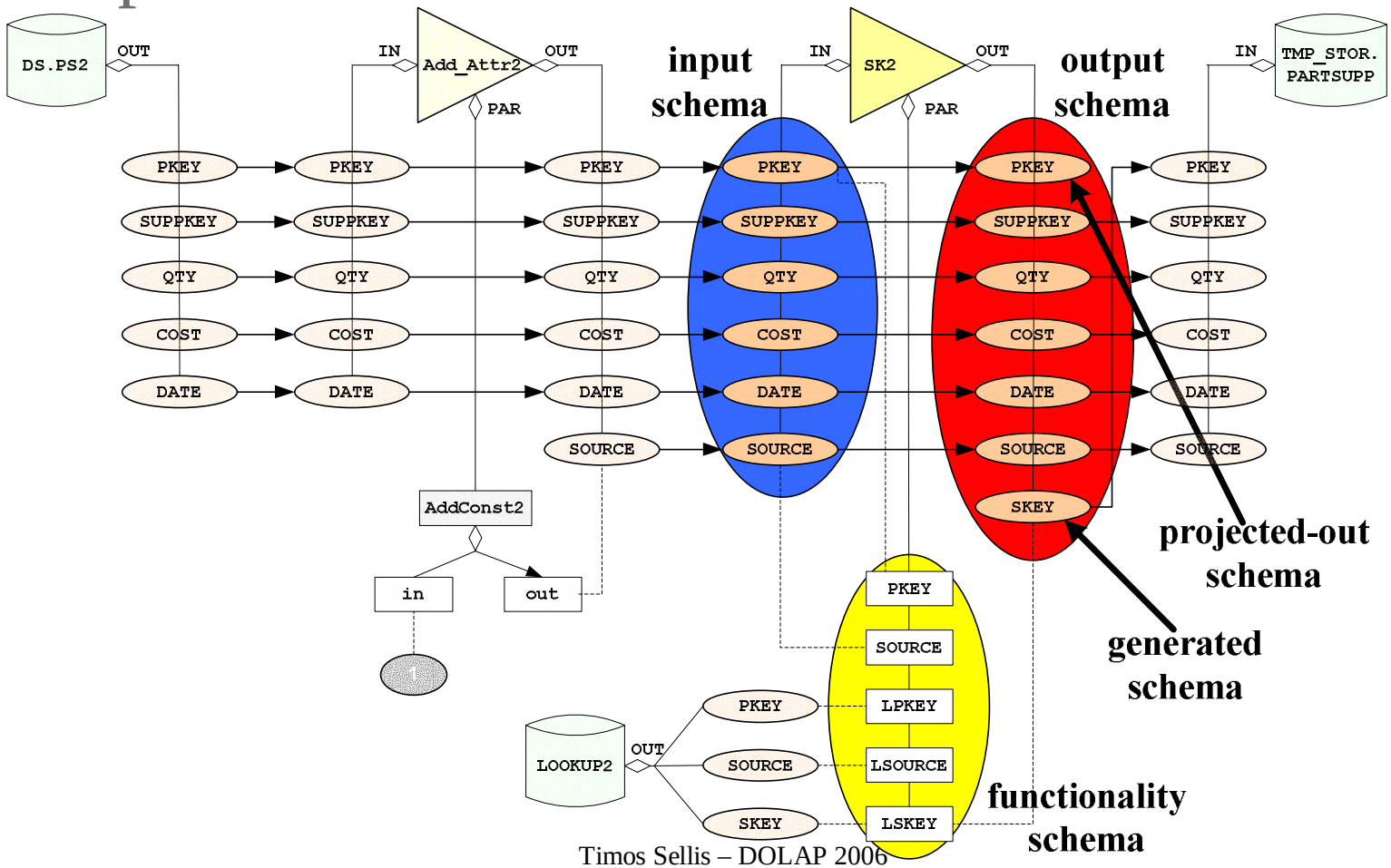
Architecture Graph

Example



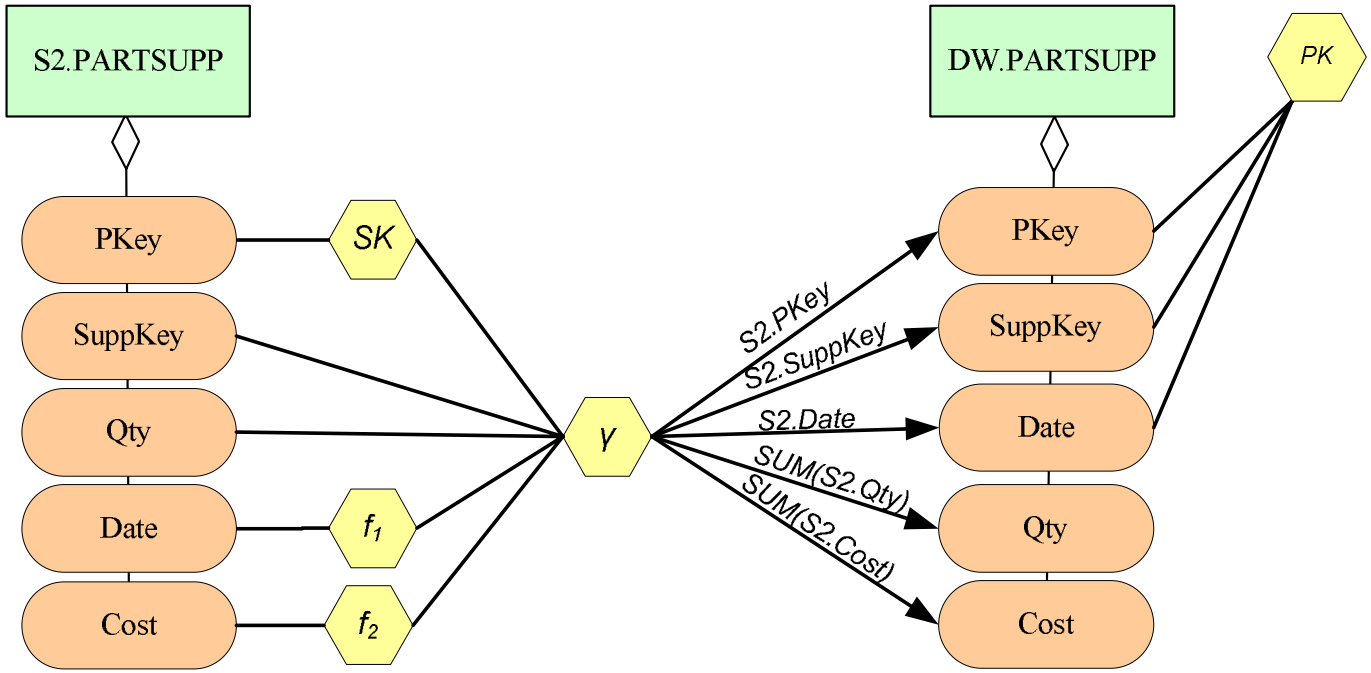
Architecture Graph

Example



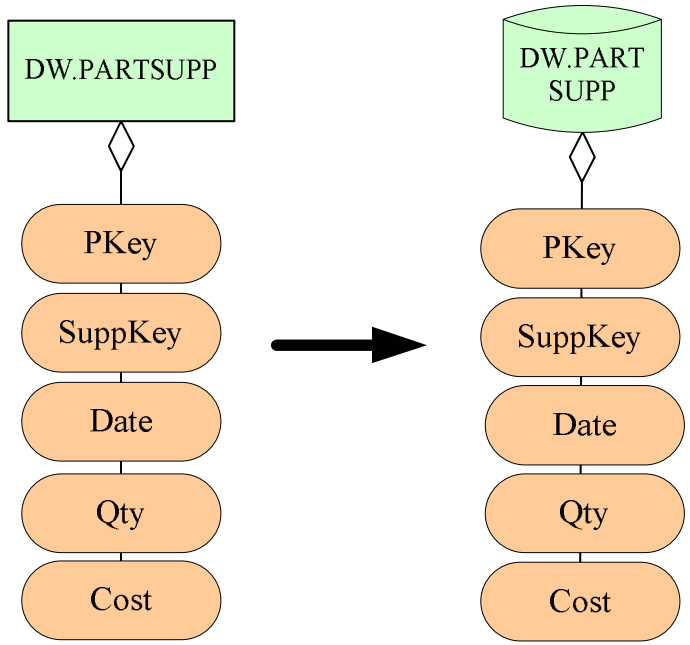
Conceptual to Logical [DOLAP 05]

Example: a conceptual scenario



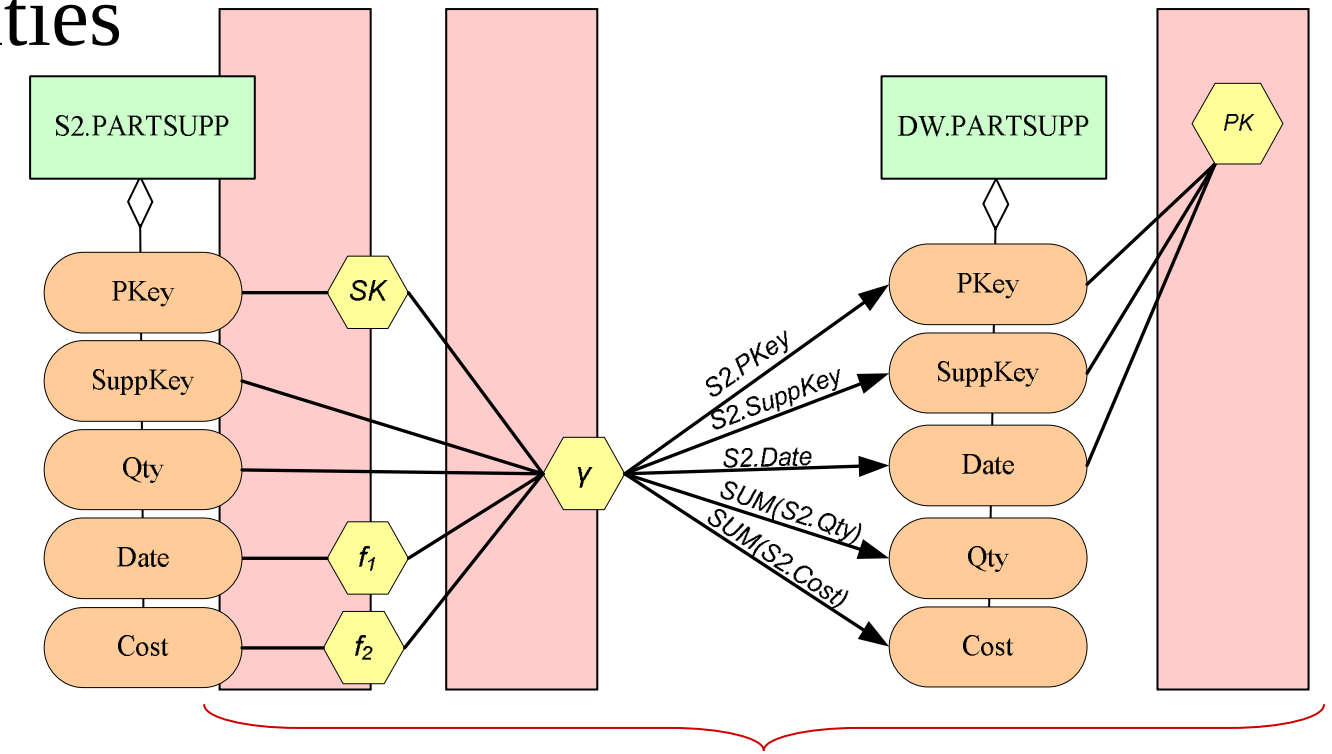
Conceptual to Logical

- Concepts and attributes → recordsets and attributes



Conceptual to Logical

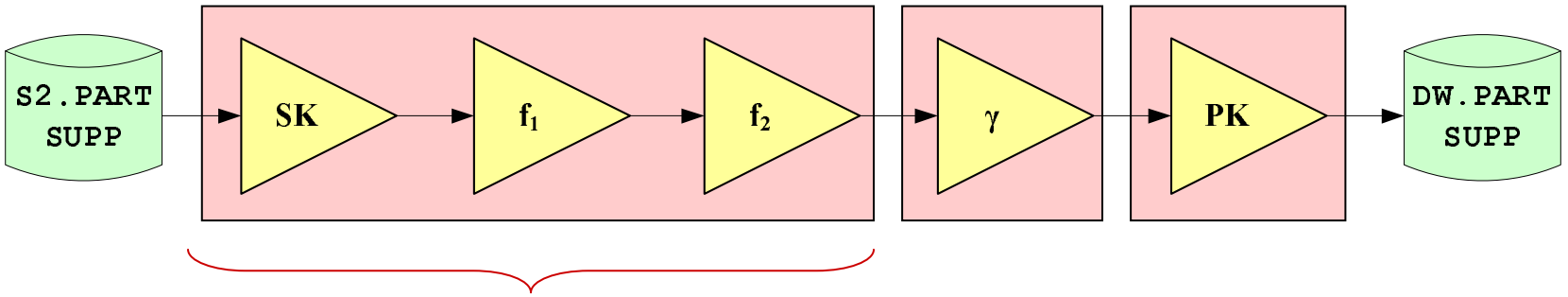
- Transformations, ETL constraints → Activities



which is the proper execution order?

Conceptual to Logical

- Example: a logical scenario



order equivalence?

SK, f_1, f_2 or **SK, f_2, f_1** or ... ?

Optimization of ETL Processes [ICDE 05]

- ETL workflows
  - are complex
  - involve a lot of recordsets and activities
  - comprises of activities that perform the same process to the same set of data
- Common settlement:
  - ad-hoc optimization based on the experience of the designer
  - execute ETL workflow as it is; hopefully, the optimizer of the DBMS would improve the performance

Optimization of ETL Processes

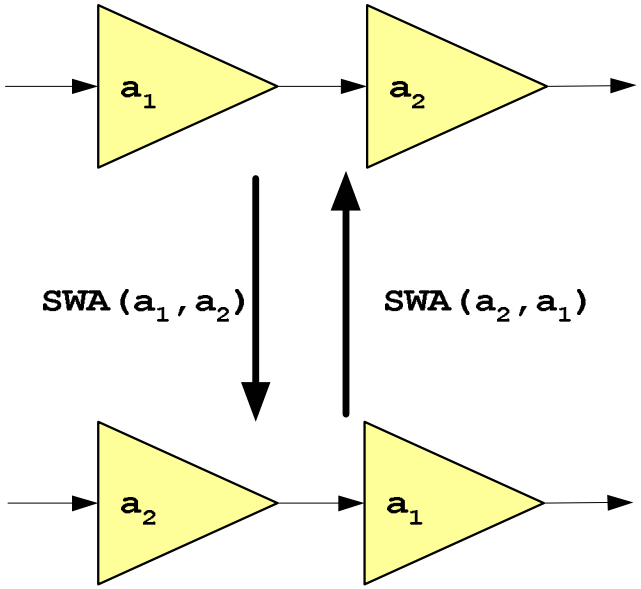
- An ETL workflow is **NOT** a *big query*
- Techniques adapted from traditional optimization are not enough
  - existence of functions
    - where it is allowed to push an activity before/after a function?
  - existence of black-box activities
    - unknown semantics
    - can not interfere in their interior
  - naming conflicts

Optimization of ETL Processes

- How can we improve an ETL workflow in terms of execution time?
- We model the ETL processes optimization problem as a state search problem
  - we consider each ETL workflow as a state
  - we construct the search space
  - the optimal state is chosen according to our cost model's criteria, in order to minimize the execution time of an ETL workflow

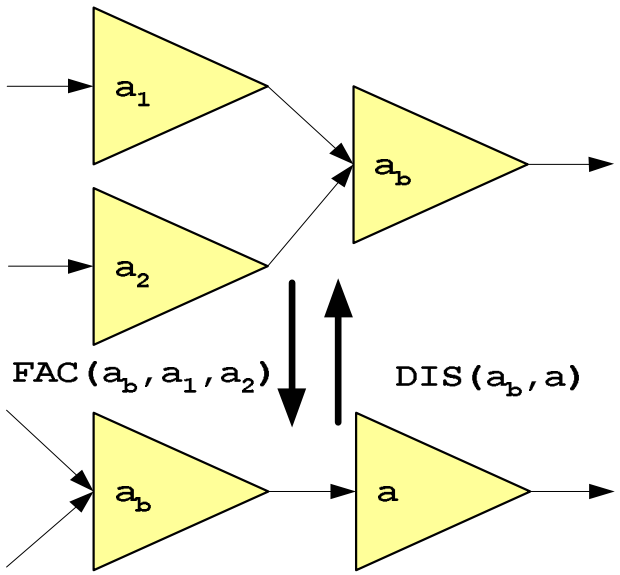
Optimization of ETL Processes

- Transition from one state to the other
  - interchange two activities of the workflow



Optimization of ETL Processes

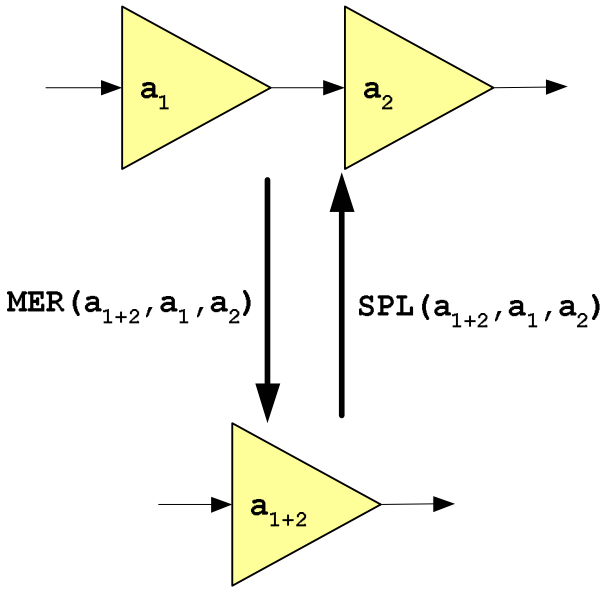
- Transition from one state to the other
  - replace homologous tasks in parallel flows with an equivalent task over a flow to which these parallel flows converge
  - divide tasks of a joint flow to clones applied to parallel flows that converge towards the joint flow



a, a_1, a_2: homologous activities

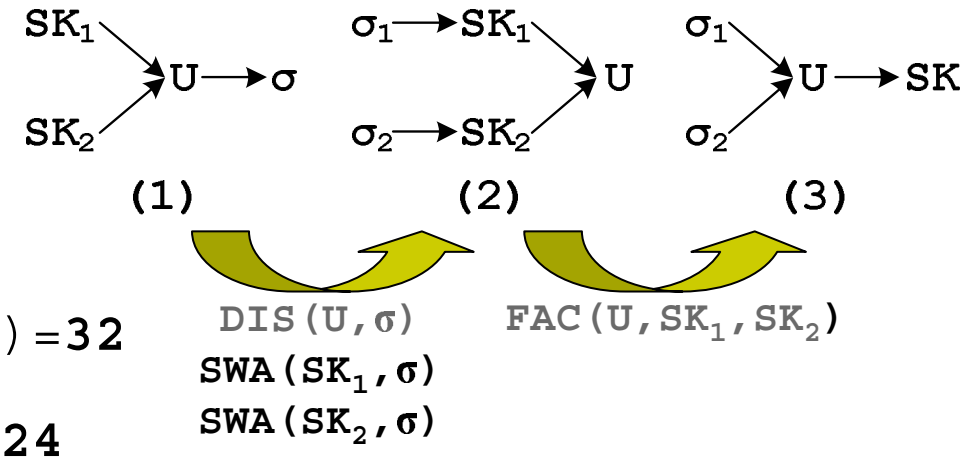
Optimization of ETL Processes

- "Transition" from one state to the other :
  - merge / split group of activities



Optimization of ETL Processes

- Example:
  - cost model = *f* (card(processed_rows))
  - input of 8 rows in each flow
  - selectivities: σ = 50%, SK_1 = SK_2 = 100%
  - cost formulae: cost(SK) = $n\log_2 n$, cost(σ) = n (ignore the cost of U)



$c_1 = 2n\log_2 n + n = \mathbf{56}$

$c_2 = 2(n + (n/2)\log_2(n/2)) = \mathbf{32}$

$c_3 = 2n + (n/2)\log_2(n/2) = \mathbf{24}$

Optimization of ETL Processes

- Transition Applicability
  - when the *swap* is allowed?
  - when the *factorize* is allowed?
  - when the *distribute* is allowed?
- Correctness of the transitions
  - *post-conditions* of ETL workflows
  - *equivalence* of ETL workflows

Optimization of ETL Processes

- Algorithms
  - exhaustive (1)
  - heuristic (2)
  - greedy (3)
- Briefly, algorithms (2) and (3) improve the performance of ETL workflows over 70% (avg) during a satisfactory for DW's period of time (in a time range of sec..10min)

Research Challenges

- Extension of the ETL mechanisms for **non-traditional data**, like XML/HTML, spatial and biomedical data
- Apply the techniques described to **different environments** (like Active DWs)
- Use **richer semantics** to describe sources, reason about them , etc.

Research Challenges – use of ontologies

- Key idea
  - an ontology-based approach to facilitate the conceptual design of an ETL scenario
- An ontology
  - is a “formal, explicit specification of a shared conceptualization”
  - describes the knowledge in a domain in terms of classes, properties, and relationships between them
  - machine processable
  - formal semantics
  - reasoning mechanisms
- The Web Ontology Language (OWL) is used as the language for the ontology

Research Challenges – can it scale?

- Think of new models for the case of large distributed environments with many sources **e.g. P2P**
  - Can the techniques scale?
  - Can they adapt to the different semantics, like approximate and incomplete answers?
  - Can we make the techniques “goal”-driven rather than strict: e.g. I want to have 100% over this week’s data, 80% over last week’s, etc?
  - How to integrate static and dynamic cases (peers come and leave, others stay there for a long period)?