भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

An Innovative Approach for Achieving Composability in Concurrent Systems using Multi-Version Object Based STMs

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Outline

1. Introduction to STMs
2. Correctness Criteria of STMs
3. Problem with read-write STM
4. Object Based STMs
5. Motivation towards MV-OSTM
6. Correctness of MV-OSTM
7. Conclusion
8. Future Work

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Introduction to STMs

Software Transactional Memory

What is a transaction?

- Sequence of instructions executing in memory.
- Satisfying ACI

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- Execute code optimistically

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Methods of STMs :

- Read
- Write
- TryC

Illustration of STMs methods

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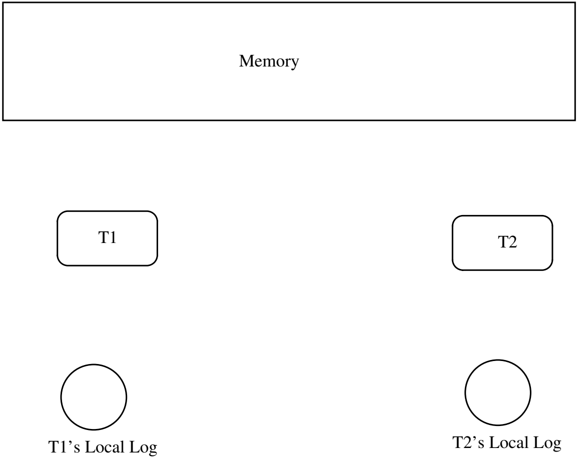
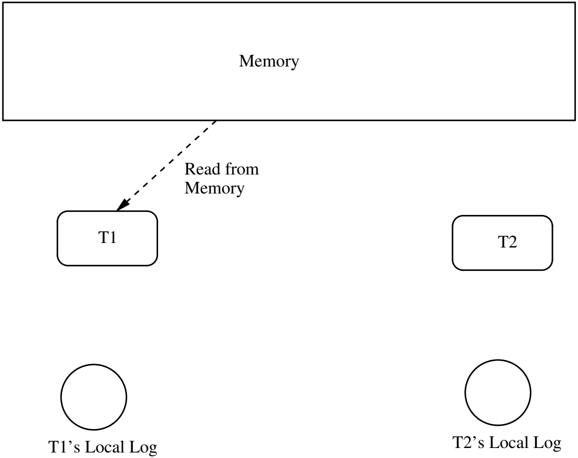


Figure: Working of STM System

Illustration of STMs methods



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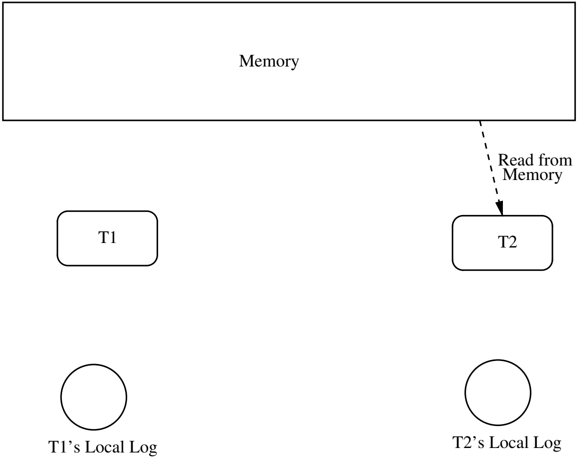

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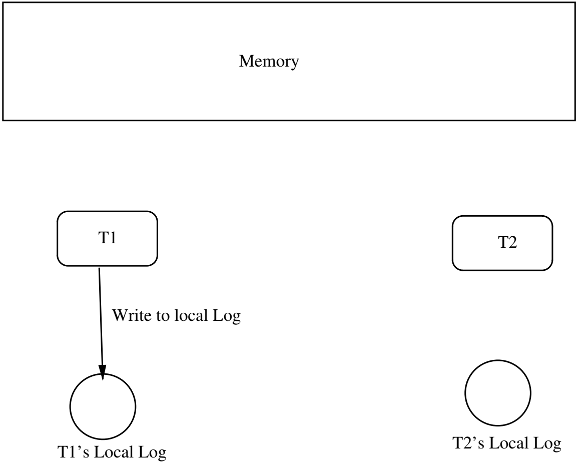

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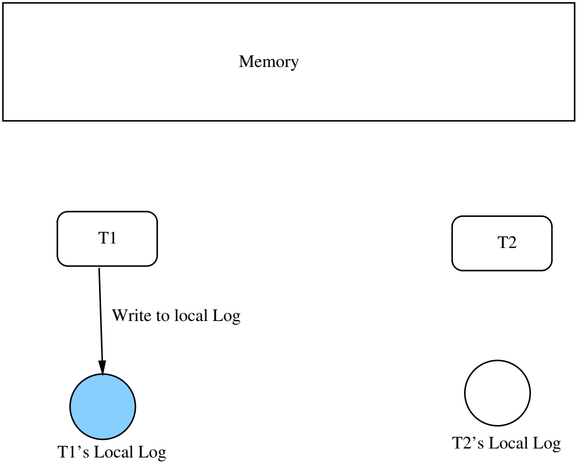

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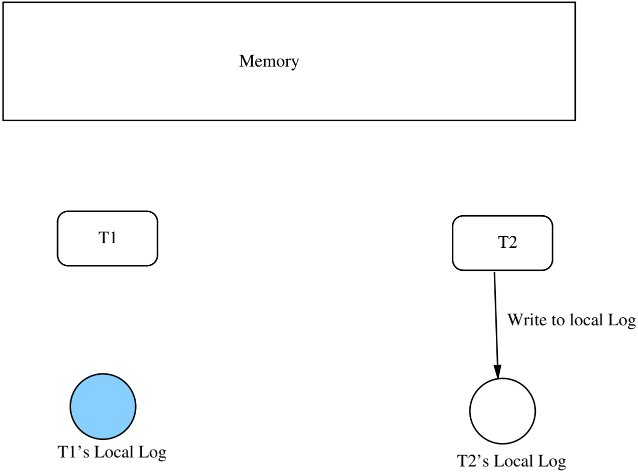

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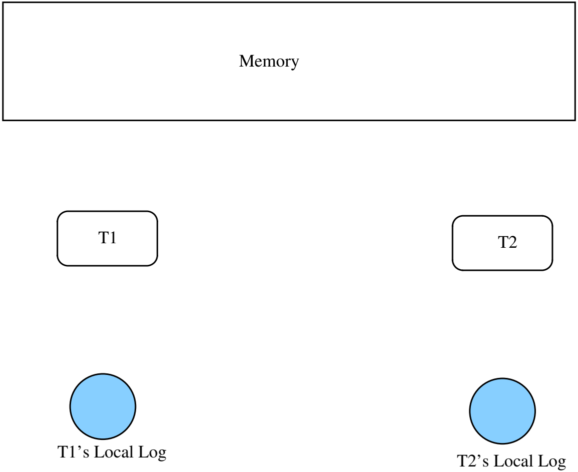

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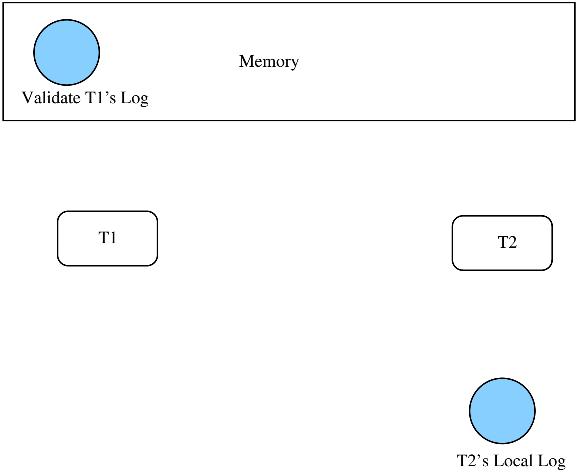

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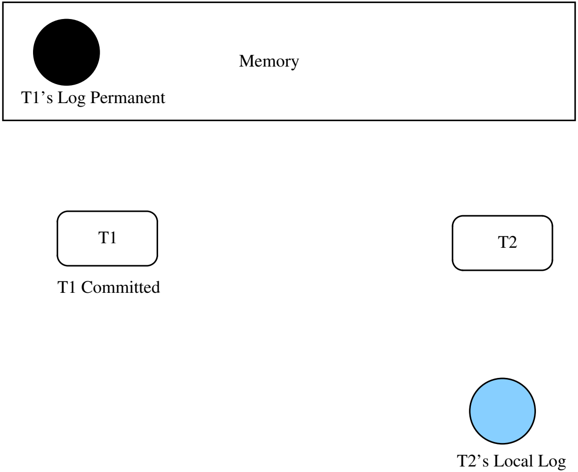

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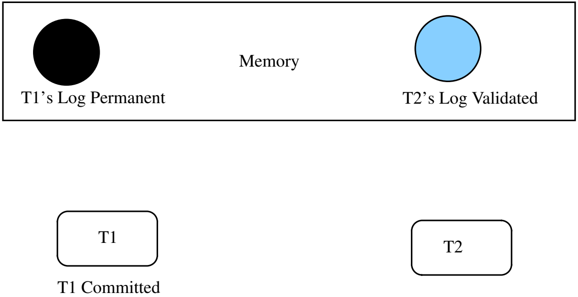

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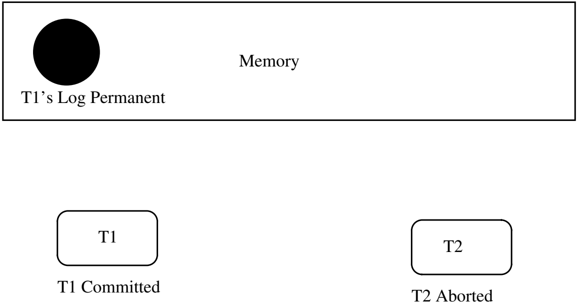

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Correctness of STM System

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Correcness criteria for STMs (Opacity)

- A history H is opaque if there exists a serial history S s.t.
  1. Operations of H and S are same
  2. S respects real time order $\prec_H^{RT}$ and
  3. $\forall$ trans(T_i) $\in$ S are legal in S

Correctness of STM System

Example of opacity

- H: r_1(x,0)w_2(x,10)w_2(y,10)$C_2 r_1$(y,A)A_1

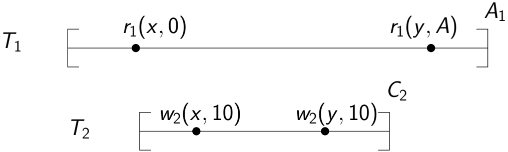

Figure: Opaque History H

Correctness of STM System

Example of opacity

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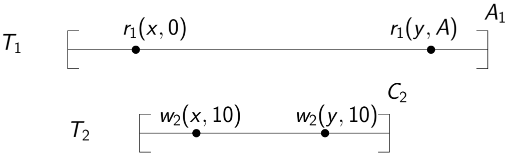

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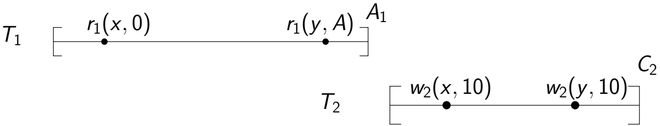

Figure: Equivalent serial history S: T_1, T_2

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Problem with read-write STM

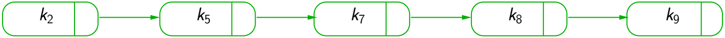


Figure: A sample concurrent object

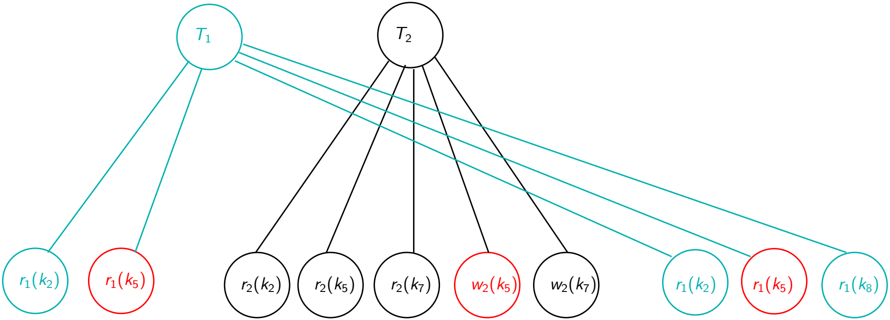
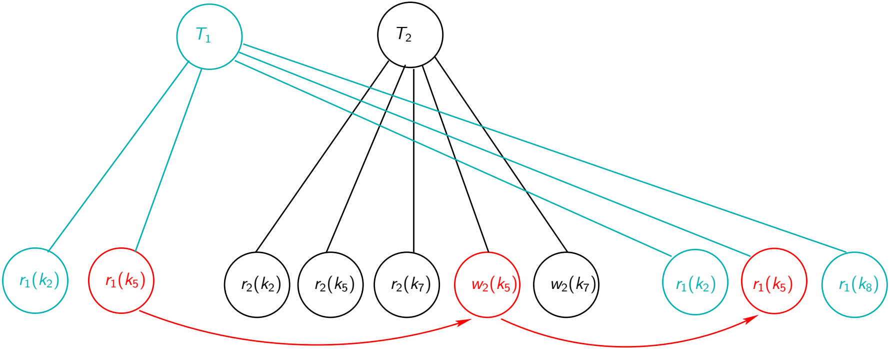


Figure: Tree Structure : conflicts are $(r_1(k_5), w_2(k_5))$ and $(w_2(k_5), r_1(k_5)$

Problem at read-write level



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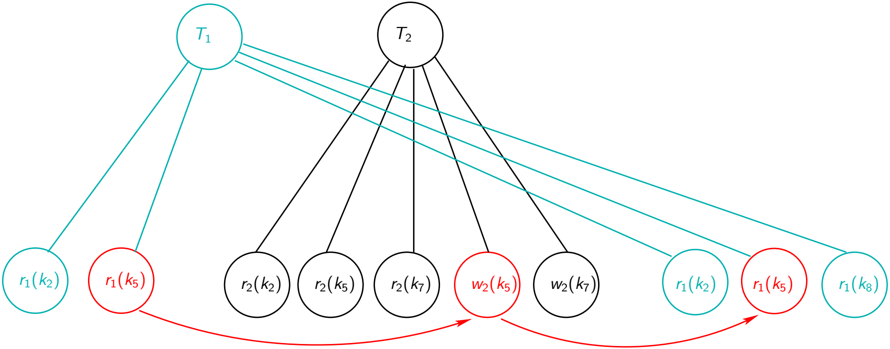

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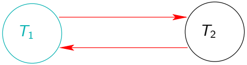

Figure: Cycle (Not Serial)

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OSTM

Introduction

- **Object-based STMs (OSTM)** operate on higher level objects rather than primitive read & writes which act upon memory locations.

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- OSTM model can adapted:
    - OSTM for stacks may export *t_push*, *t_pop* & *t_peek*.
    - OSTM for sets may export *t_begin(), t_insert(), t_del(), t_lookup() and tryC()*.

OSTM

Execution at layer-1

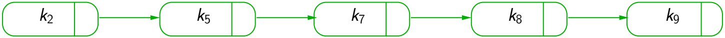


Figure: A sample representing a OSTM object

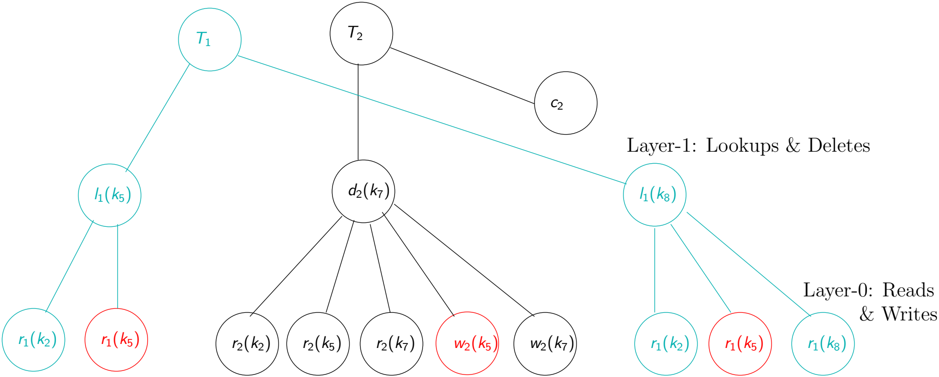


Figure: Tree Structure : no conflict at Layer-1

OSTM

Execution at layer-1

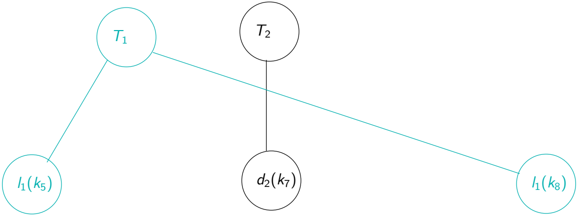
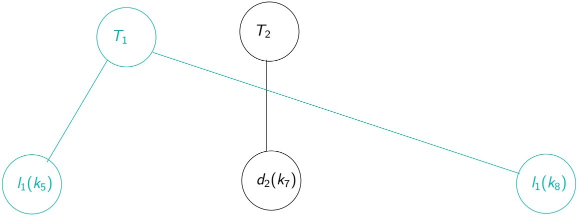


Figure: Pruned Tree

OSTM

Execution at layer-1



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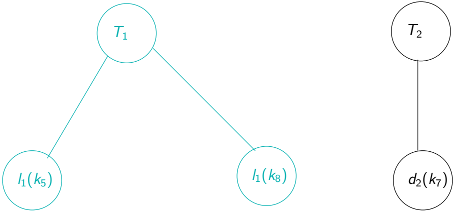
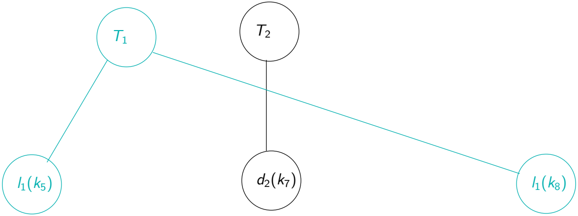


Figure: Sequential Schedule

OSTM

Execution at layer-1



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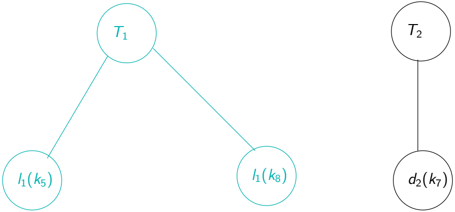

Figure: Sequential Schedule

Figure: Serial History

OSTM

Problem with OSTM

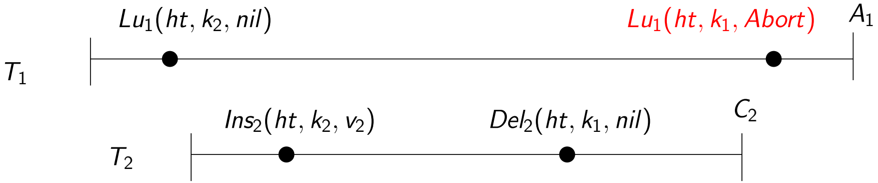

Figure: Single version OSTM

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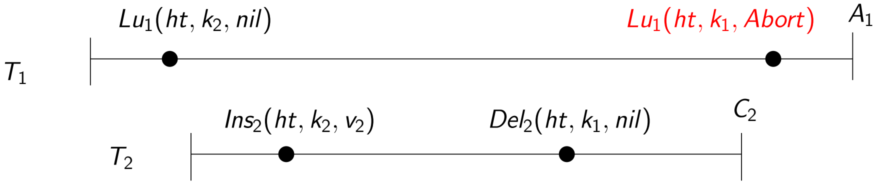
Proposed Algorithm : MV-OSTM

Advantages of multi-version over single version OSTM



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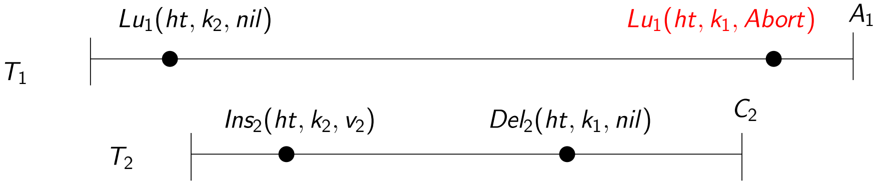

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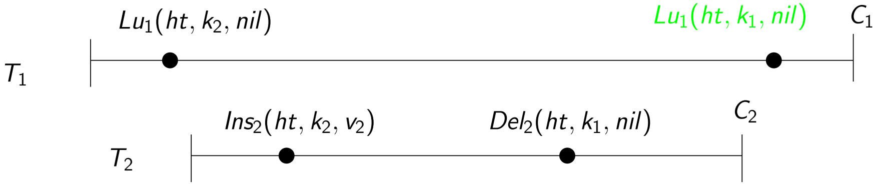
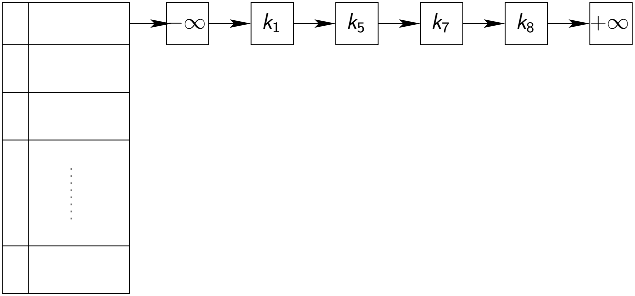


Figure: Multi-version OSTM (MV-OSTM) : (T_1, T_2)

Proposed Algorithm : MV-OSTM

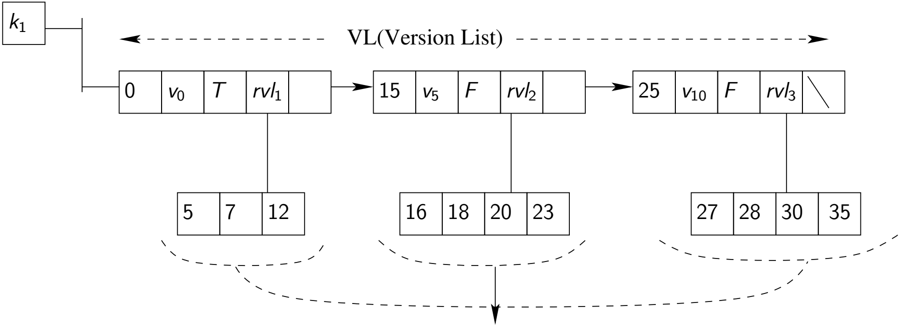
Illustration of data structure



a) Underlying DS

Proposed Algorithm : MV-OSTM

Illustration of data structure cont'd..



RVL(Return Value List)

b) DS for maintaining Versions

Proposed Algorithm : MV-OSTM

Lookup method

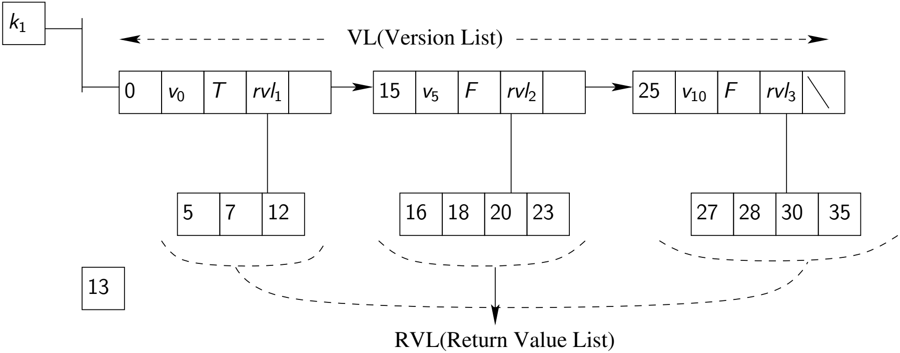


Figure: Lookup on key k_1 by T_{13}

Proposed Algorithm : MV-OSTM

Lookup method cont'd..

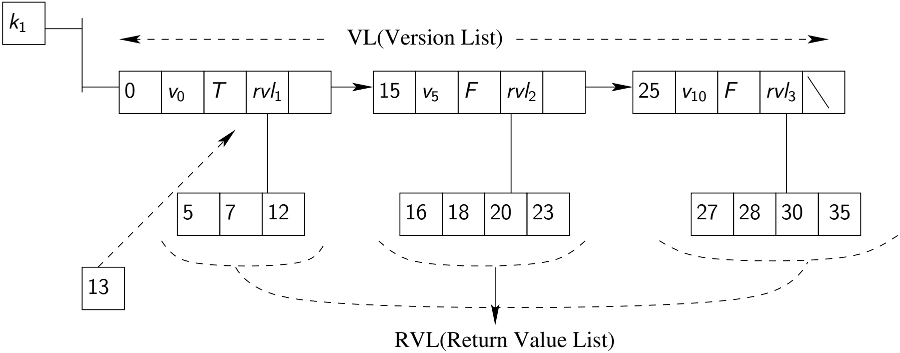


Figure: T_{13} searching appropriate place in version list of k_1

Proposed Algorithm : MV-OSTM

Lookup method cont'd..

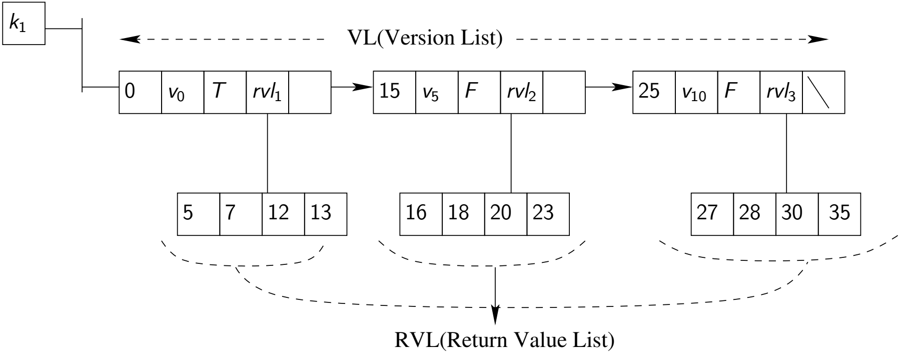


Figure: T_{13} successfully added into rvl_1

Proposed Algorithm : MV-OSTM

tryC : Insert method

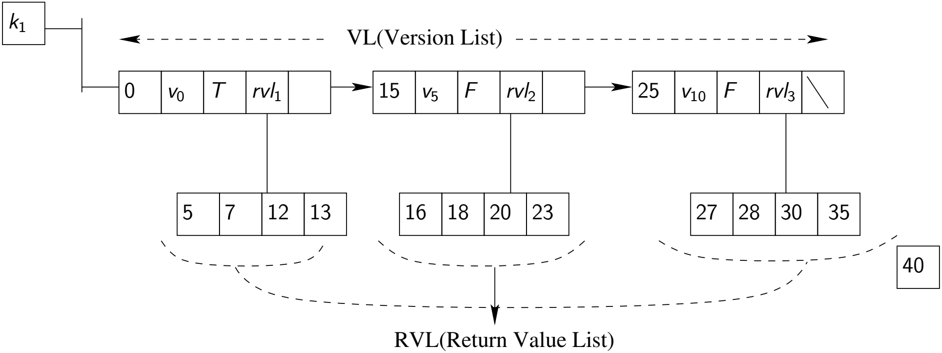
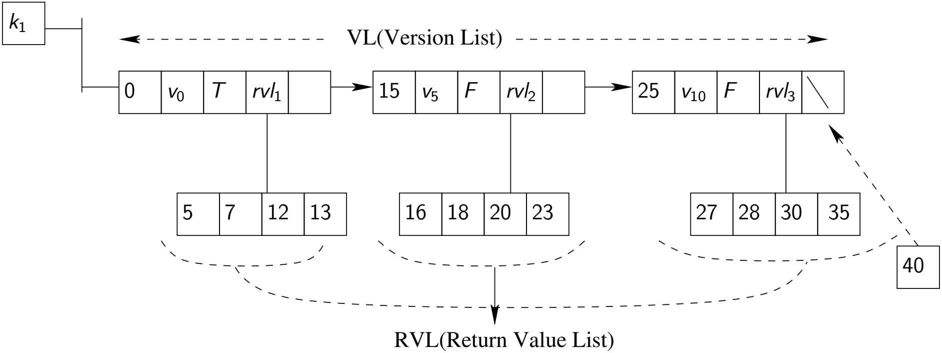


Figure: Insert a version of key k_1 by T_{40}

Proposed Algorithm : MV-OSTM

tryC : Insert method cont'd..



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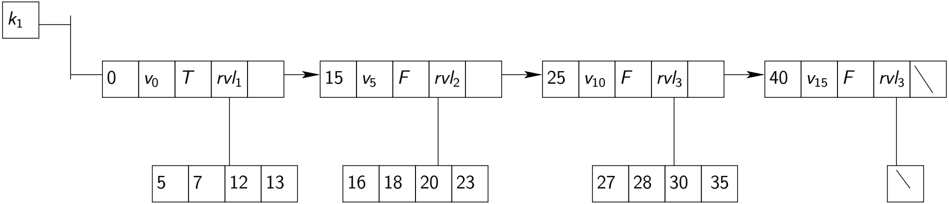

Figure: T_{40} successfully created a new version of k_1

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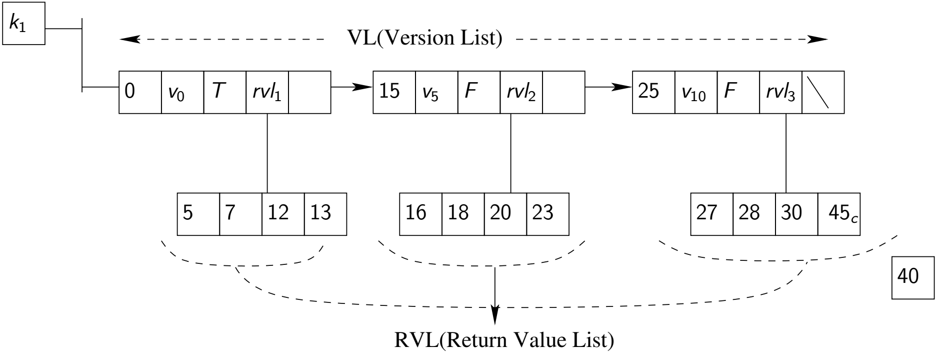
tryC : Insert method cont'd..



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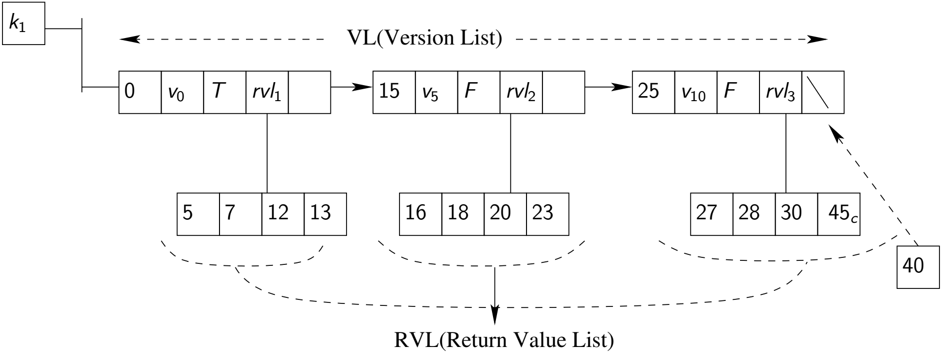

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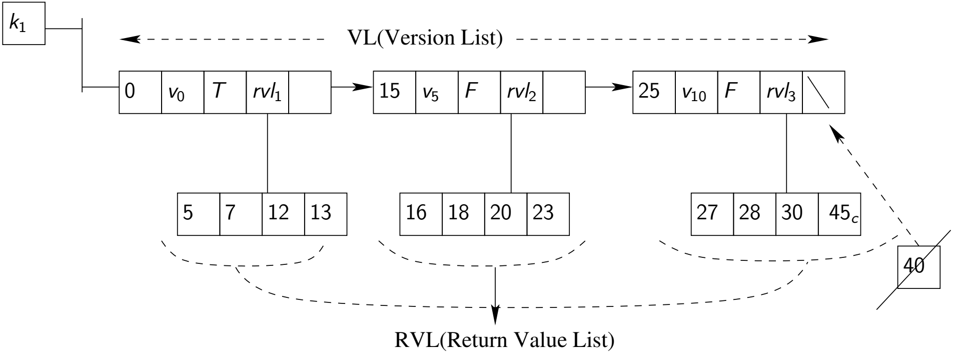

Figure: Abort T_{40} : T_{45} committed before T_{40}

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Correctness of MV-OSTM

Theorem

Any history H generated by MV-OSTM algorithm with a given version order $\ll$, if $OPG(H, \ll)$ is acyclic, then H is opaque.

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- Transactions are *composable [Harris et.al, 2005]*, *[Ziv et.al, 2015]*.

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- Nesting : open *[Yang et.al, 2007]* and close.

References

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Thank You!

Any Questions?