

# On Extending a Full-Sharing Multithreaded Tabling Design with Batched Scheduling

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Yap Prolog: *<http://www.dcc.fc.up.pt/~vsc/Yap>*

Project SIBILA: *<http://cracs.fc.up.pt/>*



# Prolog and SLD Resolution

- Prolog systems are known to have good performances and flexibility, but they are based on SLD resolution, which limits the potential of the Logic Programming paradigm.
- SLD resolution cannot deal properly with the following situations:
  - ◆ **Positive Infinite Cycles** (insufficient expressiveness)
  - ◆ **Negative Infinite Cycles** (inconsistence)
  - ◆ **Redundant Computations** (inefficiency)

# SLD Resolution: Infinite Cycles

```
c1)    a(X) :- b(X).  
c2)    a(2).  
  
c3)    b(X) :- a(X).  
c4)    b(1).
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1.a(X)

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Infinite Cycle

# Tabling in Prolog Systems

- **Tabling** is an **implementation technique** that **overcomes** some of the **limitations** of **Prolog** systems:
  - ◆ Tabled subgoals are evaluated by storing their answers in an appropriate data space, called the **table space**.
  - ◆ Repeated calls to tabled subgoals are resolved by **consuming** the answers already stored in the table instead of **being re-evaluated** against the program clauses.



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- Implementations of **Tabling** are currently available in systems like:
  - ◆ XSB Prolog, **Yap Prolog**, B-Prolog, ALS-Prolog, Mercury, Ciao Prolog and more recently Picat.
- **Multithreading** combined with **Tabling**:
  - ◆ XSB Prolog
  - ◆ **YapTab-Mt** [ICLP 2012].

# YapTab-Mt - Advantages

- An **abstraction layer** with **high-level constructors** that provide access to the **dynamic programming (tabling)** support:
  - ◆ Instruction: **`:- table predicate/arity.`**
  - ◆ Scheduling: **`:- tabling_mode(predicate, batched).`**

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- **Thread API** is **POSIX Threads compliant**:
  - ◆ **Management** - creating, joining , yielding, etc.
  - ◆ **Monitoring** - statistics, properties, etc.
  - ◆ **Synchronization** - mutex creation, statistics, etc.

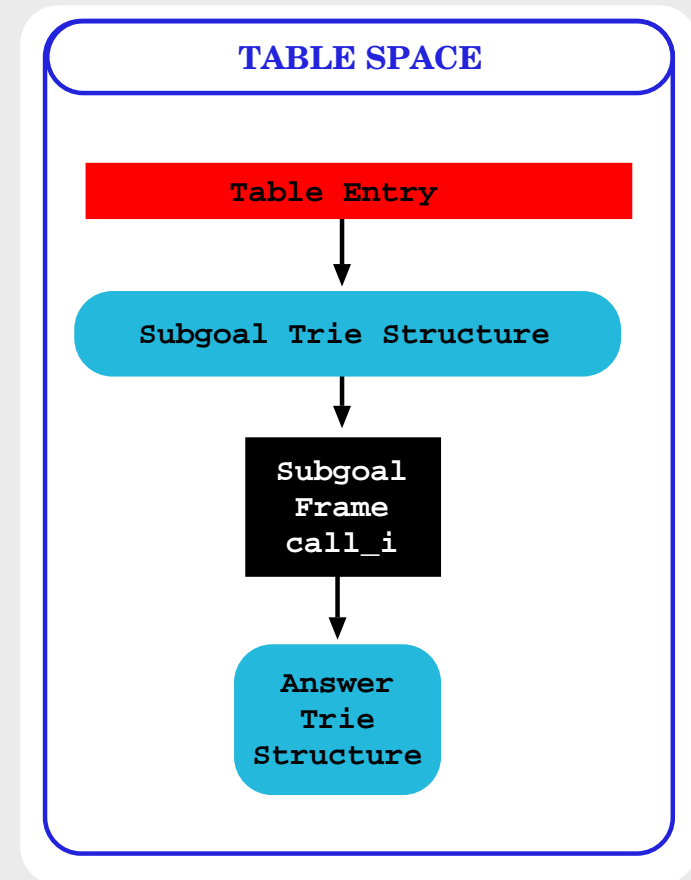
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- Write complex **dynamic programming** applications using the **Prolog** programming language.
  - ◆ **Procedures** in **Prolog** can be written as **logical specifications**, which are closer to **mathematical notation**.

# Table Space - Internal Architecture

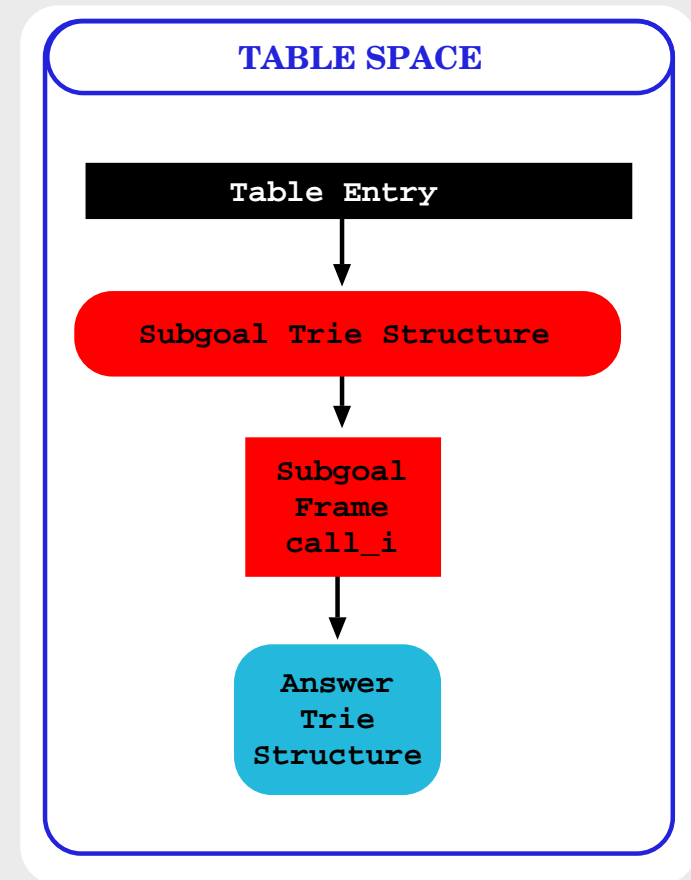
➤ **Table Entry**: stores generic about the predicates.

◆ **:-table predicate/2.**



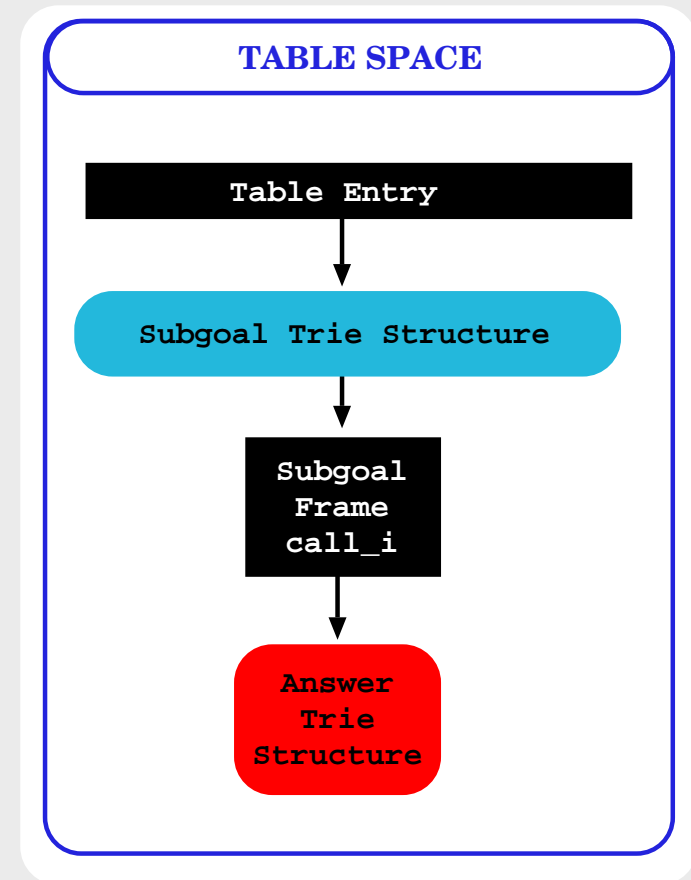
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- **Subgoal Trie Structure**: stores the **identifier** of the computations.
  - ◆ **`predicate(computation_id, Answer)`**.

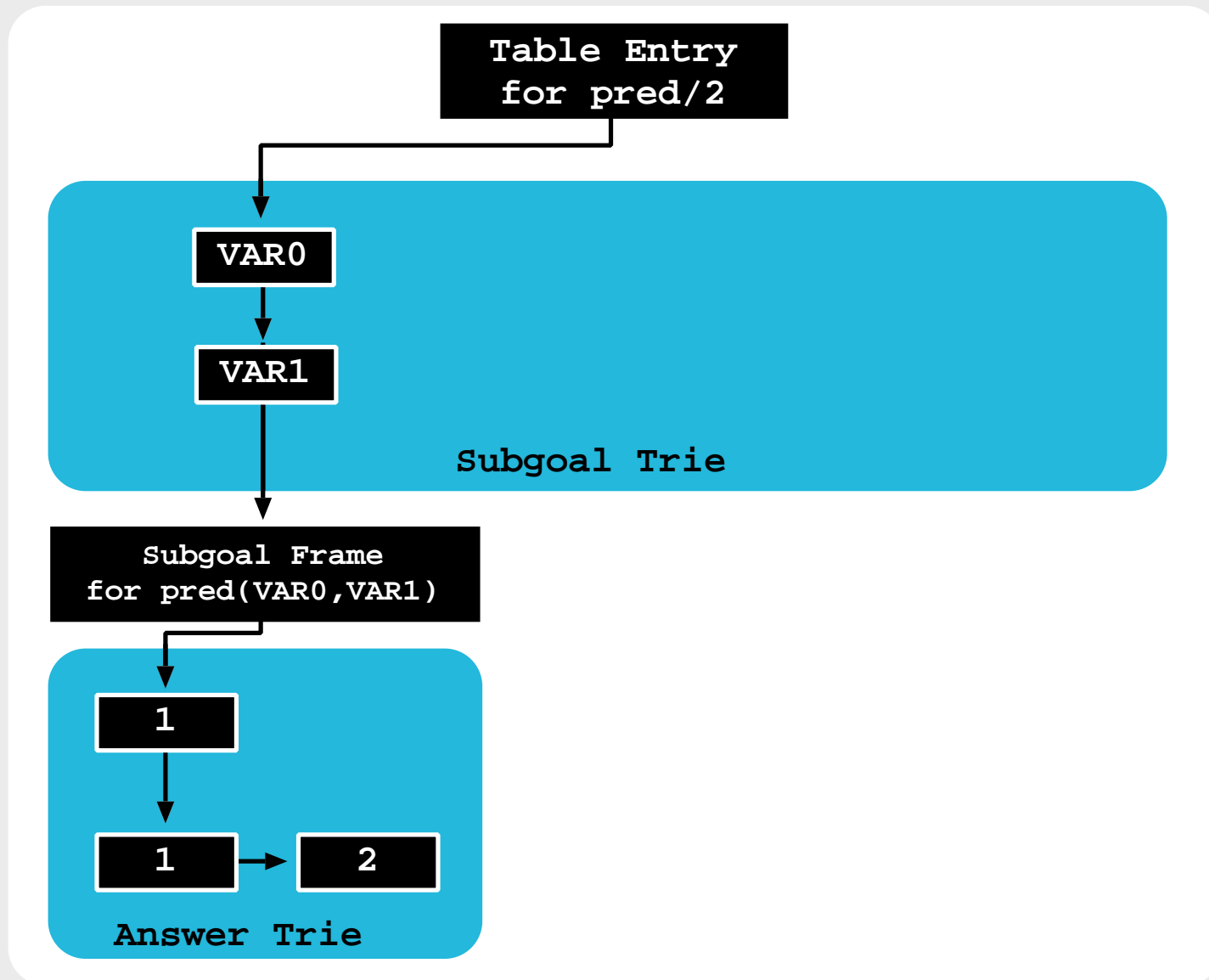


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- **Answer Trie Structure**: stores the **answers** of the computations.
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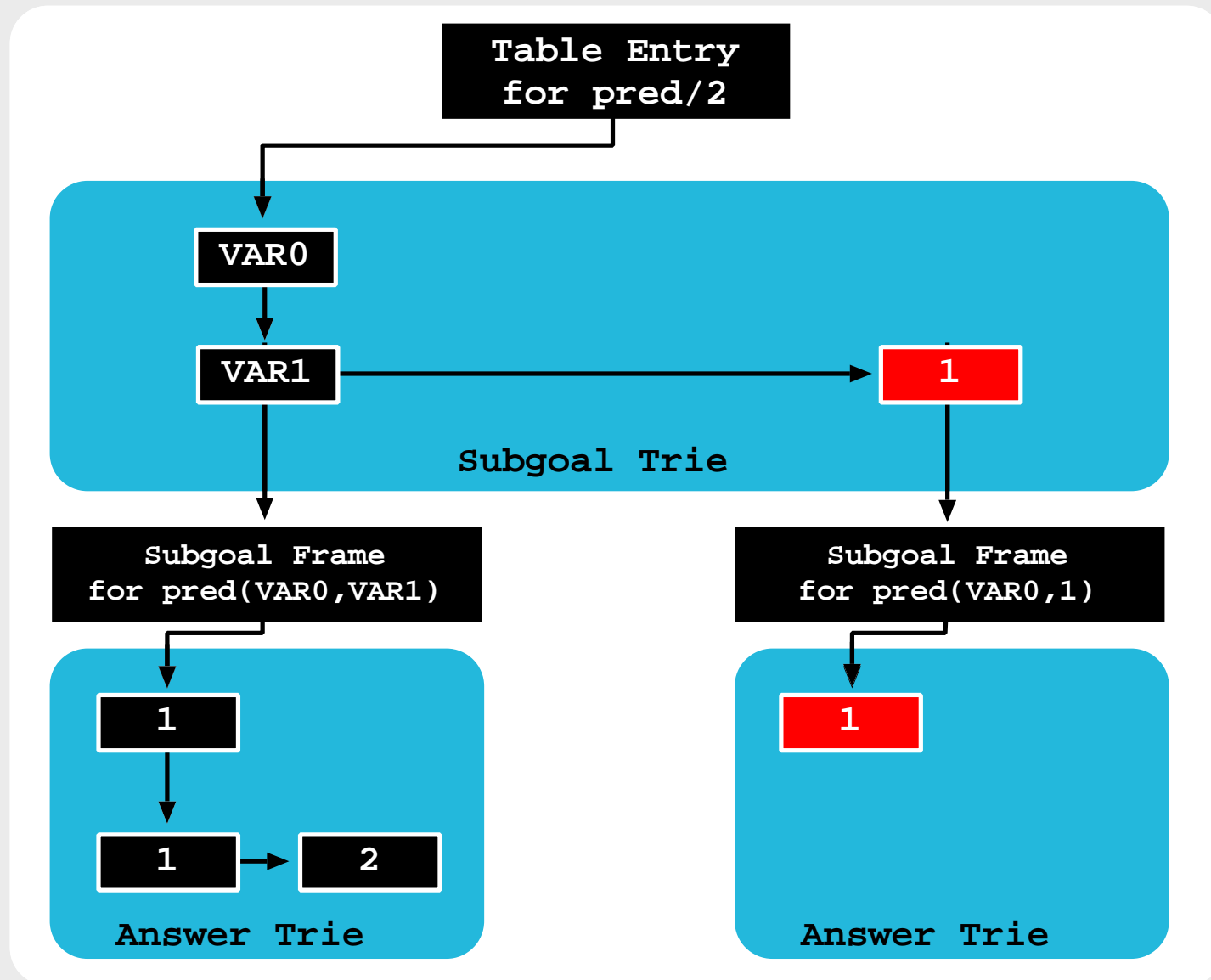


# Table Space - Example





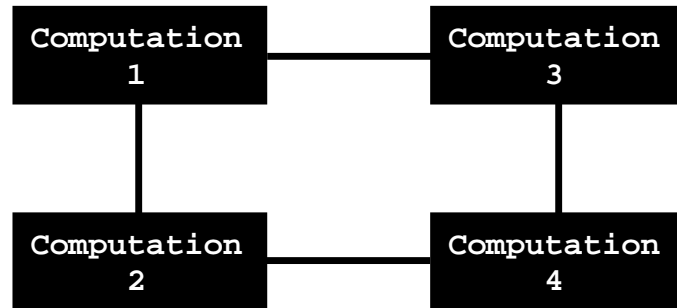
# Table Space - Example



# Tabling Scheduling Strategies - Local vs Batched

## LOCAL SCHEDULING

### Cluster of Dependent Computations

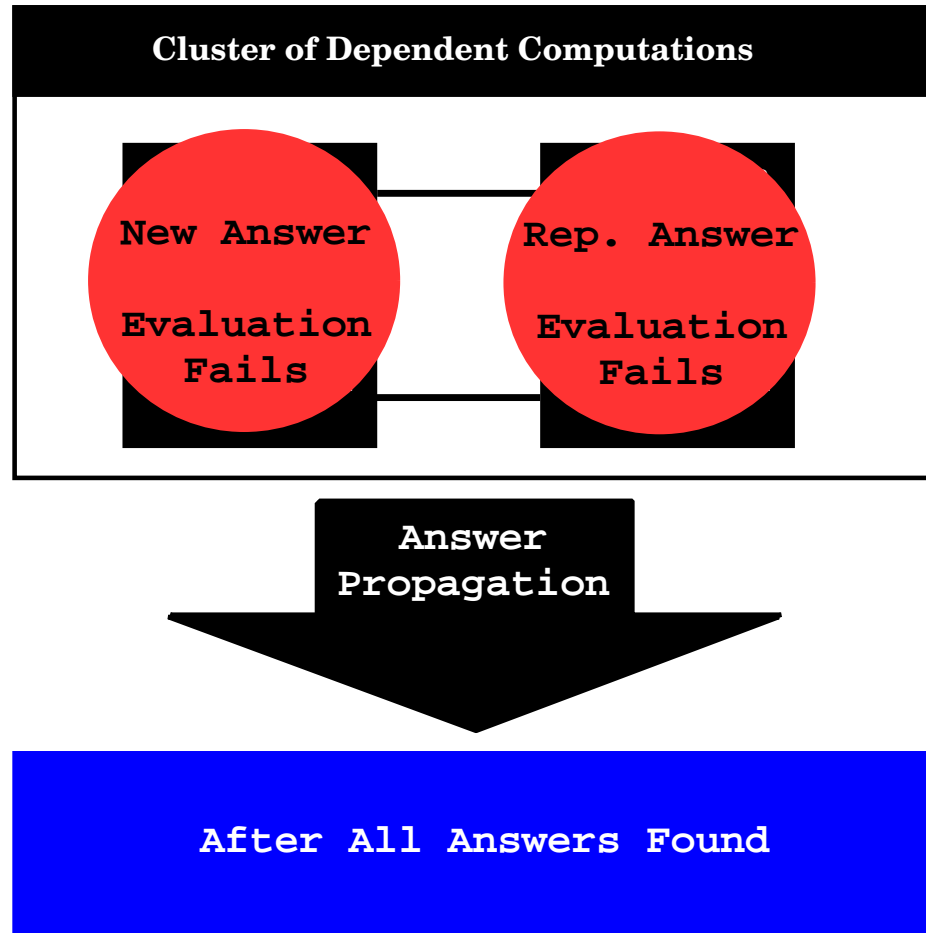


Answer  
Propagation

After All Answers Found

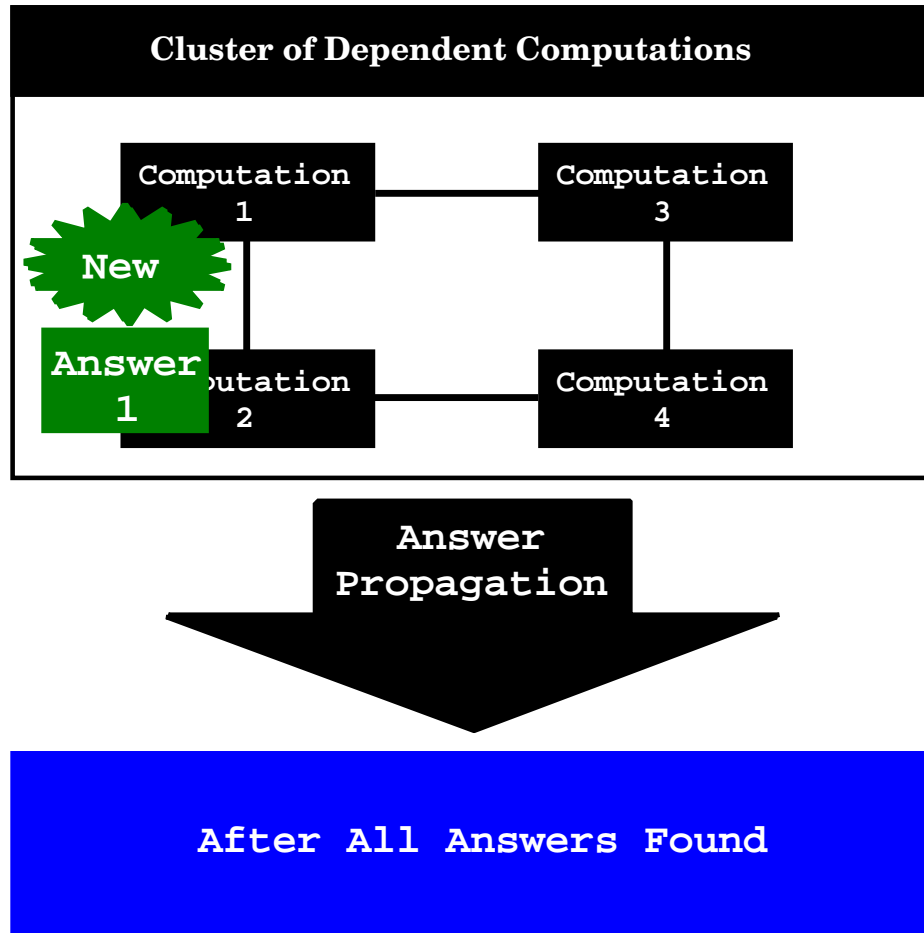
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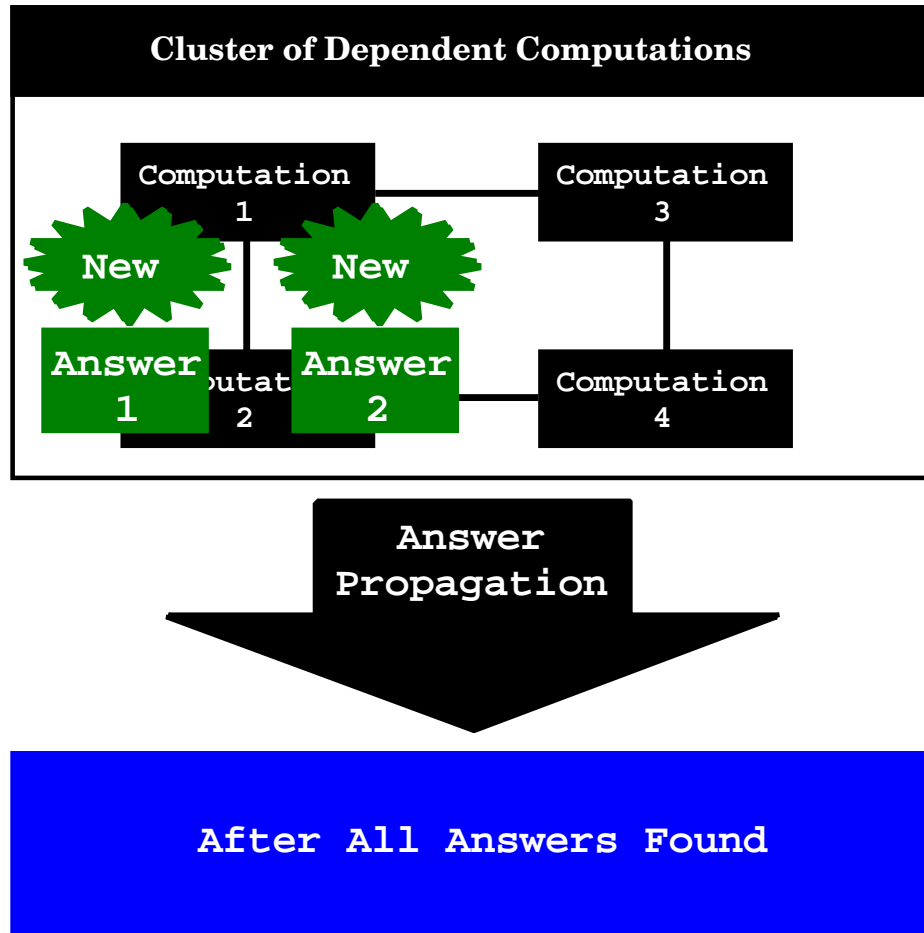
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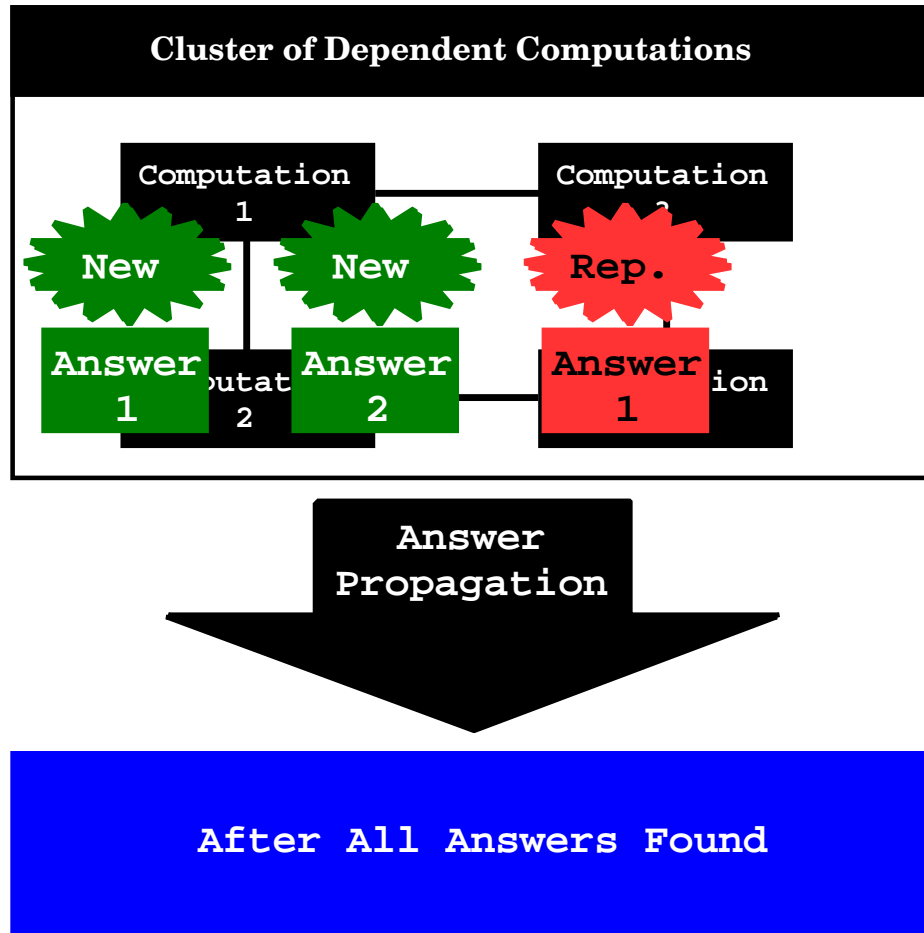
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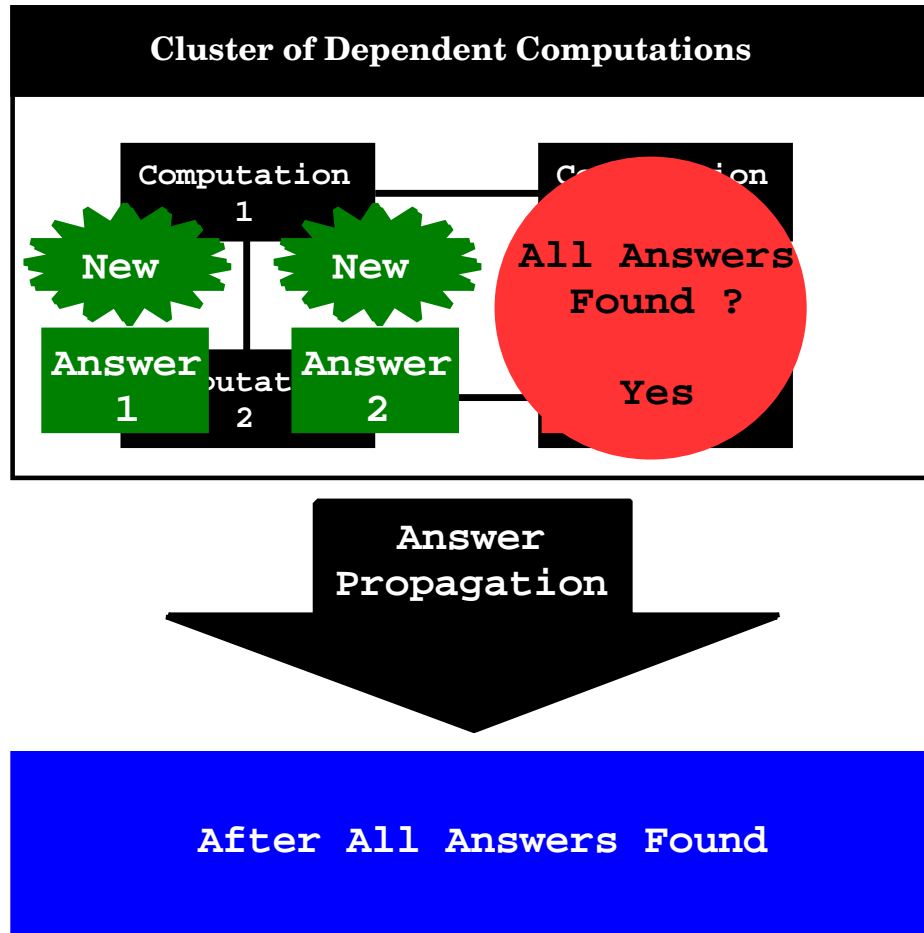
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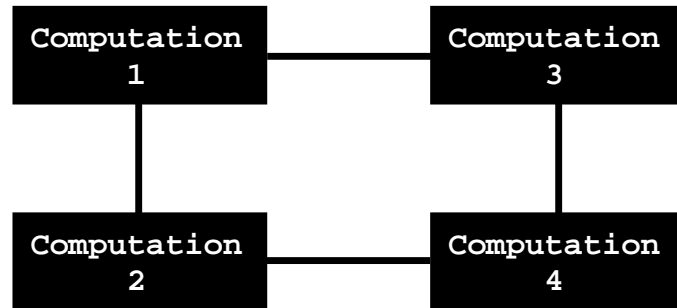
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# Tabling Scheduling Strategies - Local vs Batched

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### Cluster of Dependent Computations



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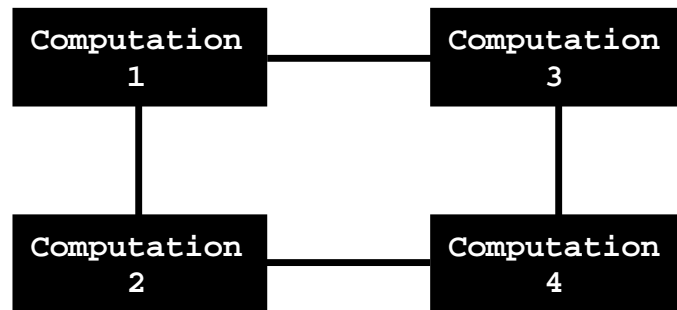
Answer 1 After Answer 2 Answers Found



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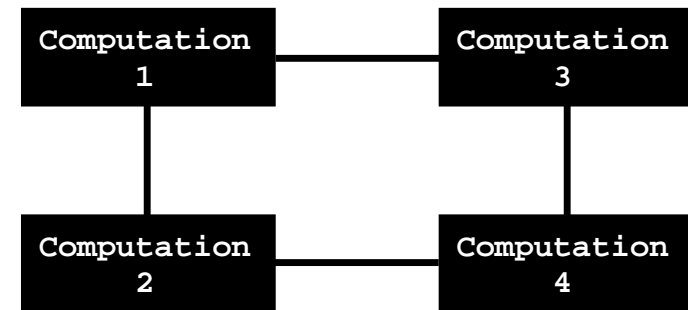


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## BATCHED SCHEDULING

### Cluster of Dependent Computations



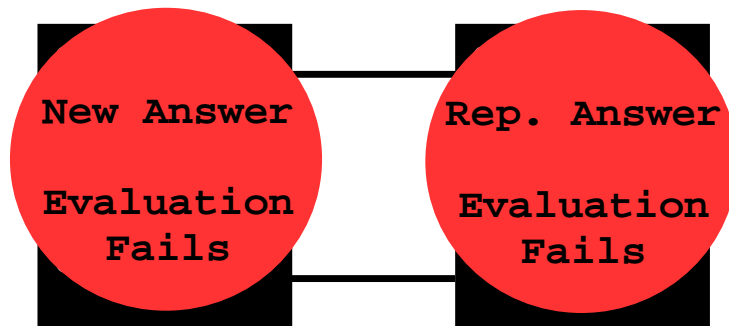
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Whenever a New Answer is Found

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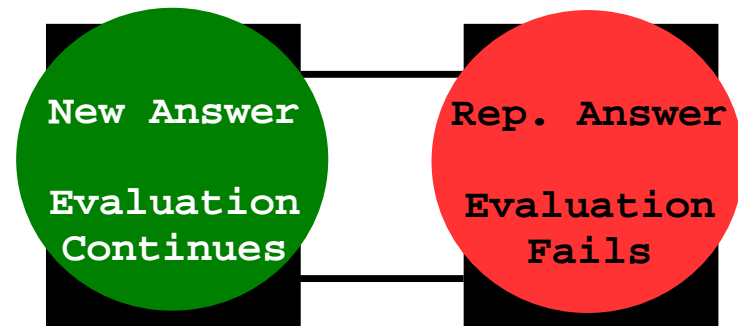


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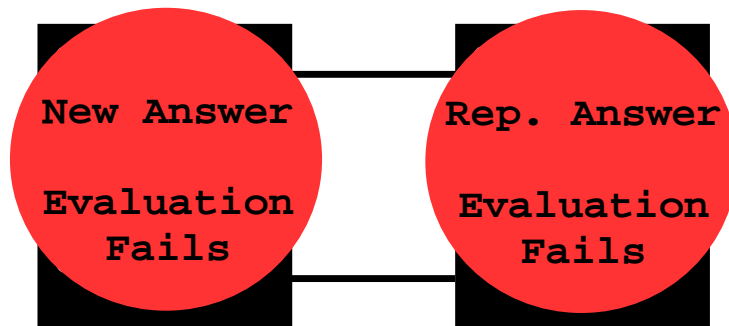
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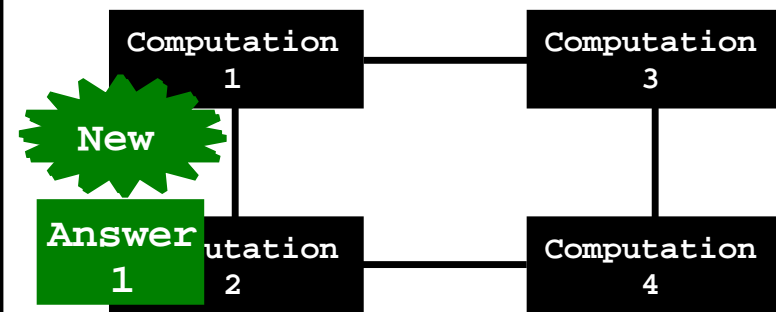


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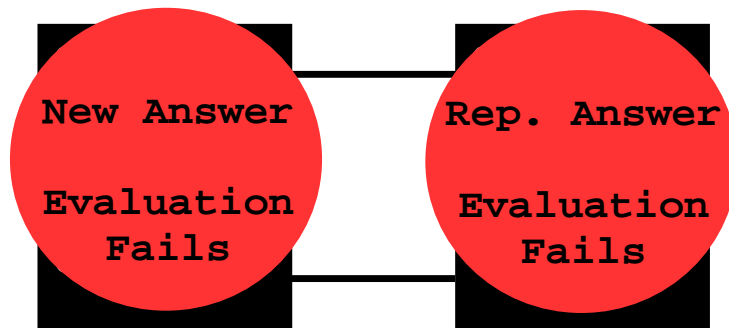
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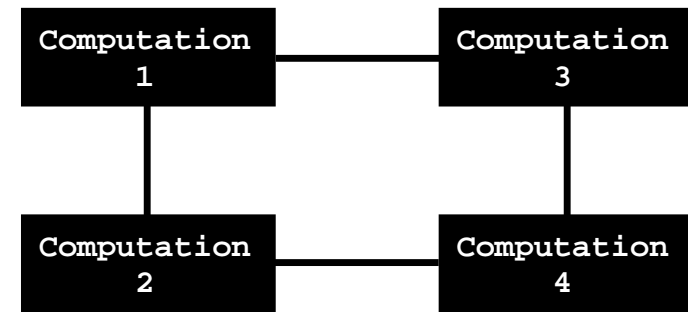


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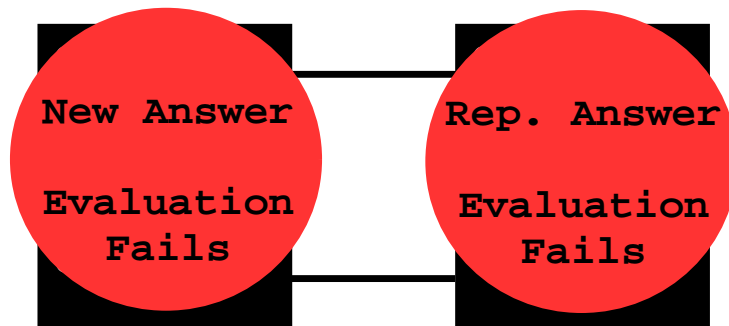
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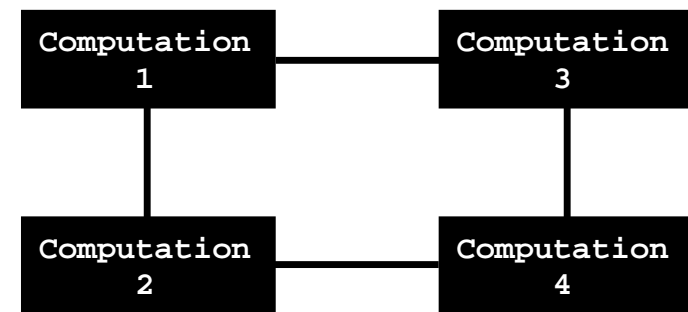


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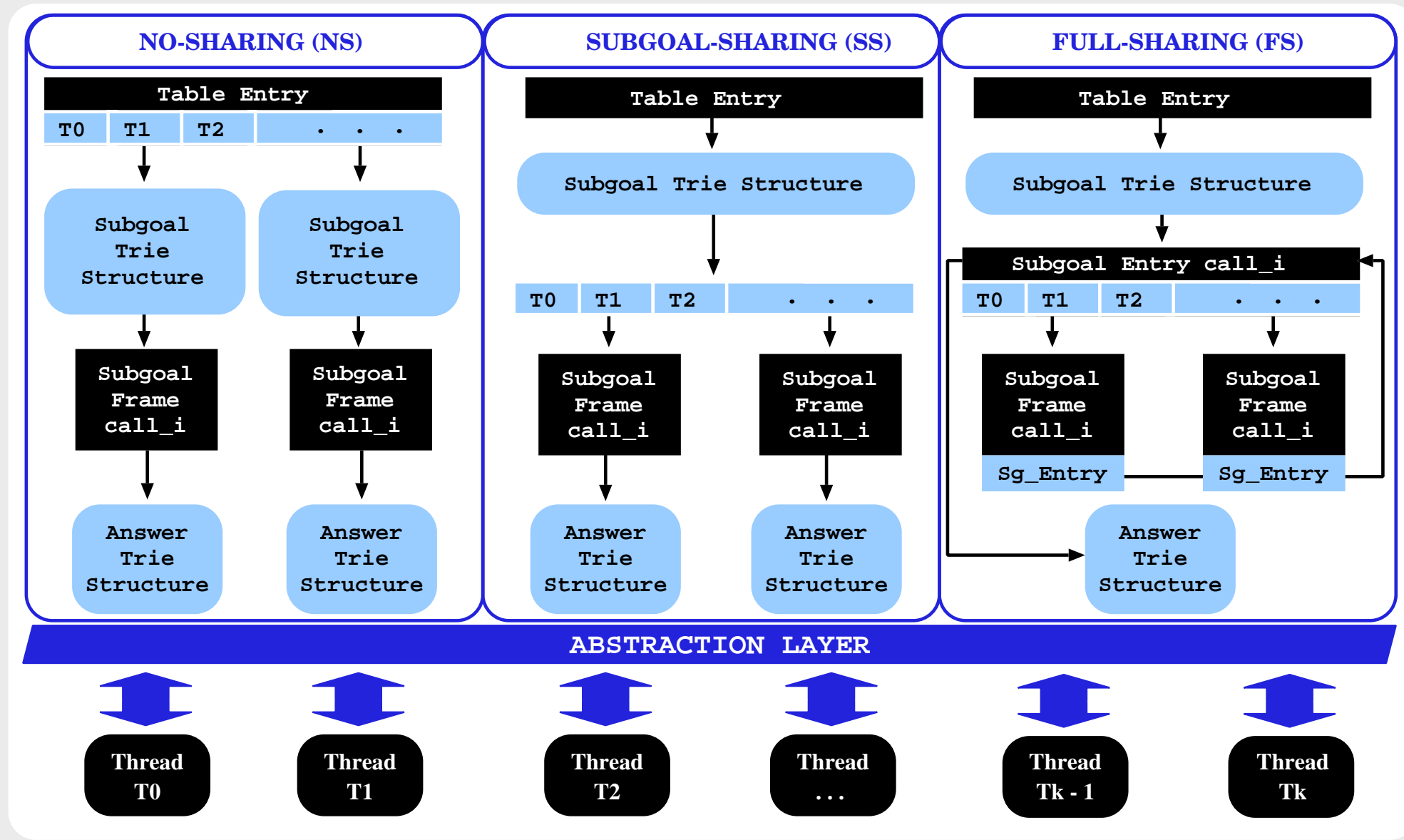
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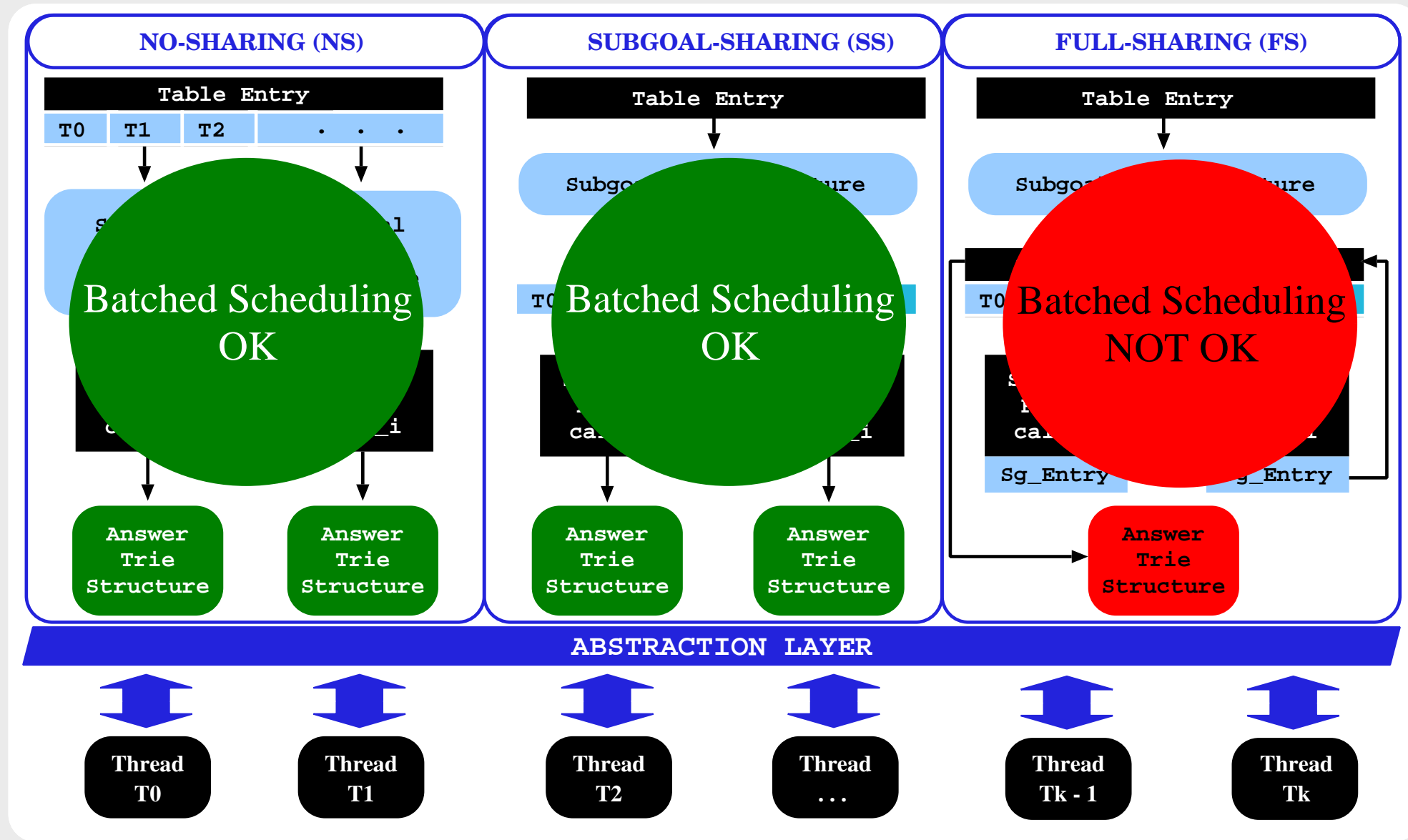
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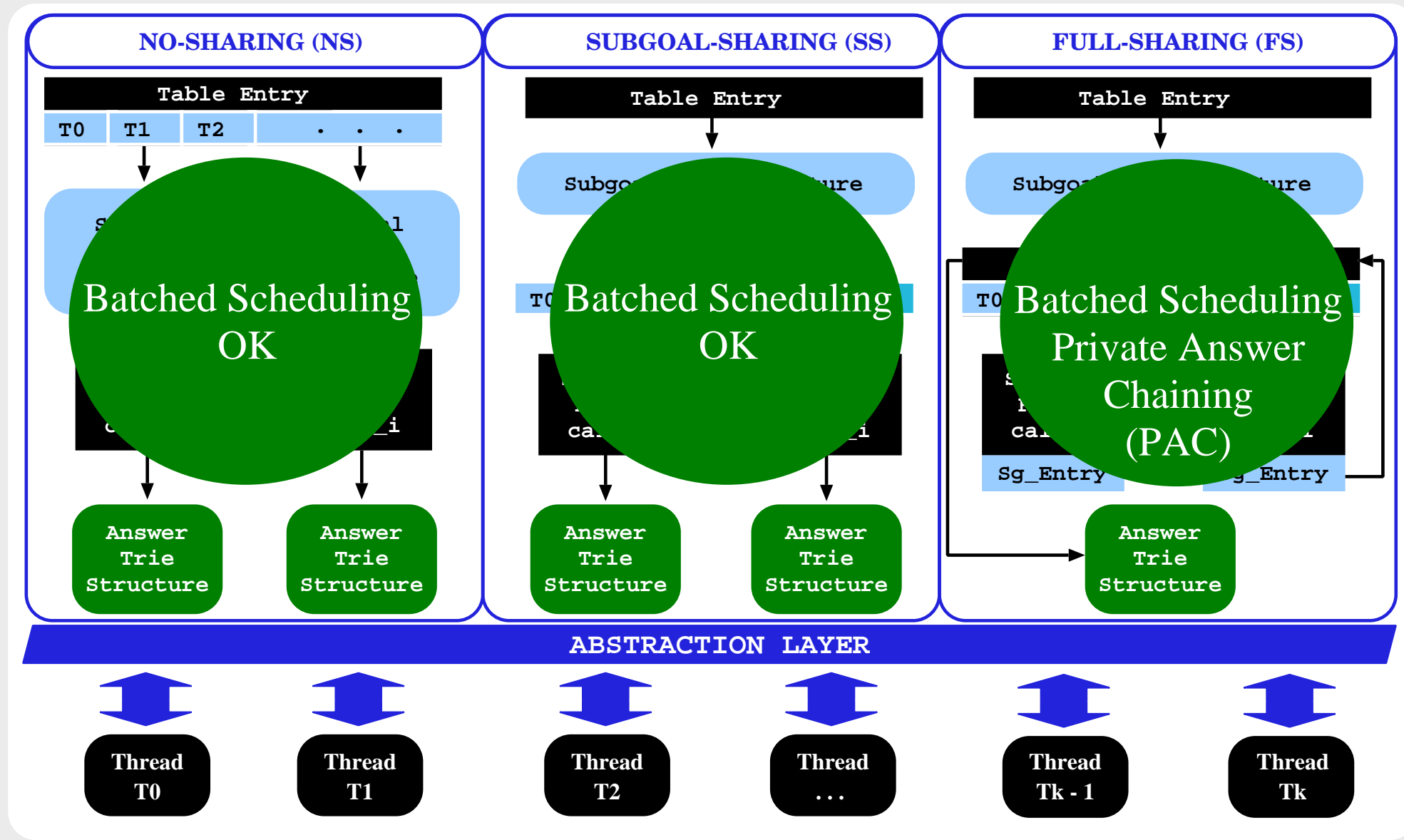
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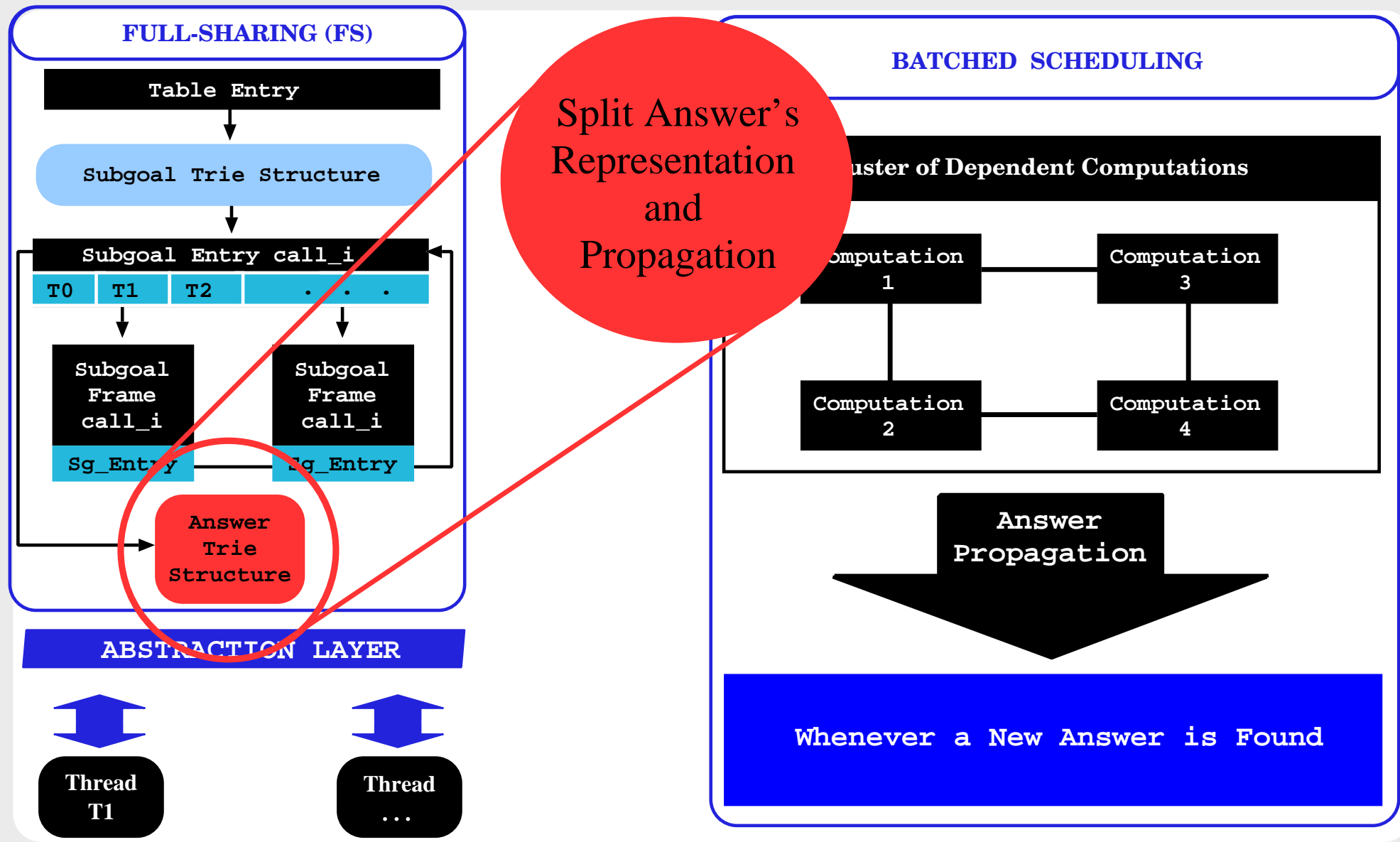


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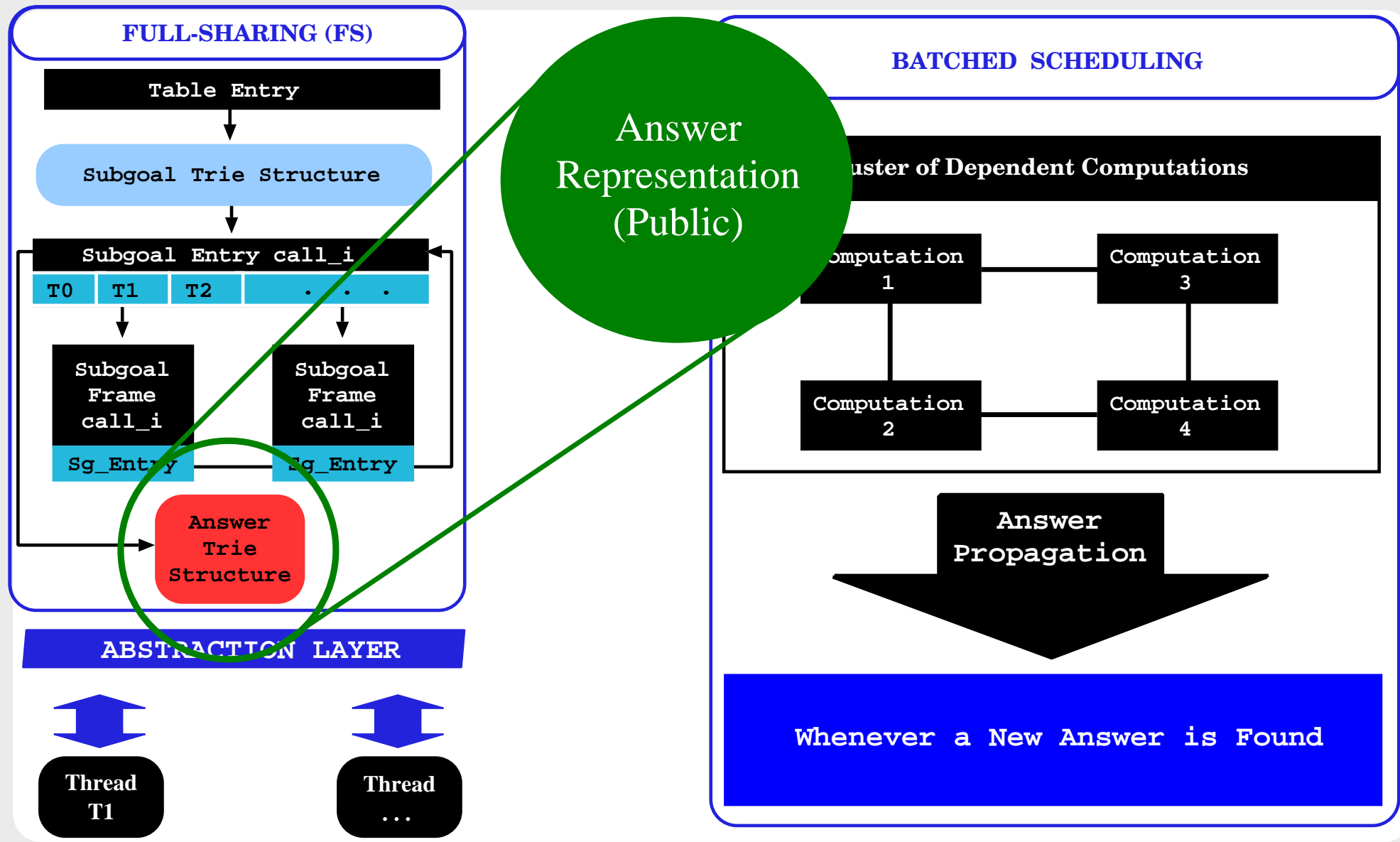




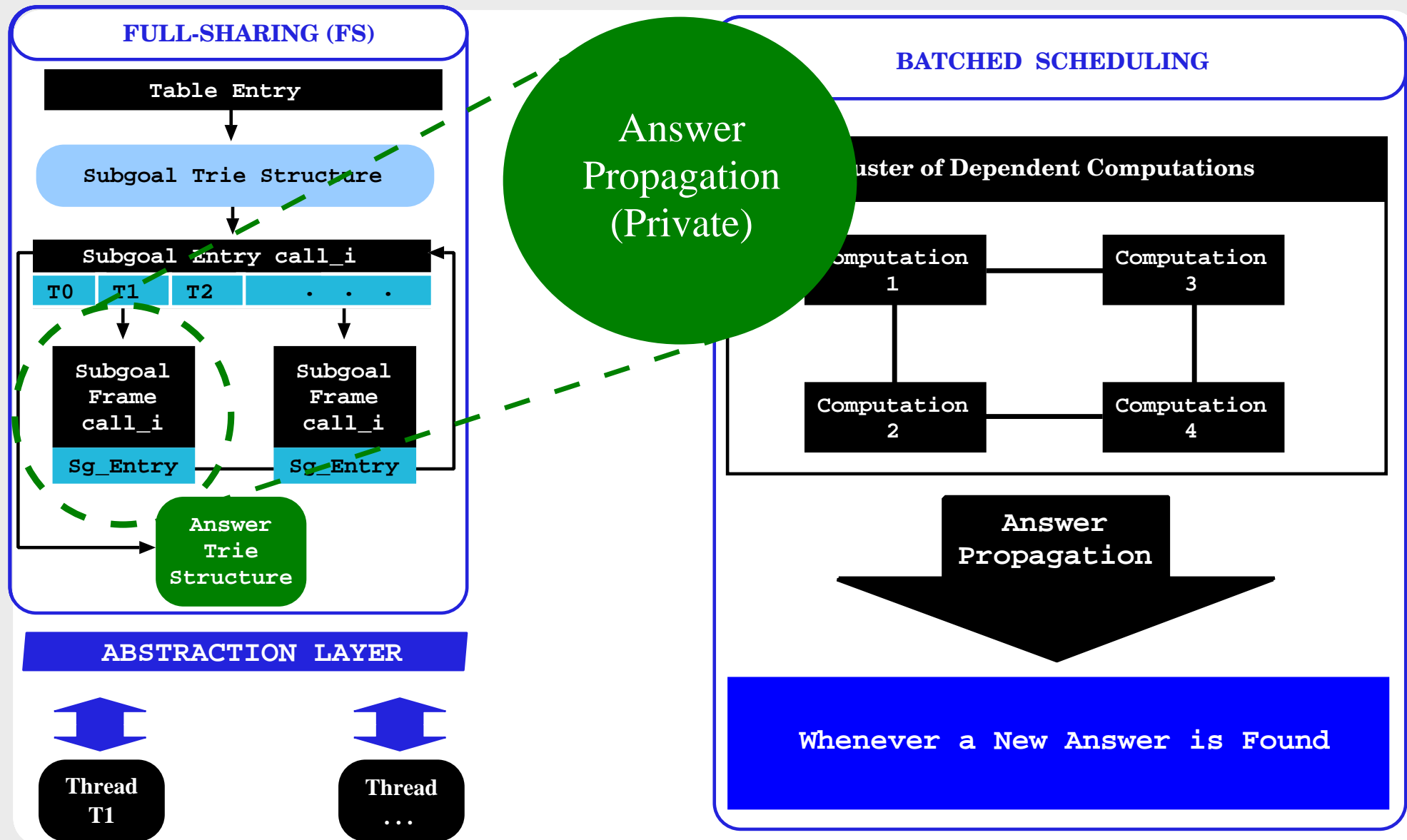
# Private Answer Chaining - Key Idea



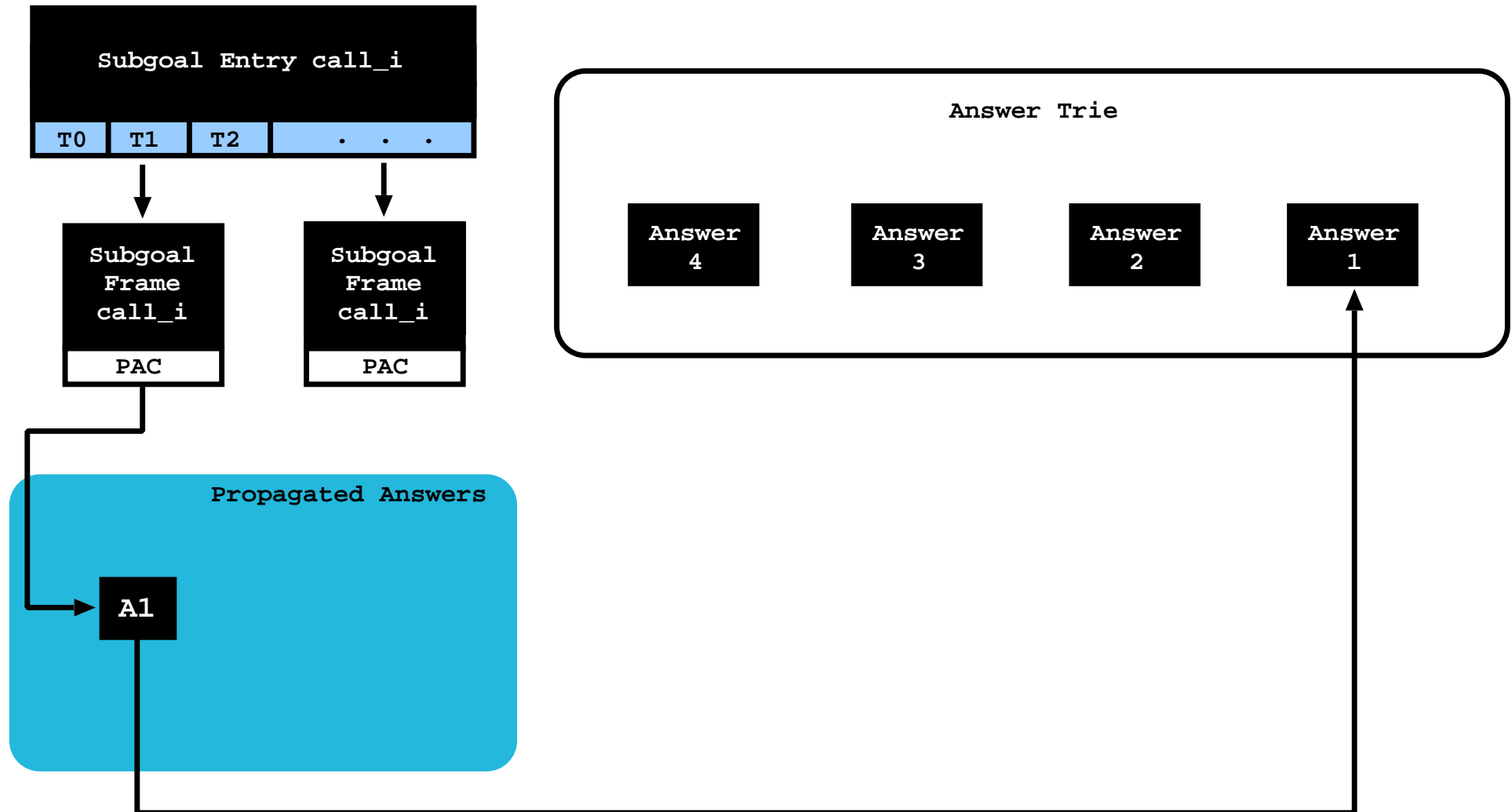
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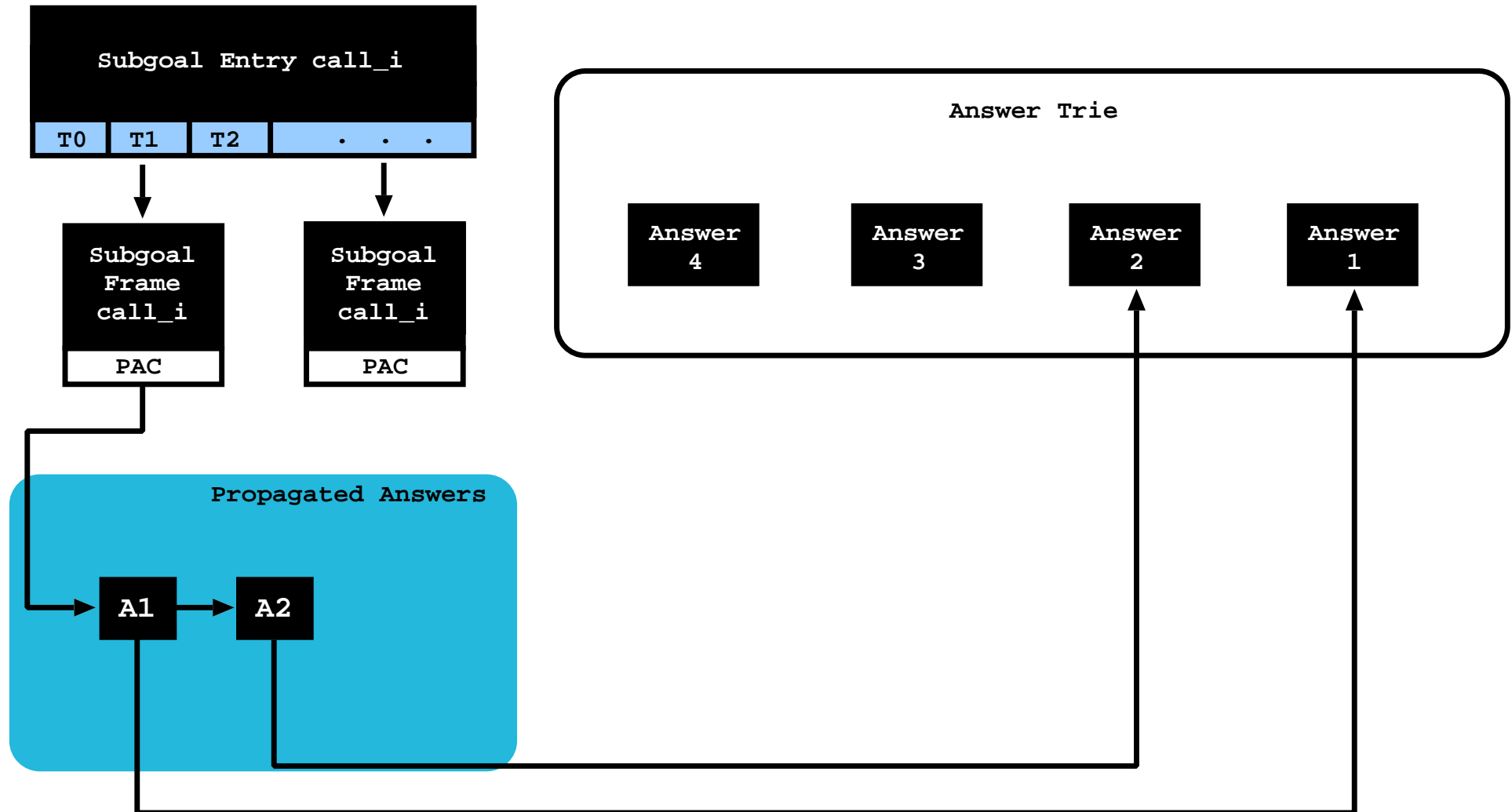
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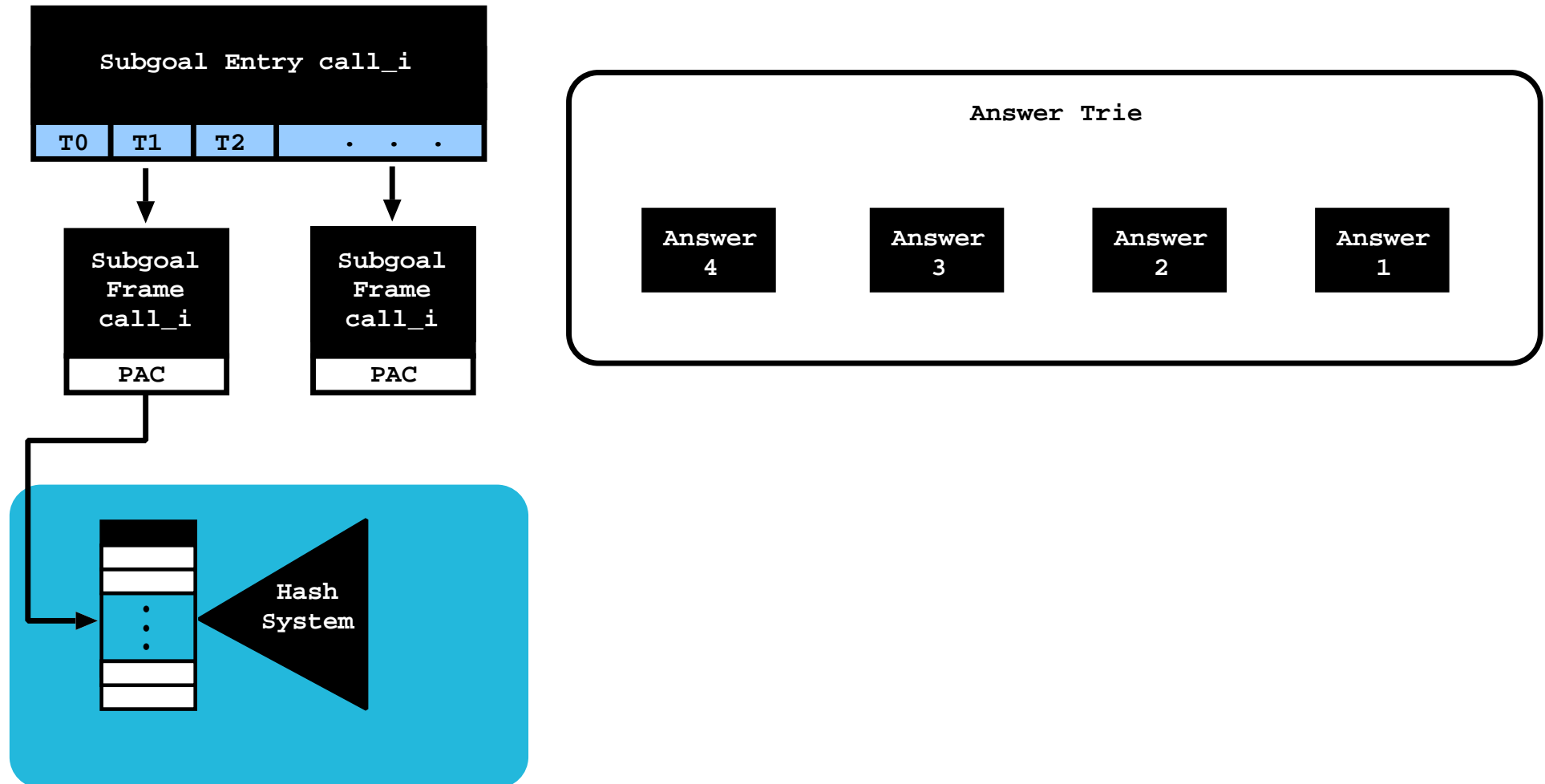
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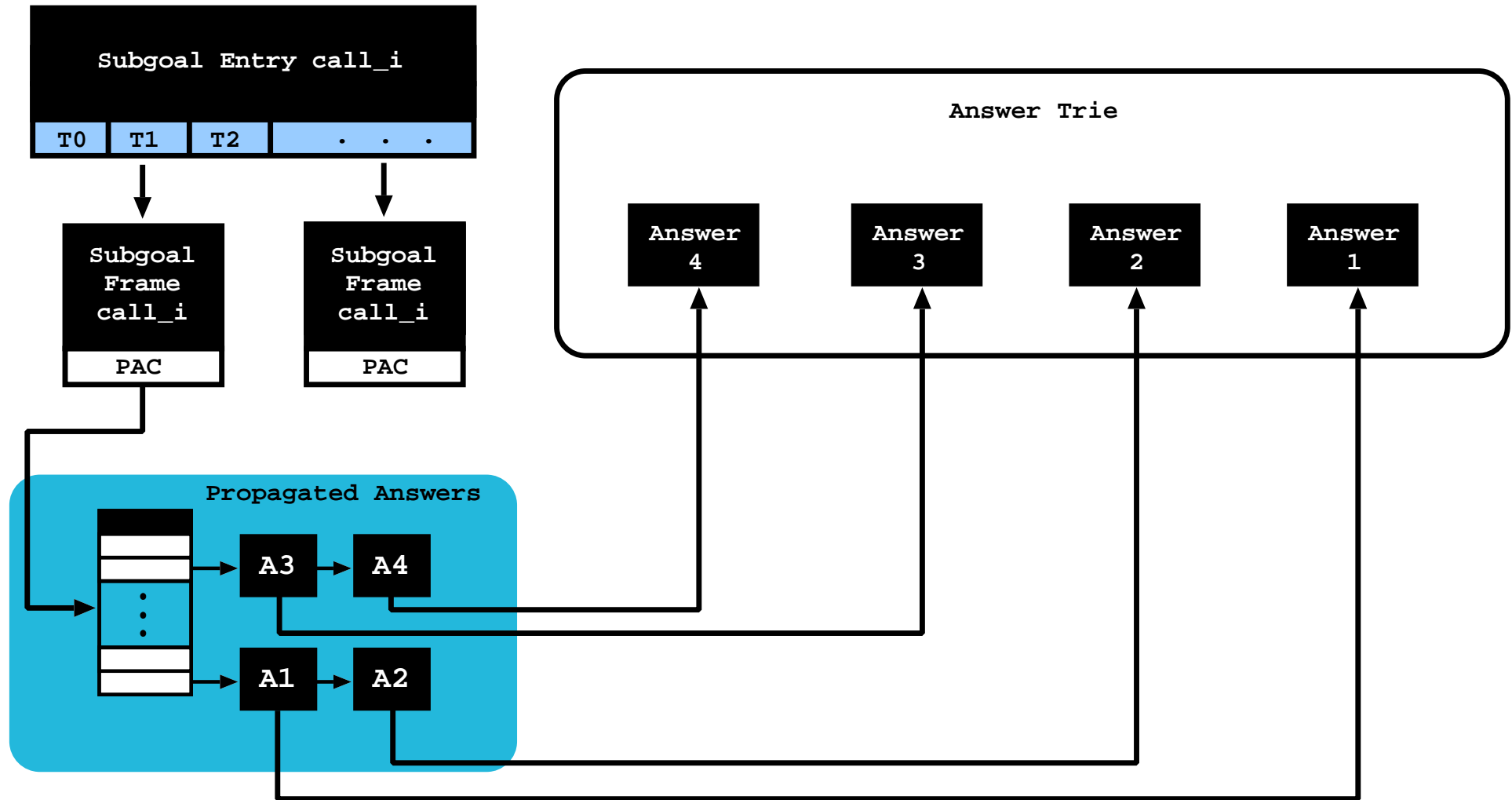
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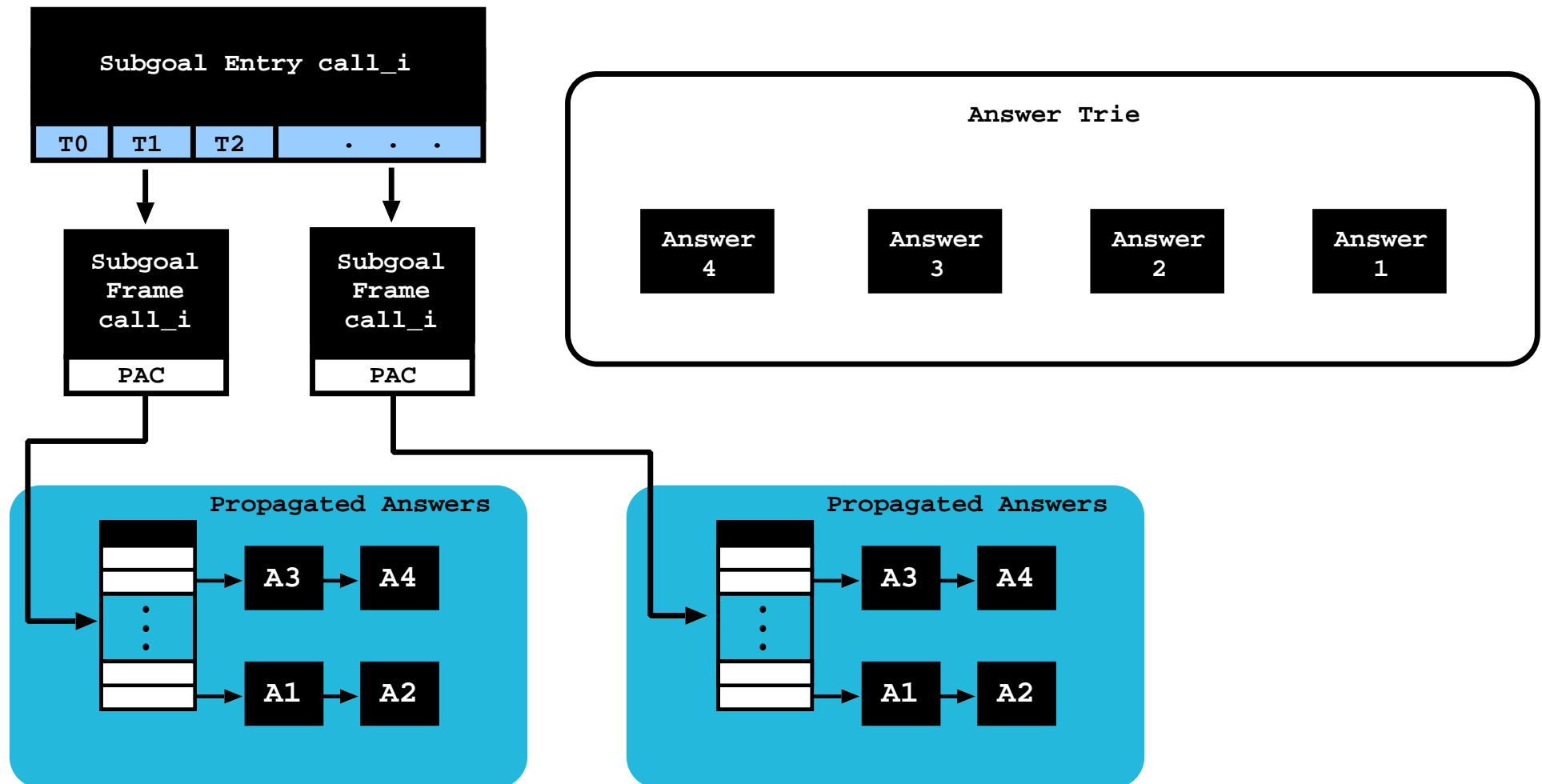
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# Experimental Results - Worst Case Scenarios

Threads		NS		FS	
		Local	Batched	Local	Batched
1	Min	0.53	0.55	1.01	0.95
	Avg	0.78	0.82	1.30	1.46
	Max	1.06	1.05	1.76	2.33
8	Min	0.66	0.63	1.16	0.99
	Avg	0.85	0.88	1.88	1.95
	Max	1.12	1.14	2.82	3.49
16	Min	0.85	0.75	1.17	1.06
	Avg	0.98	1.00	1.97	2.08
	Max	1.16	1.31	3.14	3.69
24	Min	0.91	0.93	1.16	1.09
	Avg	1.15	1.16	2.06	2.19
	Max	1.72	1.60	3.49	4.08
32	Min	1.05	1.04	1.33	1.26
	Avg	1.51	1.49	2.24	2.41
	Max	2.52	2.63	3.71	4.51

# Conclusions and Further Work

- **Batched scheduling** can be an **useful strategy** in tabled logic programs that:
  - ◆ require an **eager propagation** of answers.
  - ◆ do not require the complete set of answers to be found (**partial evaluation** of the **search space**).

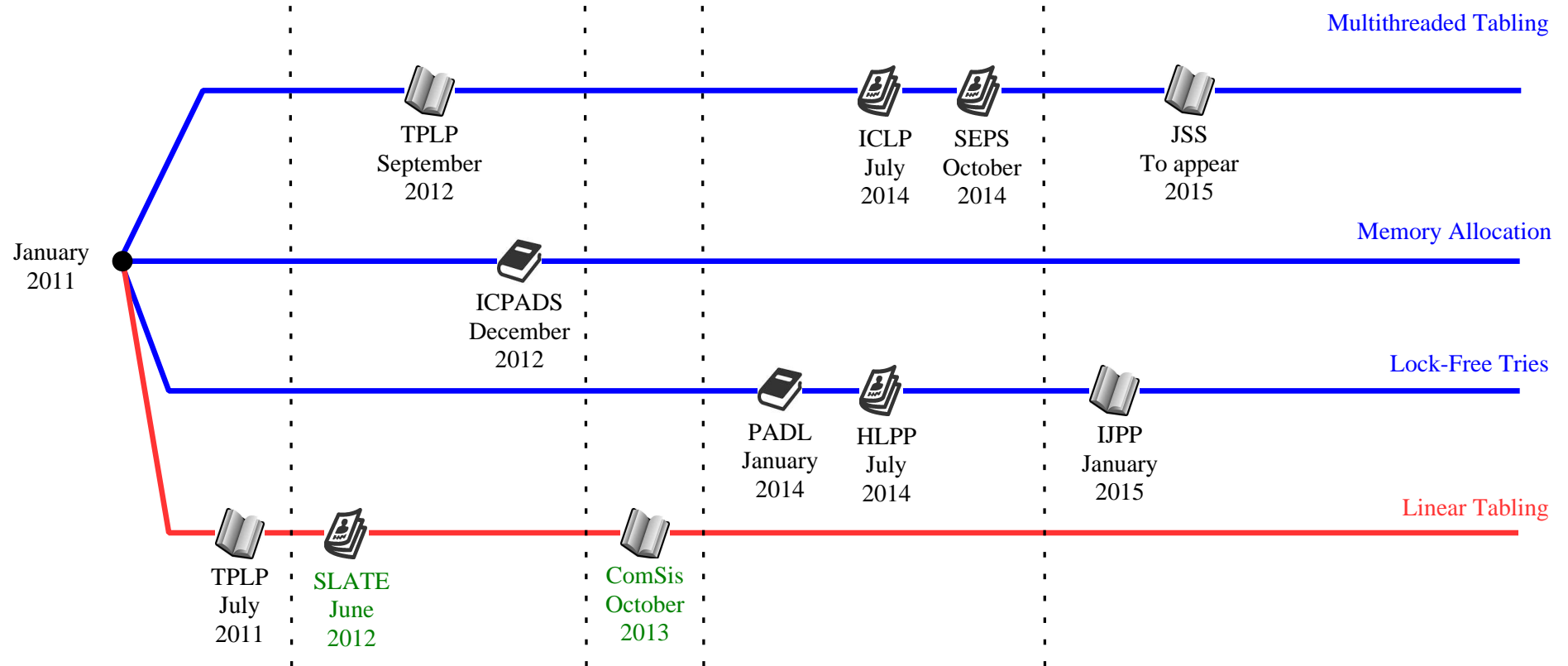
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- We have presented the **PAC (Private Answer Chaining)** strategy that **enables** the **combination** of **batched scheduling** with **Full-Sharing**.
  - ◆ Split's **answers representation (public)** and **answer propagation (private)**.
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- Experimental results showed that the **PAC** strategy is a **good first approach**, however there is still **room for improvement**.
- Further work will include:
  - ◆ Use **timestamped tries** to **avoid** the search for the already propagated answers.
  - ◆ Seek for **new real-world problems** that allow us to improve and consolidate our framework.

# Research Outline



## Work related:



3 Journals



2 Book Series



3 Workshop Proceedings

## Others:



2 Journals

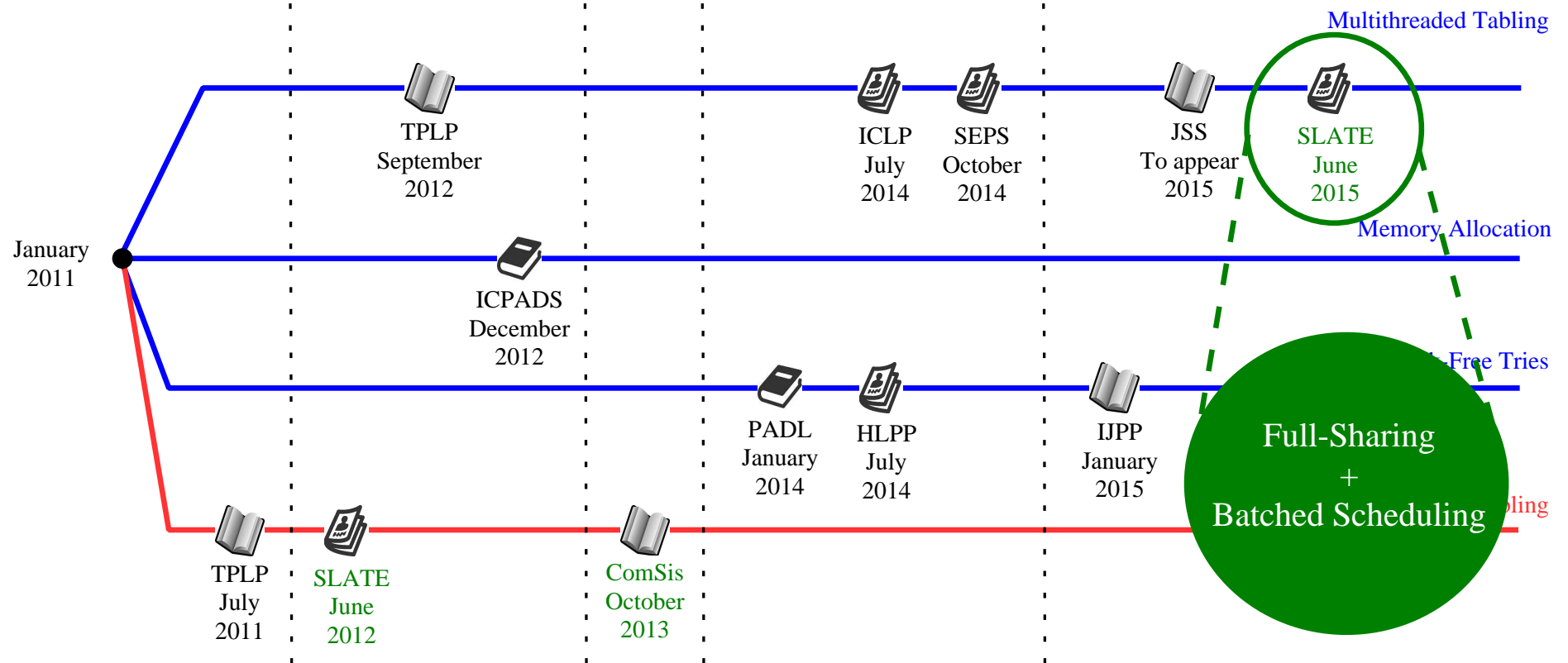


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# Thank You !!!