Locking for Concurrent Transactions on Ontologies

Stefan Scheglmann, Steffen Staab, Matthias Thimm
and Gerd Groener

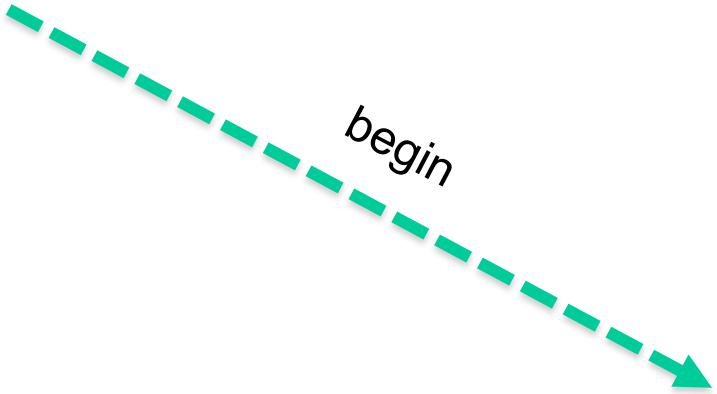
Definition

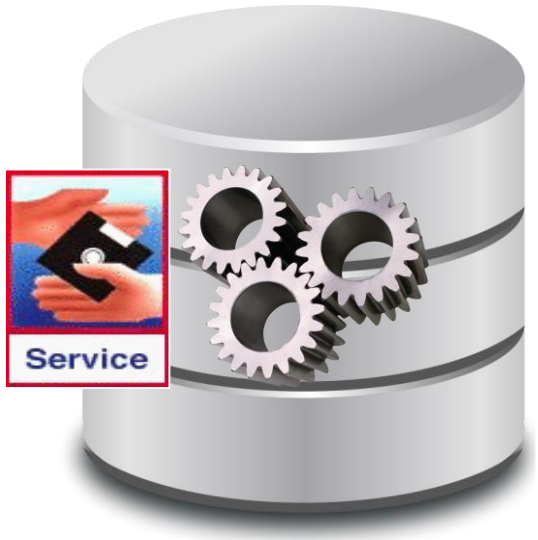
Definition

Definition:

Transaction

- begin of transaction





Definition

Definition:

Transaction

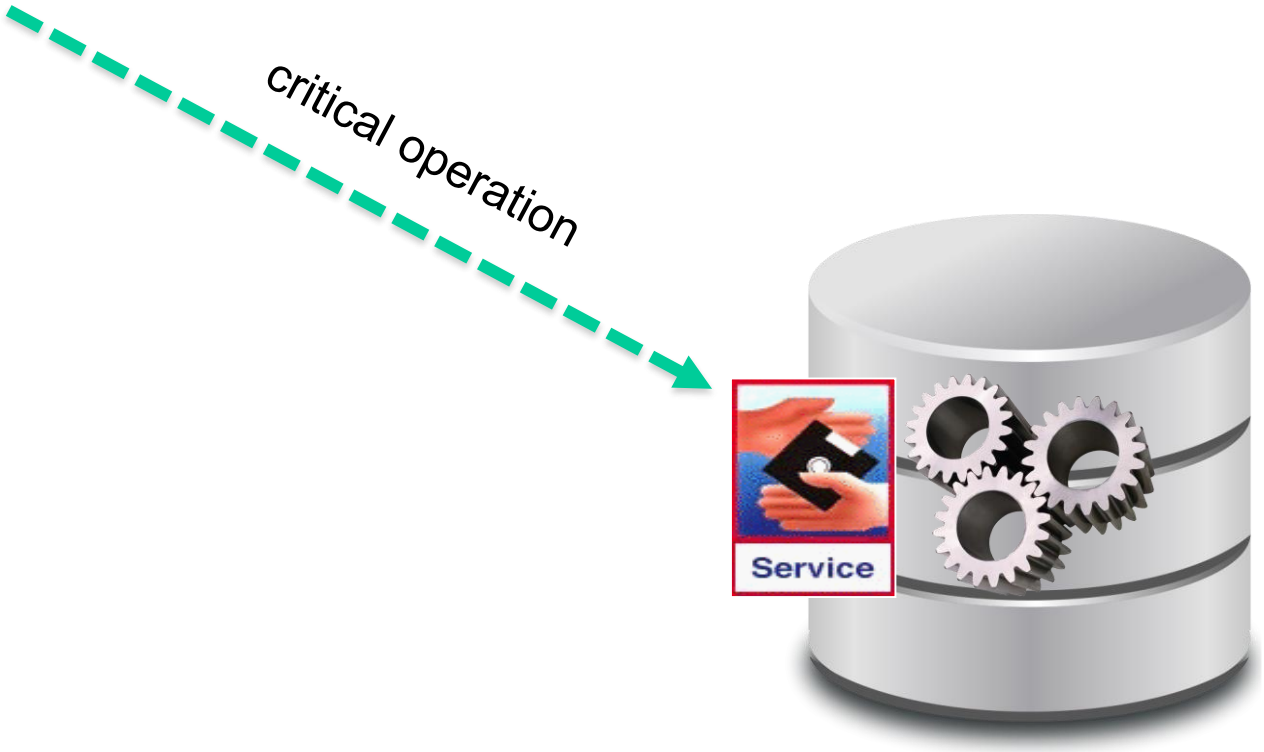
- begin of transaction
- sequence of operations

Definition

Definition:

Transaction
- begin of transaction
- sequence of operations

Critical Operations
- tell
- forget
- ask



Definition

Definition:

Transaction
- begin of transaction
- sequence of operations

Critical Operations
- tell
- forget
- ask

Non-critical operation
- user input
- response
- etc

Definition

Definition:

Transaction
- begin of transaction
- sequence of operations
- end of transaction

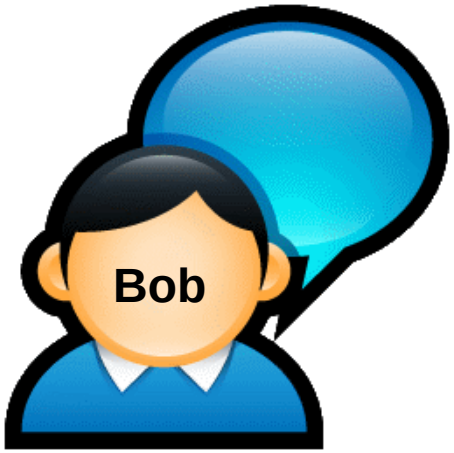
Critical Operations
- tell
- forget
- ask

end

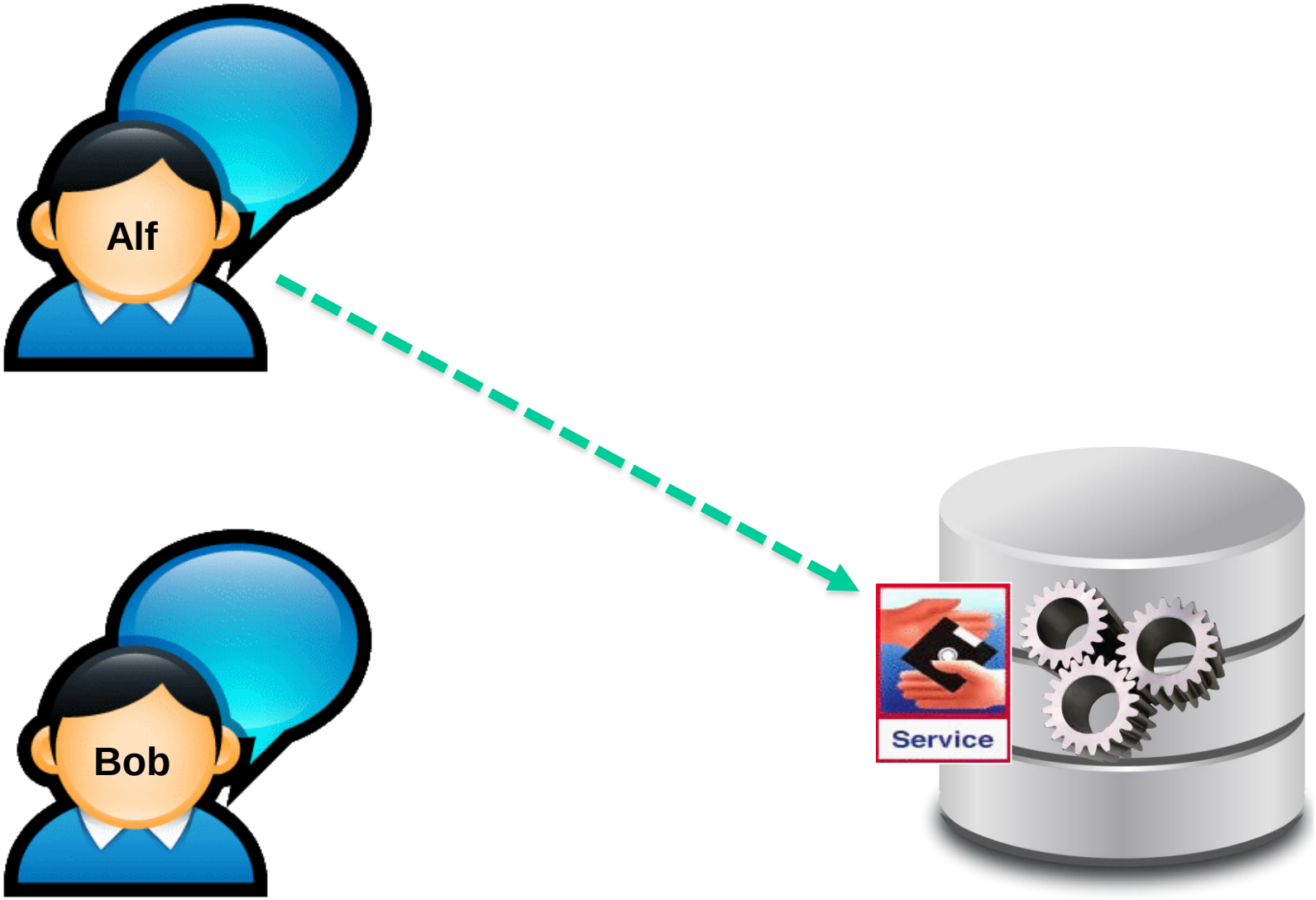
Non-critical operation
- user input
- response
- etc

Setting

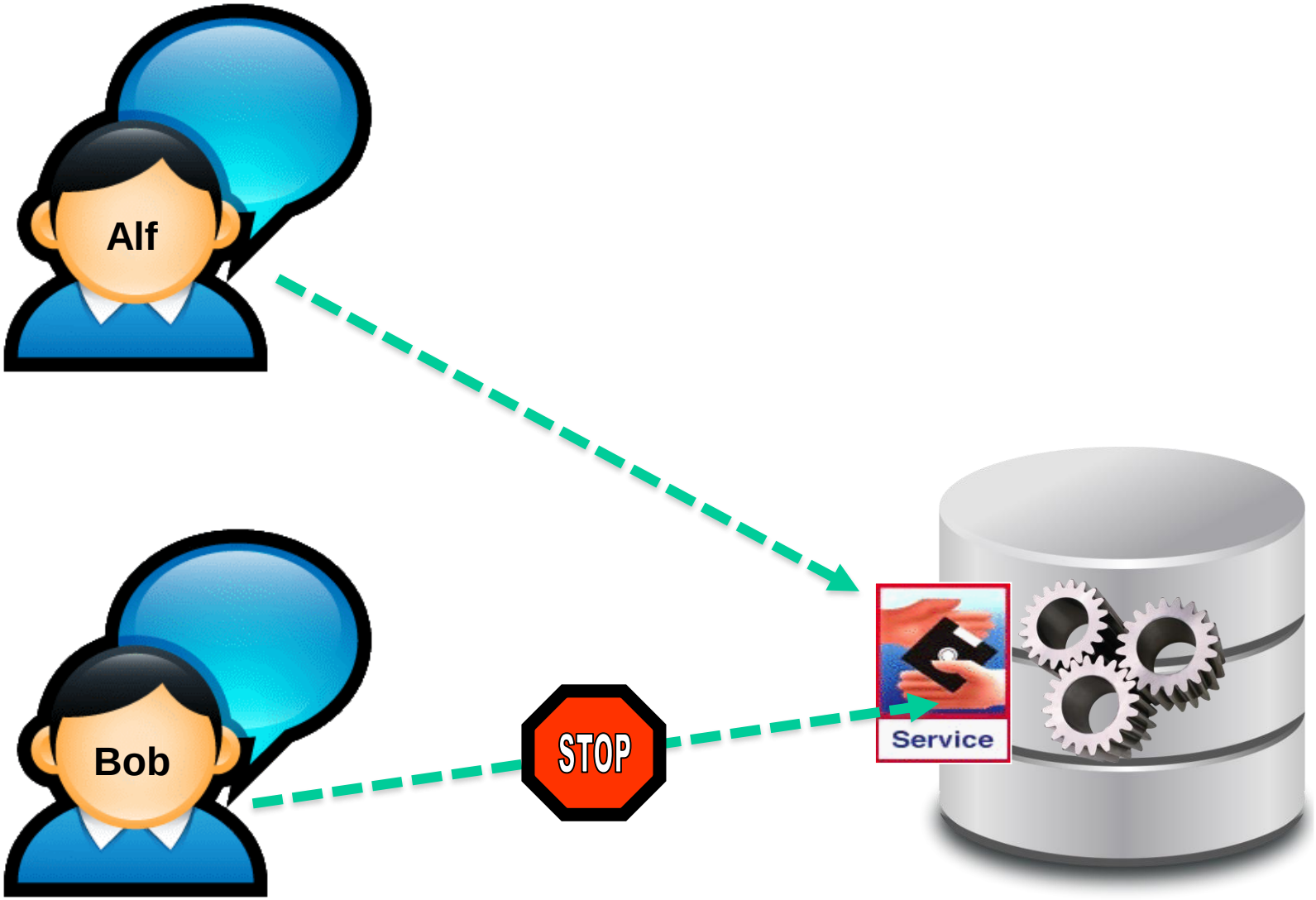
Setting



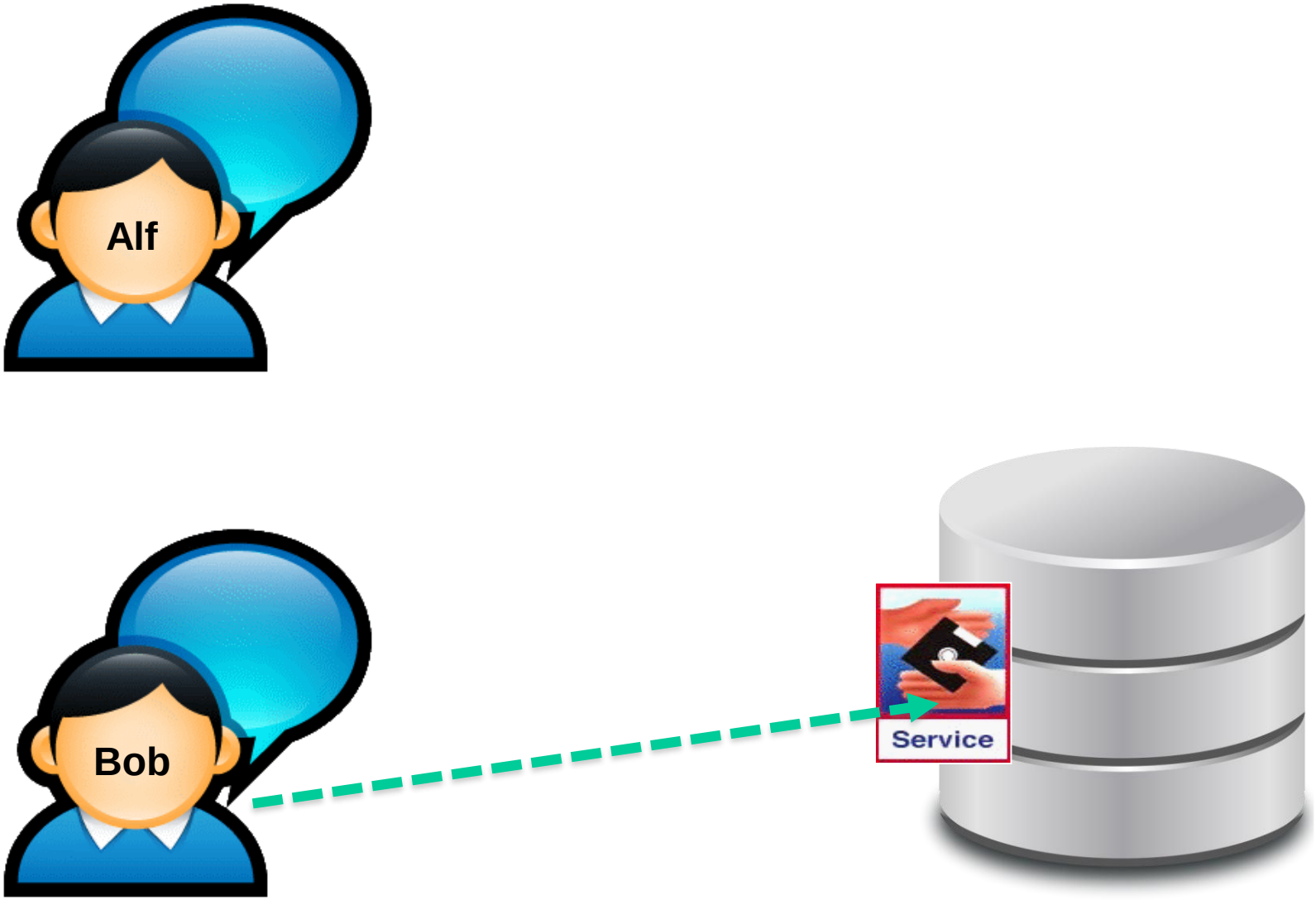
Setting



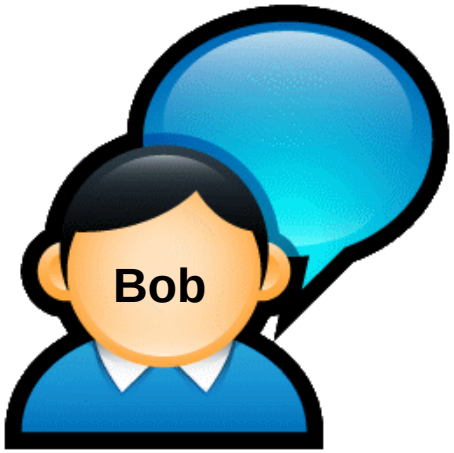
Setting



Setting



Setting

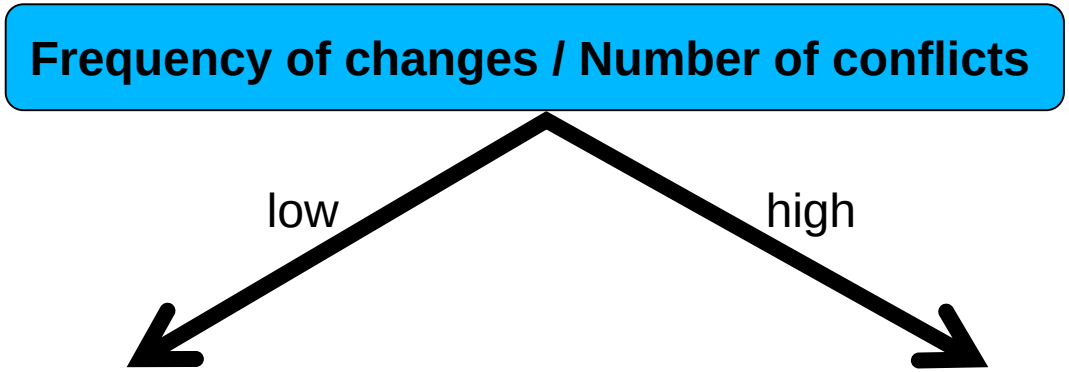


Problem Dimensions

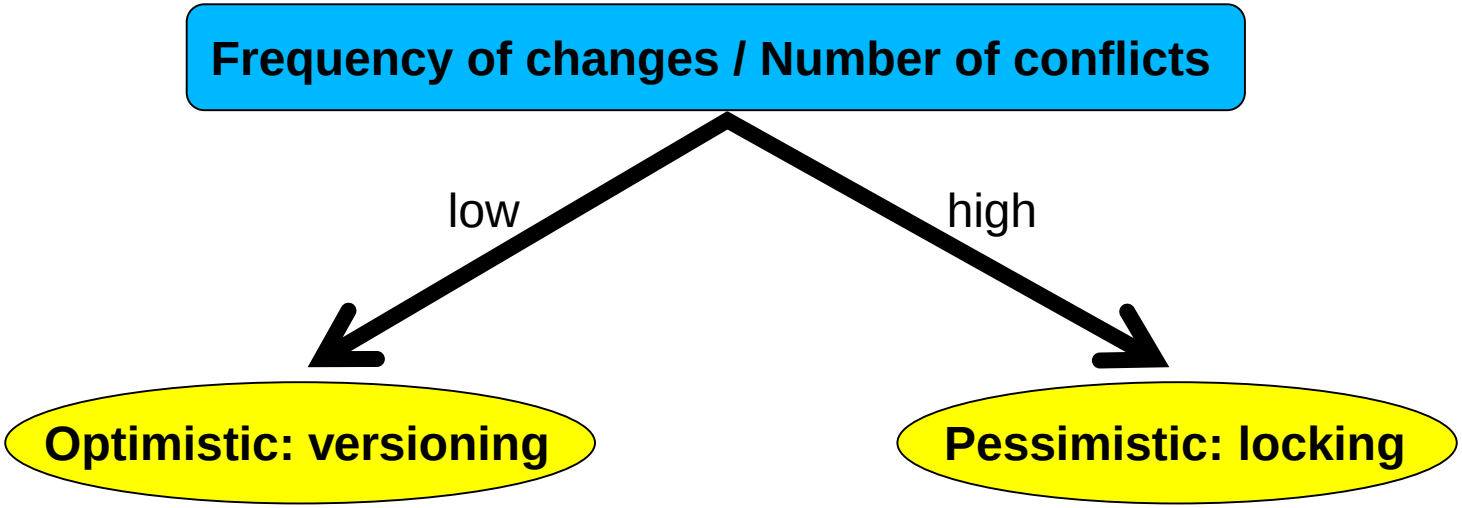
Problem Dimensions

Frequency of changes / Number of conflicts

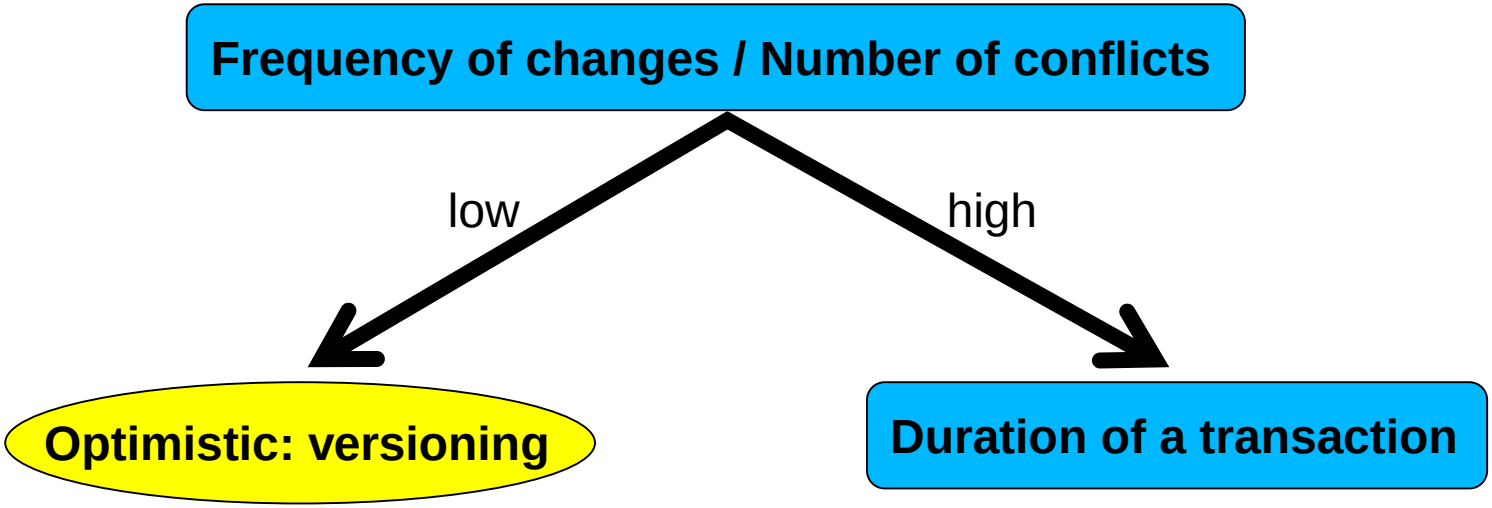
Problem Dimensions



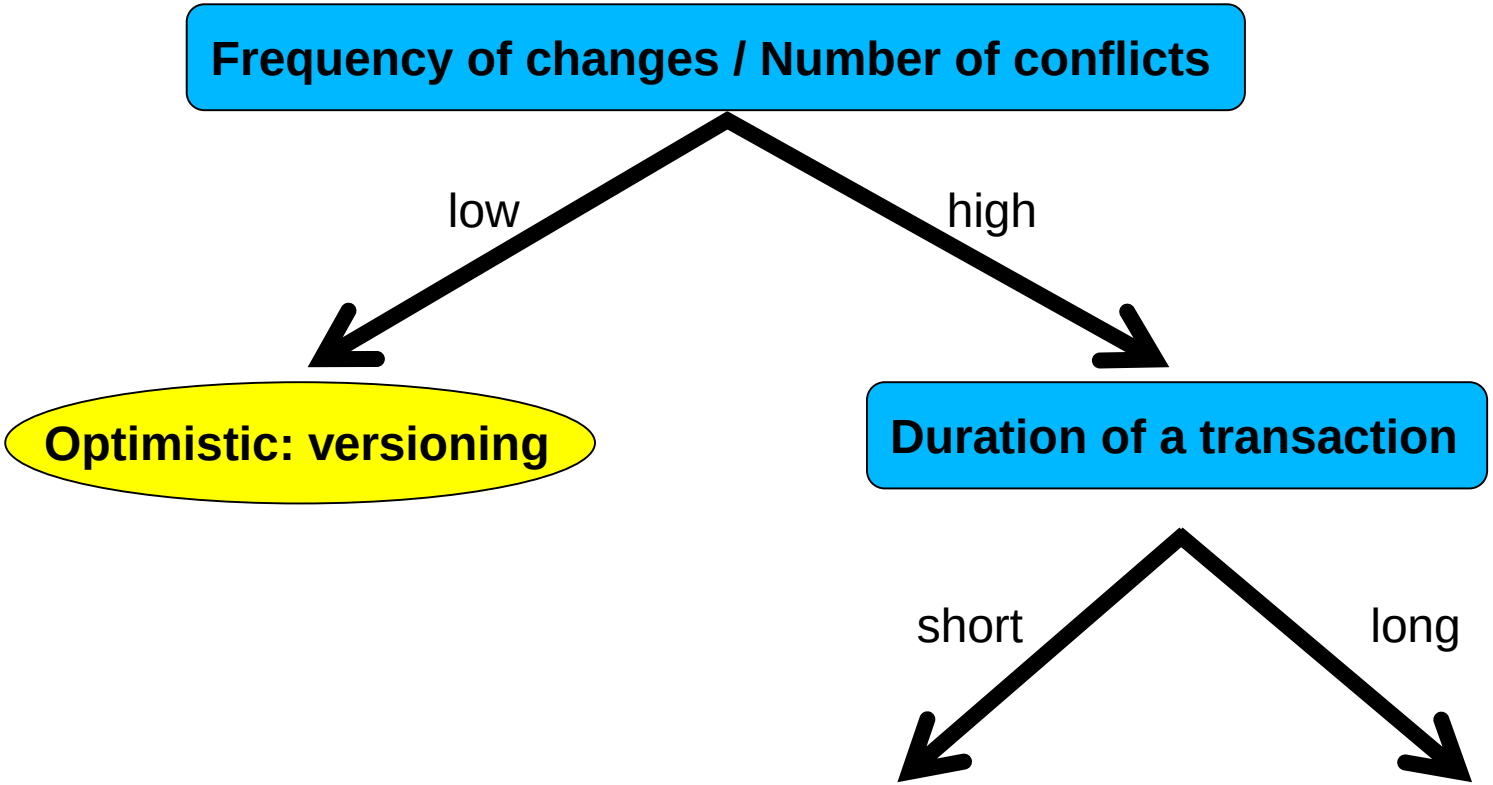
Problem Dimensions



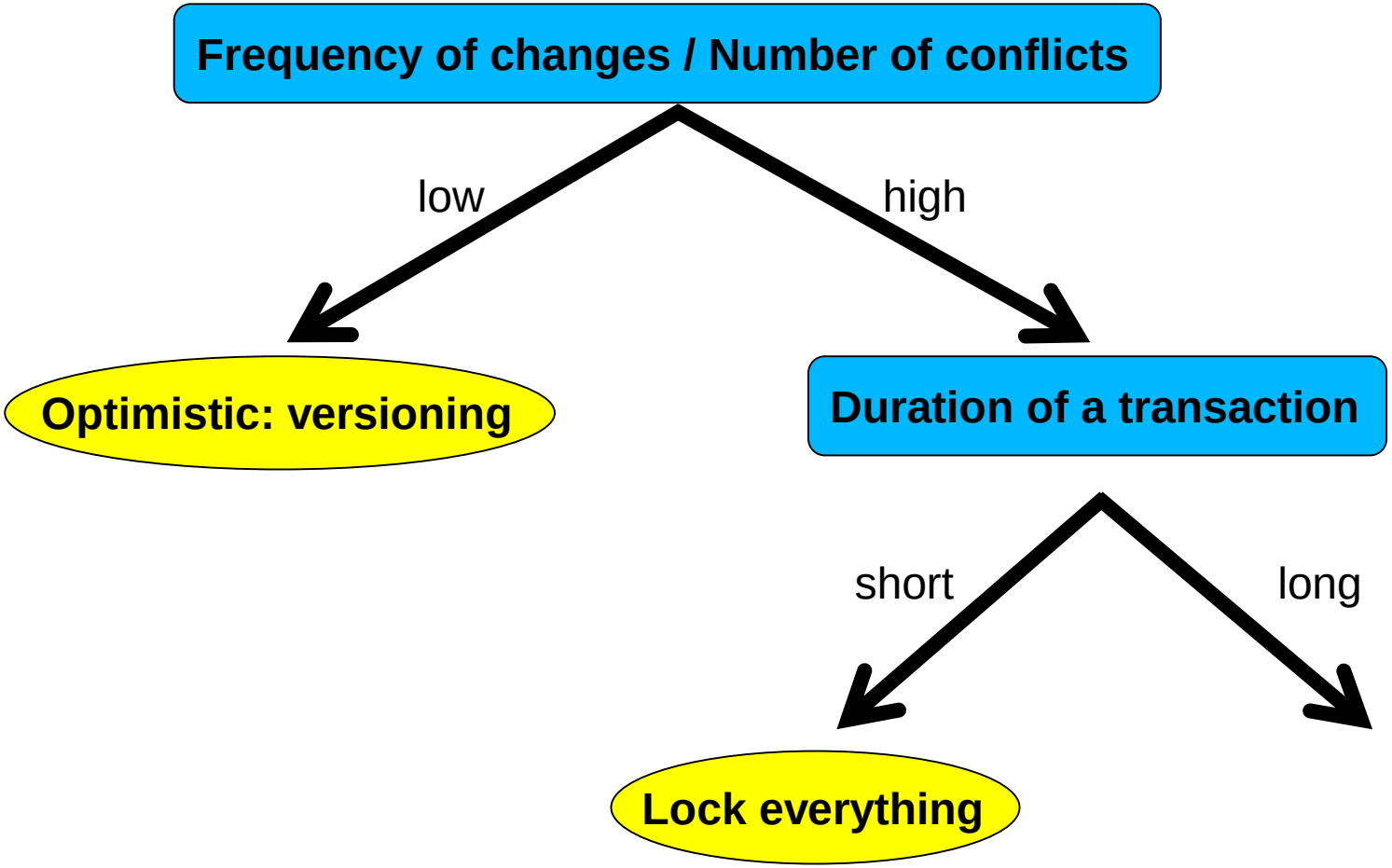
Problem Dimensions



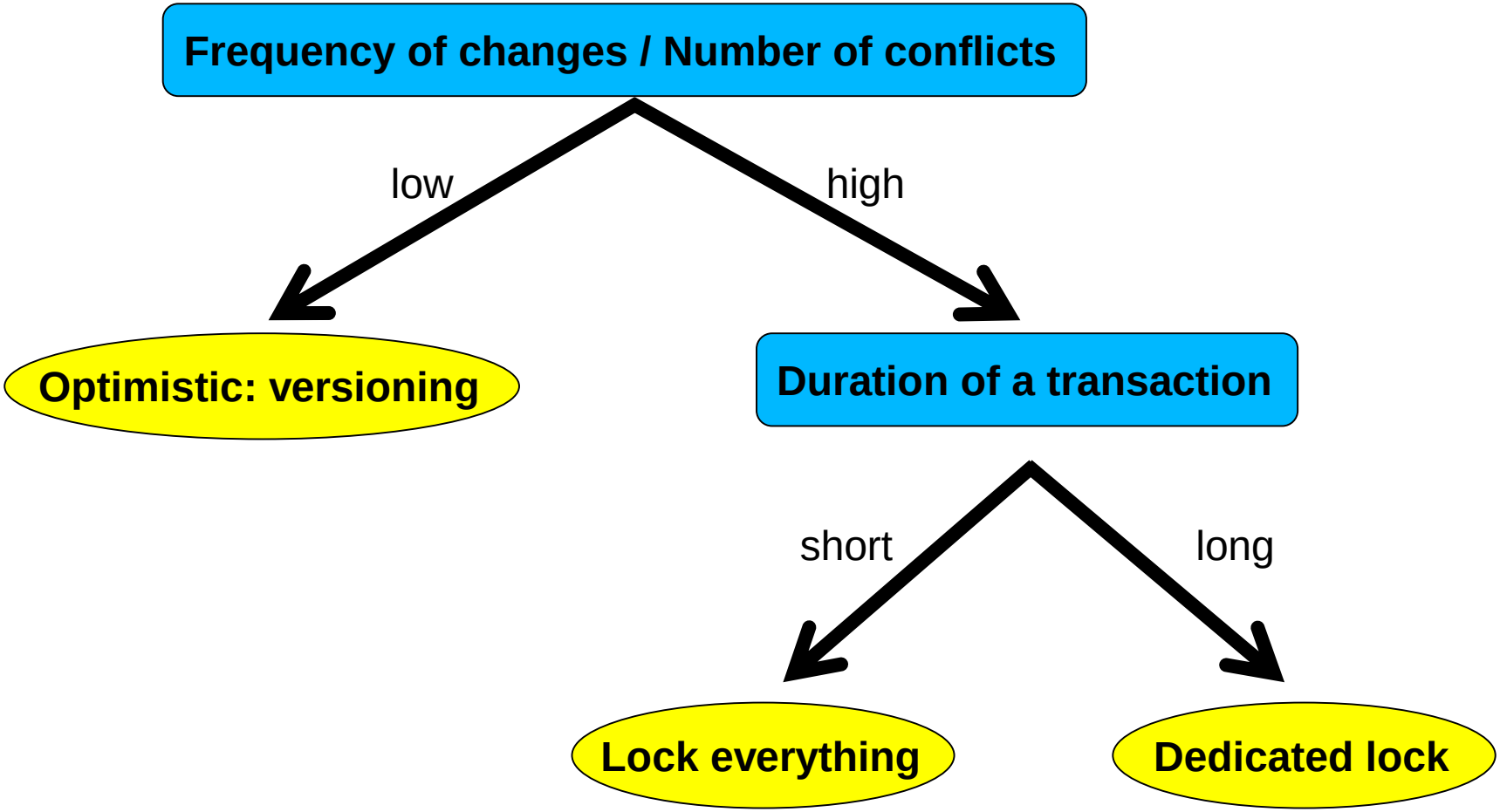
Problem Dimensions



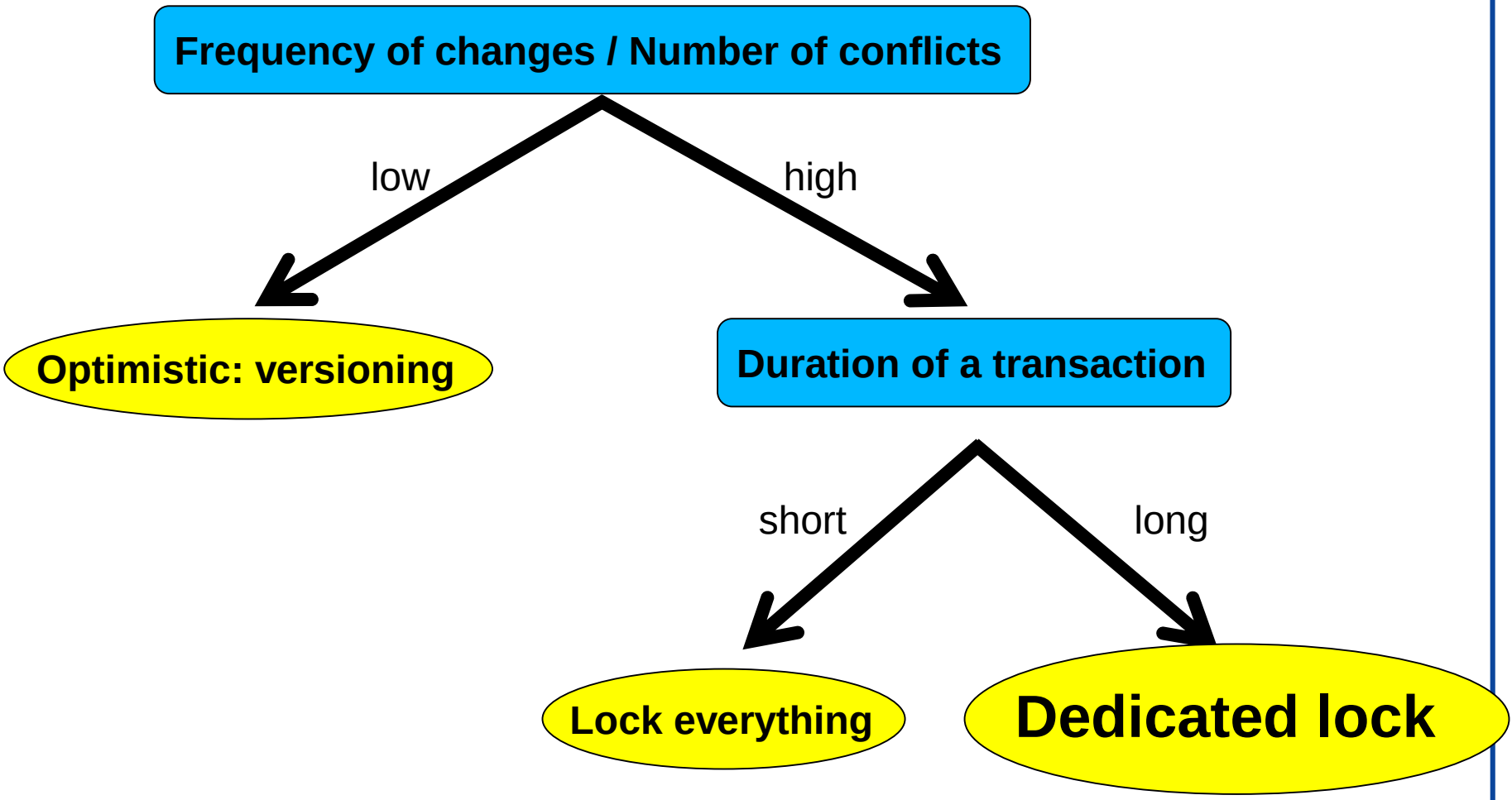
Problem Dimensions



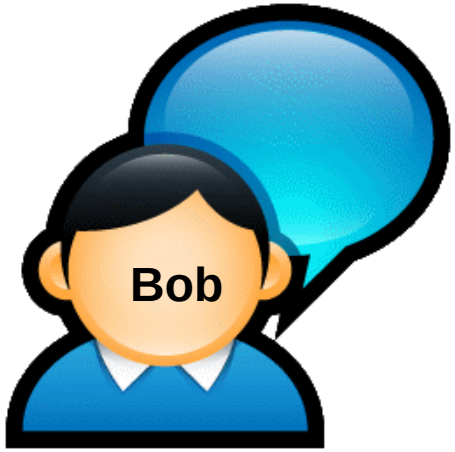
Problem Dimensions

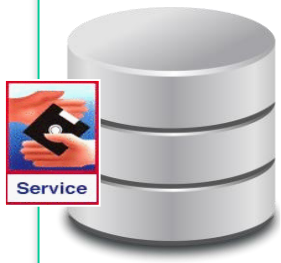


Problem Dimensions



Problem





$A_1 \equiv \forall R.D_1$

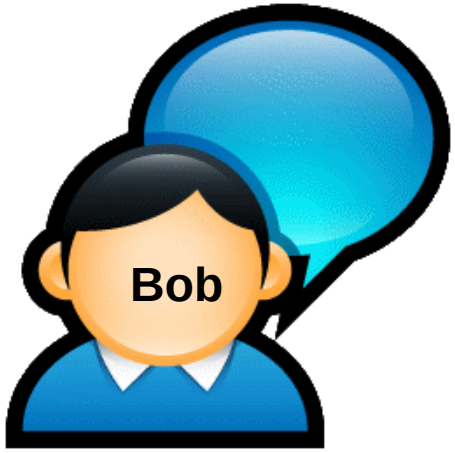
$A_2 \equiv \forall R.D_2$

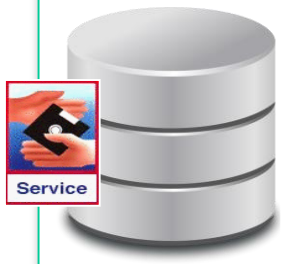
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Problem





$A_1 \equiv \forall R.D_1$

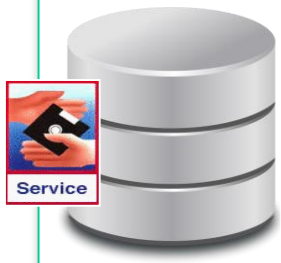
$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Problem



$A_1 \equiv \forall R.D_1$

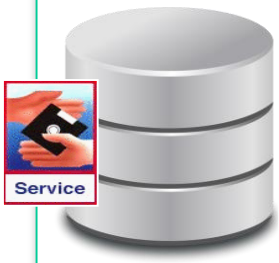
$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Problem



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

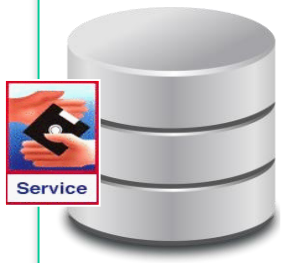
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf **Before** **Bob**

Problem

forget($B \subseteq D_1$), tell($B \subseteq D_2$)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

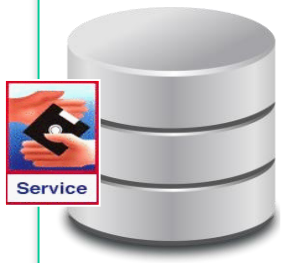
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf **Before** **Bob**

Problem

$forget(B \subseteq D_1), tell(B \subseteq D_2)$



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

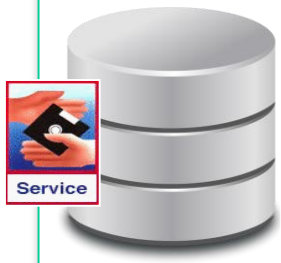
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

Alf **Before** **Bob**

Problem

$forget(B \subseteq D_1), tell(B \subseteq D_2)$



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

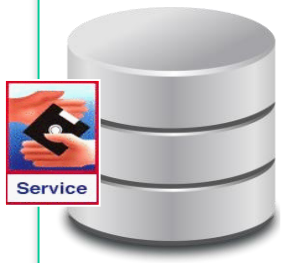
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

Alf **Before** **Bob**

Problem



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

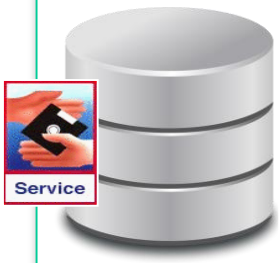
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

Alf **Before** **Bob**

Problem

ask(A ⊆ ⊥X)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

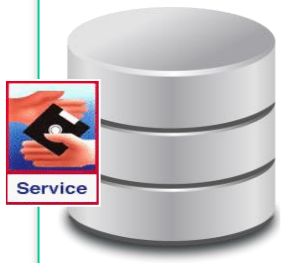
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

Alf **Before** **Bob**

Problem



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

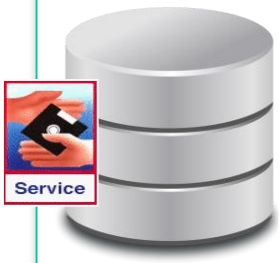
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

Alf **Before** **Bob**

Problem



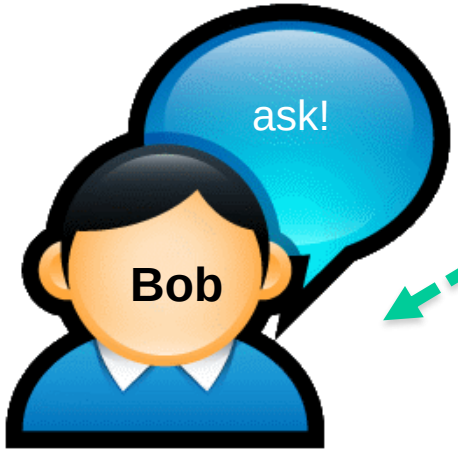
$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \sqsubseteq \forall R.B$

$D_1 \sqcap D_2 \equiv \bot$

$B \sqsubseteq D_2$

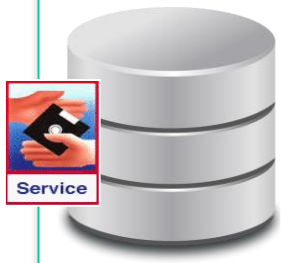


$A \sqsubseteq A_2$

Alf **Before** **Bob**

$A \sqsubseteq A_2 \sqsubseteq T$

Intermediate



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

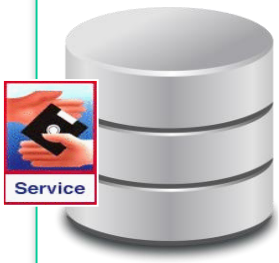
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf **Before** **Bob**

$A \subseteq A_2 \subseteq T$

Intermediate



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

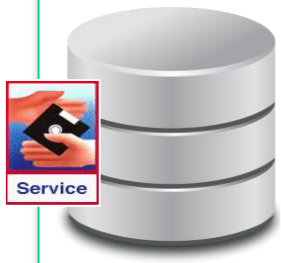
$B \subseteq D_1$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$

Intermediate

forget($B \subseteq D_1$)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

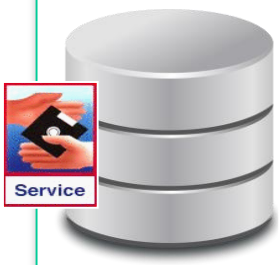
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$

Intermediate



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

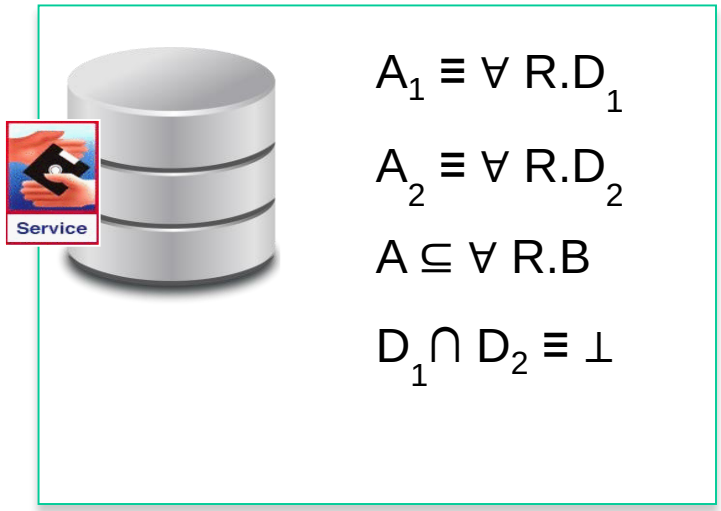
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$

Intermediate

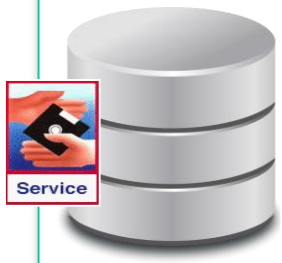


Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$

Intermediate

ask(A ⊆ ⊥X)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

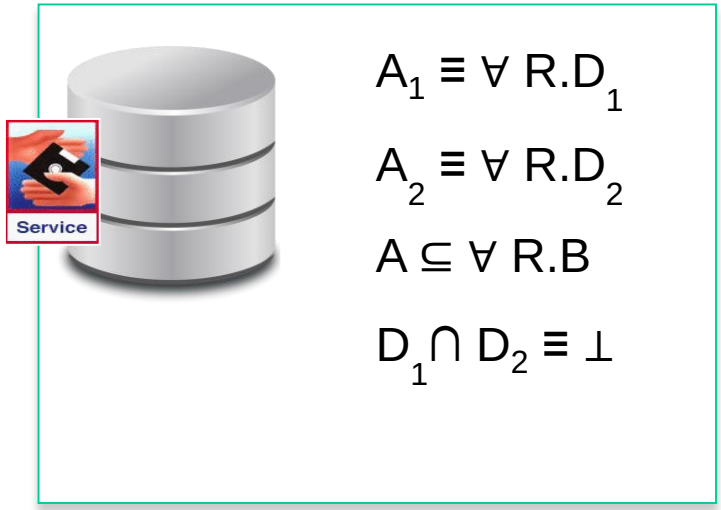
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$

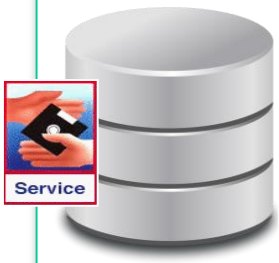
Intermediate



Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$

Intermediate

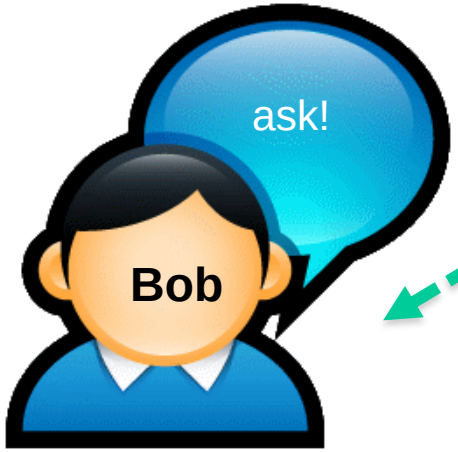


$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \sqsubseteq \forall R.B$

$D_1 \sqcap D_2 \equiv \bot$

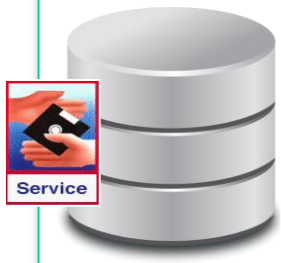


$A \sqsubseteq T$

Alf Before **Interleaved** **Bob**

$A \sqsubseteq A_2 \sqsubseteq T$ $A \sqsubseteq T$

Intermediate



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

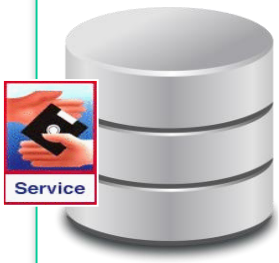
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$ $A \subseteq T$

Intermediate



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

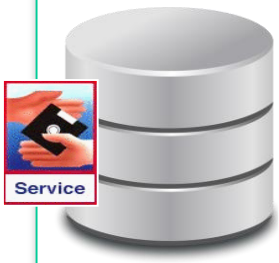
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$ $A \subseteq T$

Intermediate



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

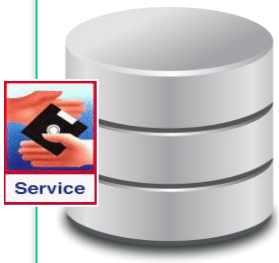
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$ $A \subseteq T$

Intermediate



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

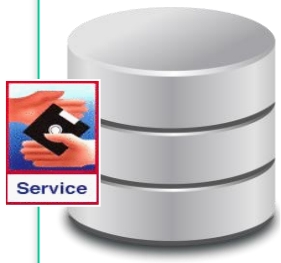
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$ $A \subseteq T$

After



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

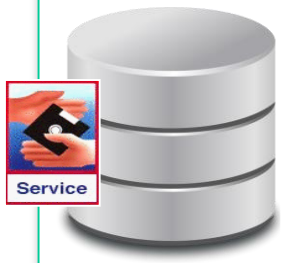
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf Before **Interleaved** **Bob**

$A \subseteq A_2 \subseteq T$ $A \subseteq T$

After



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

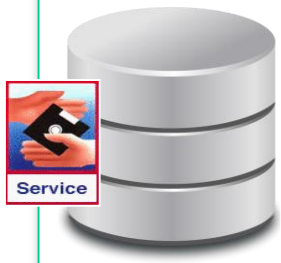
$B \subseteq D_1$

Alf Before Interleaved **After** **Bob**

$A \subseteq A_2 \subseteq T$ $A \subseteq T$

After

ask(A ⊆ ⊥X)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

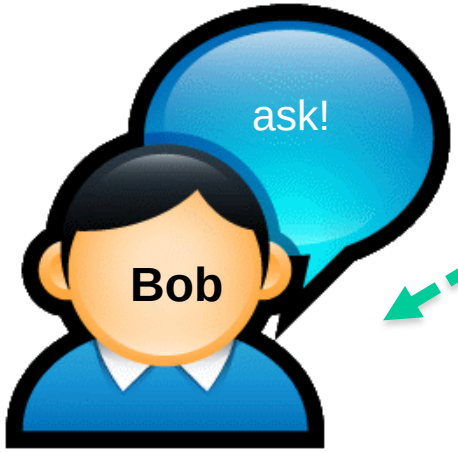
$D_1 \cap D_2 \equiv \bot$

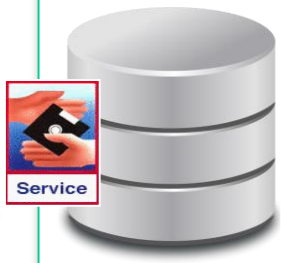
$B \subseteq D_1$

Alf Before Interleaved **After** **Bob**

$A \subseteq A_2 \subseteq T$ $A \subseteq T$

After





$A \subseteq A_1$

$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

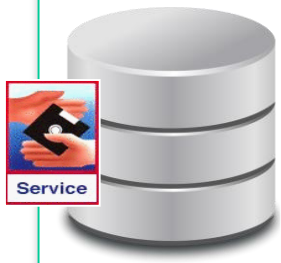
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf	Before	Interleaved	**After**	**Bob**
	$A \subseteq A_2 \subseteq T$	$A \subseteq T$	$A \subseteq A_1 \subseteq T$	

After



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

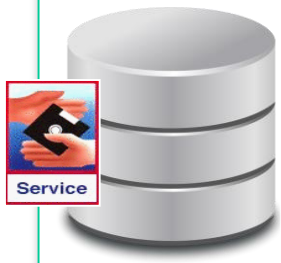
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf	Before	Interleaved	**After**	**Bob**
	$A \subseteq A_2 \subseteq T$	$A \subseteq T$	$A \subseteq A_1 \subseteq T$	

After

forget($B \subseteq D_1$), tell($B \subseteq D_2$)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

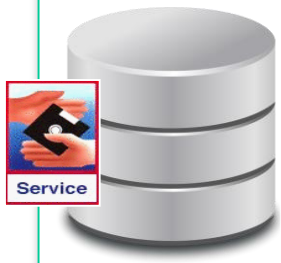
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

Alf	Before	Interleaved	**After**	**Bob**
	$A \subseteq A_2 \subseteq T$	$A \subseteq T$	$A \subseteq A_1 \subseteq T$	

After

$forget(B \subseteq D_1)$, $tell(B \subseteq D_2)$



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

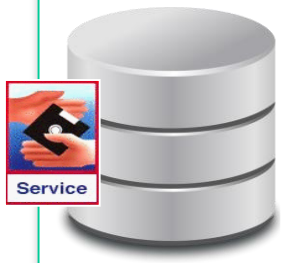
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

Alf	Before	Interleaved	**After**	**Bob**
	$A \subseteq A_2 \subseteq T$	$A \subseteq T$	$A \subseteq A_1 \subseteq T$	

After

forget($B \subseteq D_1$), tell($B \subseteq D_2$)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

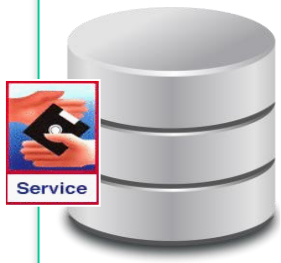
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

Alf	Before	Interleaved	**After**	**Bob**
	$A \subseteq A_2 \subseteq T$	$A \subseteq T$	$A \subseteq A_1 \subseteq T$	

After



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

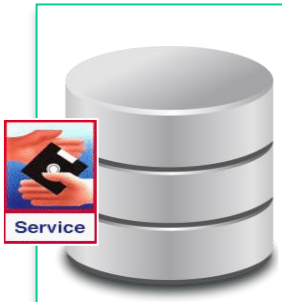
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

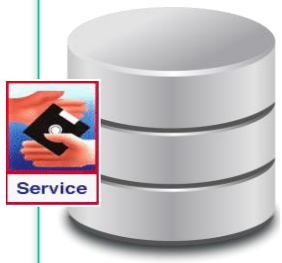
Alf	Before	Interleaved	**After**	**Bob**
	$A \subseteq A_2 \subseteq T$	$A \subseteq T$	$A \subseteq A_1 \subseteq T$	

OUR APPROACH

Transaction Processing I



Transaction Processing I



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

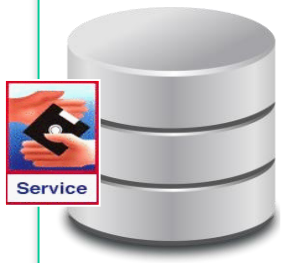
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

$X \subseteq Y$

Transaction Processing I

begin



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

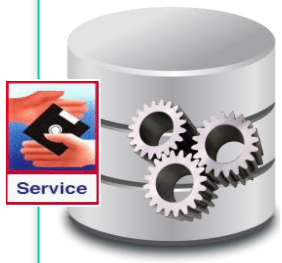
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

$X \subseteq Y$

Transaction Processing I

forget($B \subseteq D_1$)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

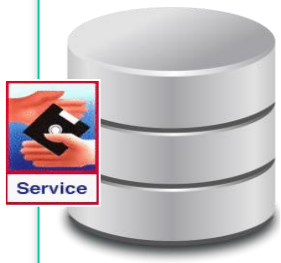
$B \subseteq D_1$

$X \subseteq Y$

Core idea: Ontology module based locks

- Syntactical locality based module approximation
- Function S()
  - given a set of axioms
  - provides us with a signature
- Function M()
  - given a signature
  - provides us with a module for S

forget($B \subseteq D_1$)



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

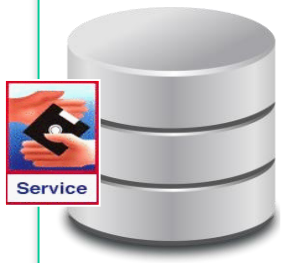
$B \subseteq D_1$

$X \subseteq Y$

Transaction Processing II

forget($B \subseteq D_1$)

$M(S(\{B \sqsubseteq D_1\}))$



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

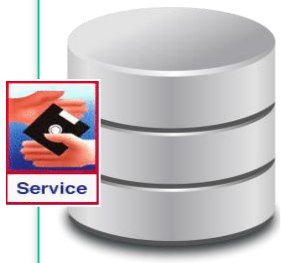
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

$X \subseteq Y$

forget($B \subseteq D_1$)

$M(S(\{B \sqsubseteq D_1\}))$



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

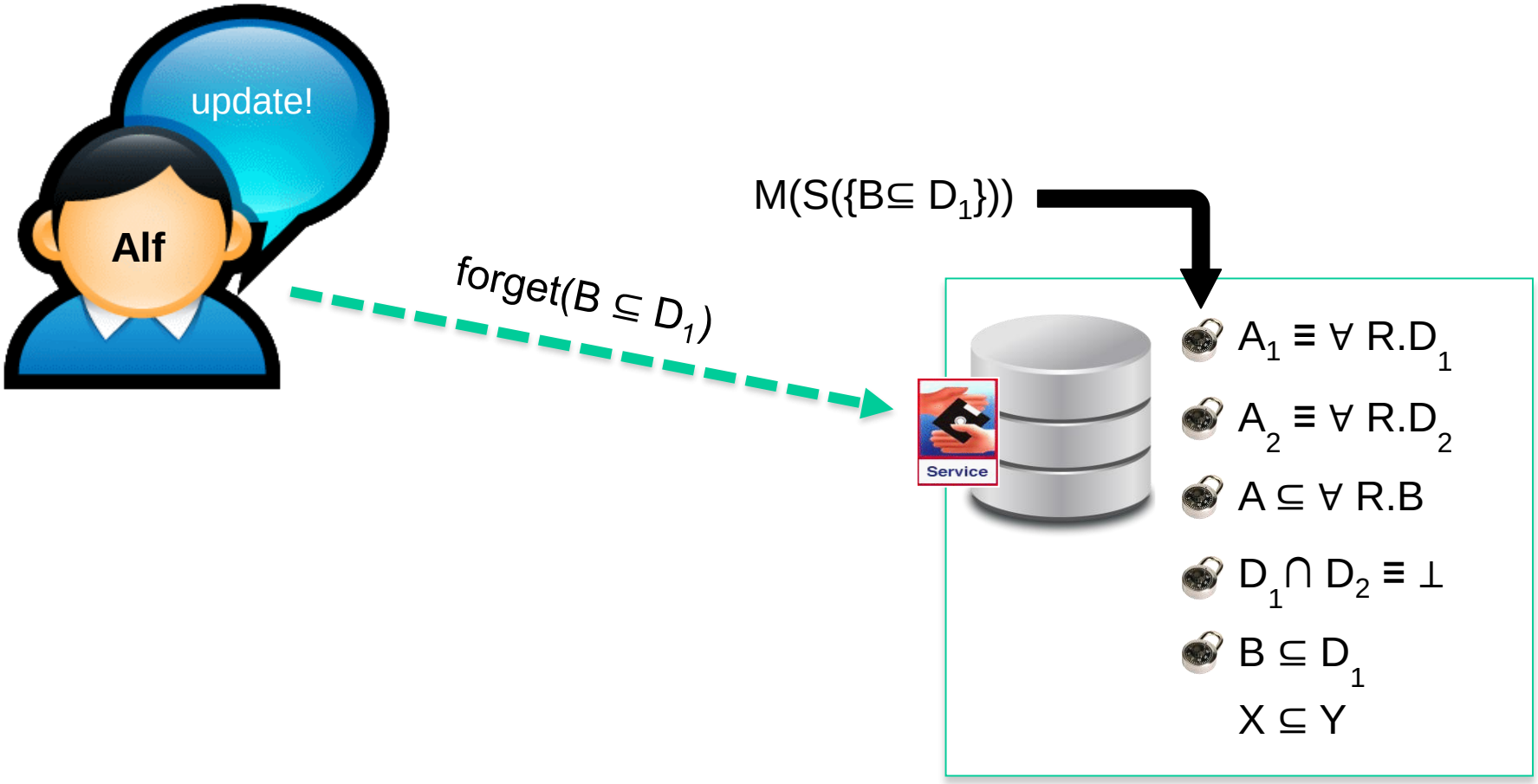
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_1$

$X \subseteq Y$

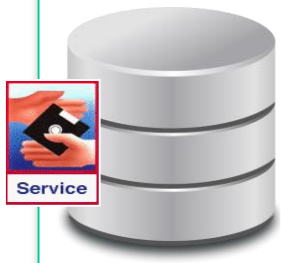
Transaction Processing II



Transaction Processing II

$M(S(\{B \sqsubseteq D_1\}))$

forget$(B \sqsubseteq D_1)$

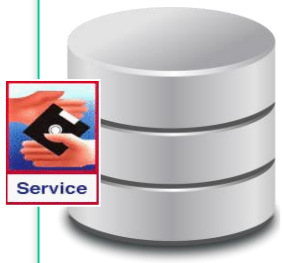


- $A_1 \equiv \forall R.D_1$
- $A_2 \equiv \forall R.D_2$
- $A \sqsubseteq \forall R.B$
- $D_1 \sqcap D_2 \equiv \bot$
- $B \sqsubseteq D_1$

$X \sqsubseteq Y$

Transaction Processing II

$M(S(\{B \sqsubseteq D_1\}))$

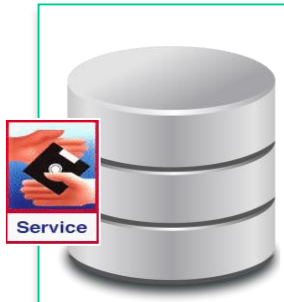


- $A_1 \equiv \forall R.D_1$
- $A_2 \equiv \forall R.D_2$
- $A \sqsubseteq \forall R.B$
- $D_1 \sqcap D_2 \equiv \bot$

$X \sqsubseteq Y$

Transaction Processing II

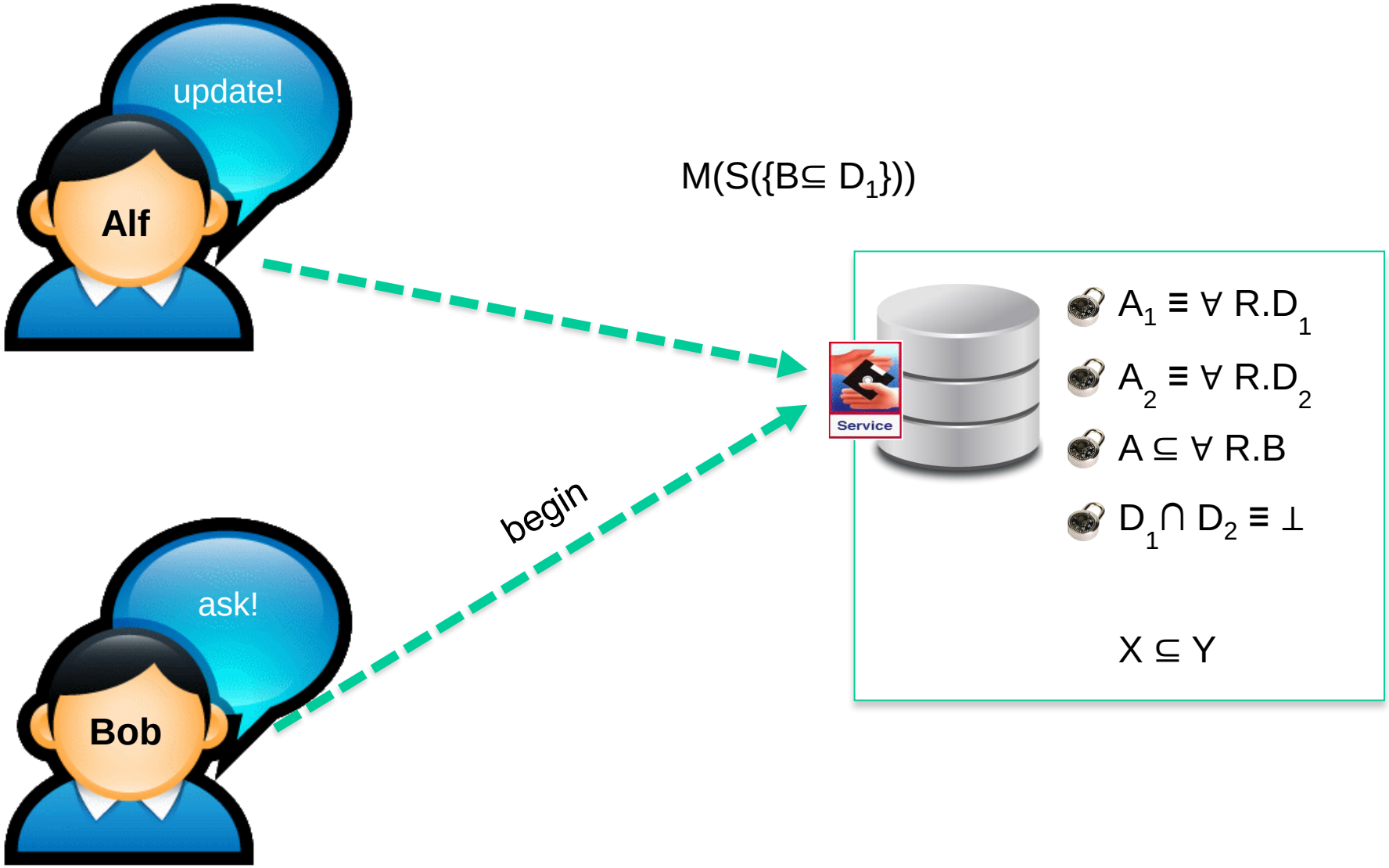
M(S({B⊑ D_1}))



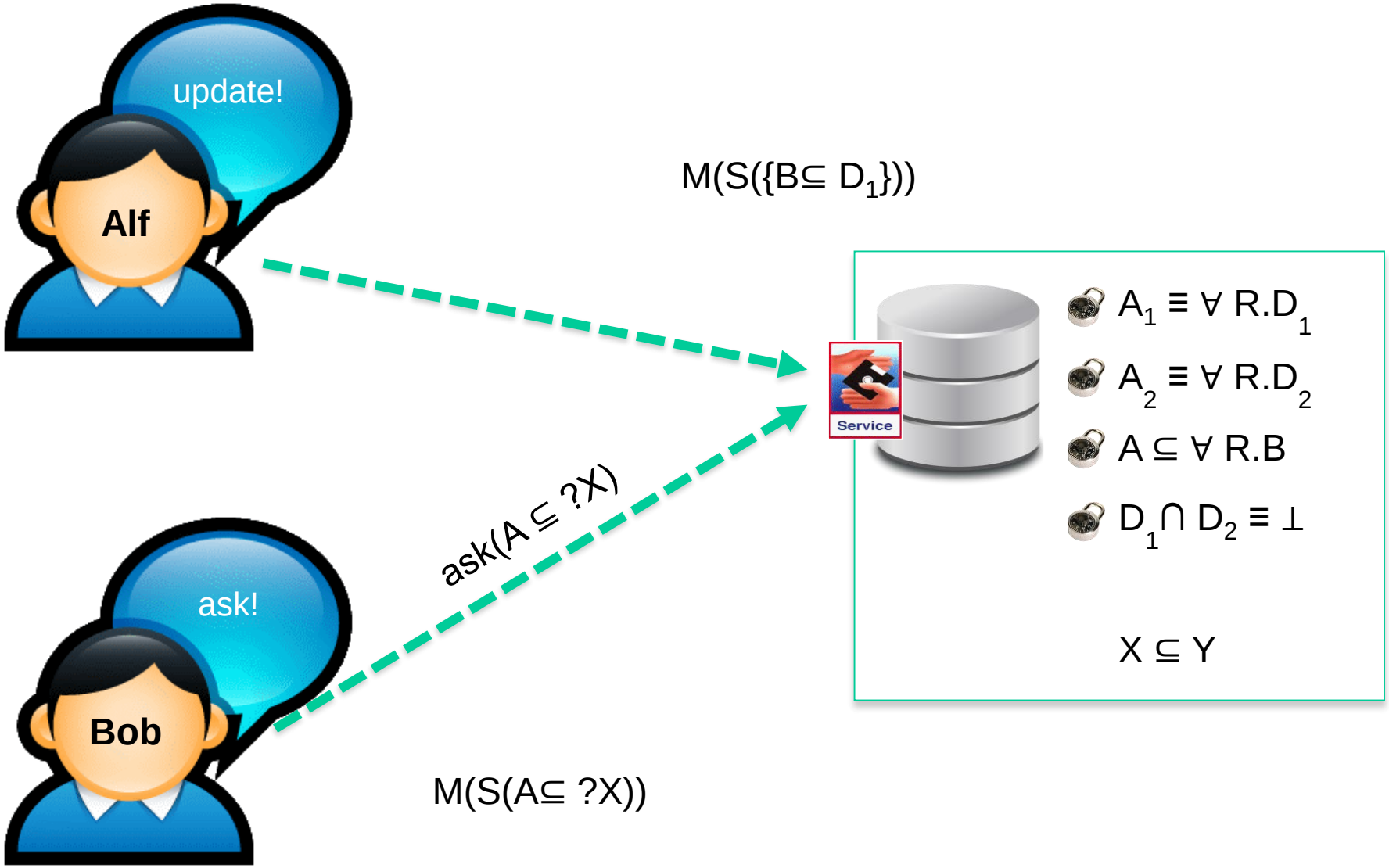
- $A_1 \equiv \forall R.D_1$
- $A_2 \equiv \forall R.D_2$
- $A \sqsubseteq \forall R.B$
- $D_1 \sqcap D_2 \equiv \bot$

$X \sqsubseteq Y$

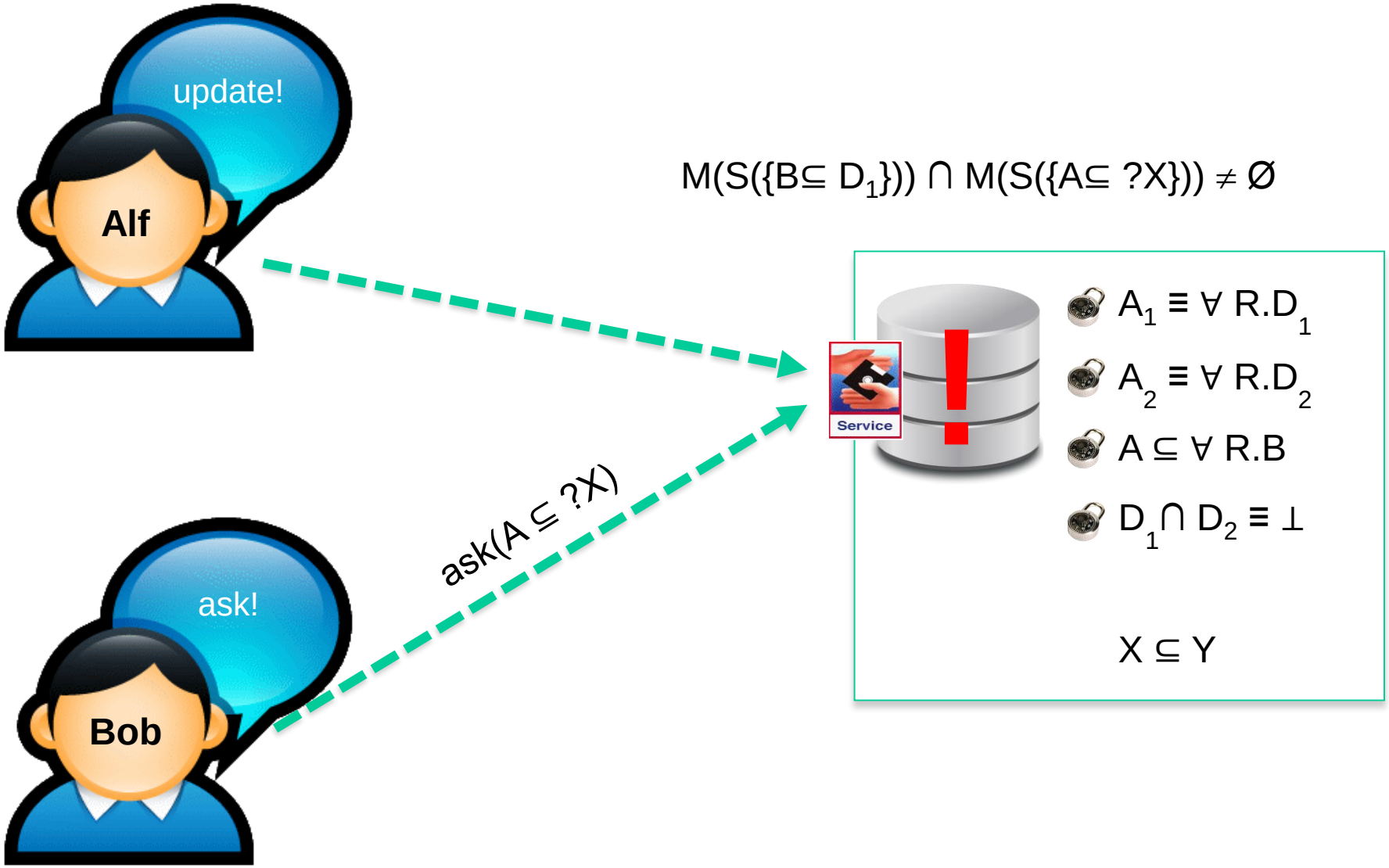
Transaction Processing II



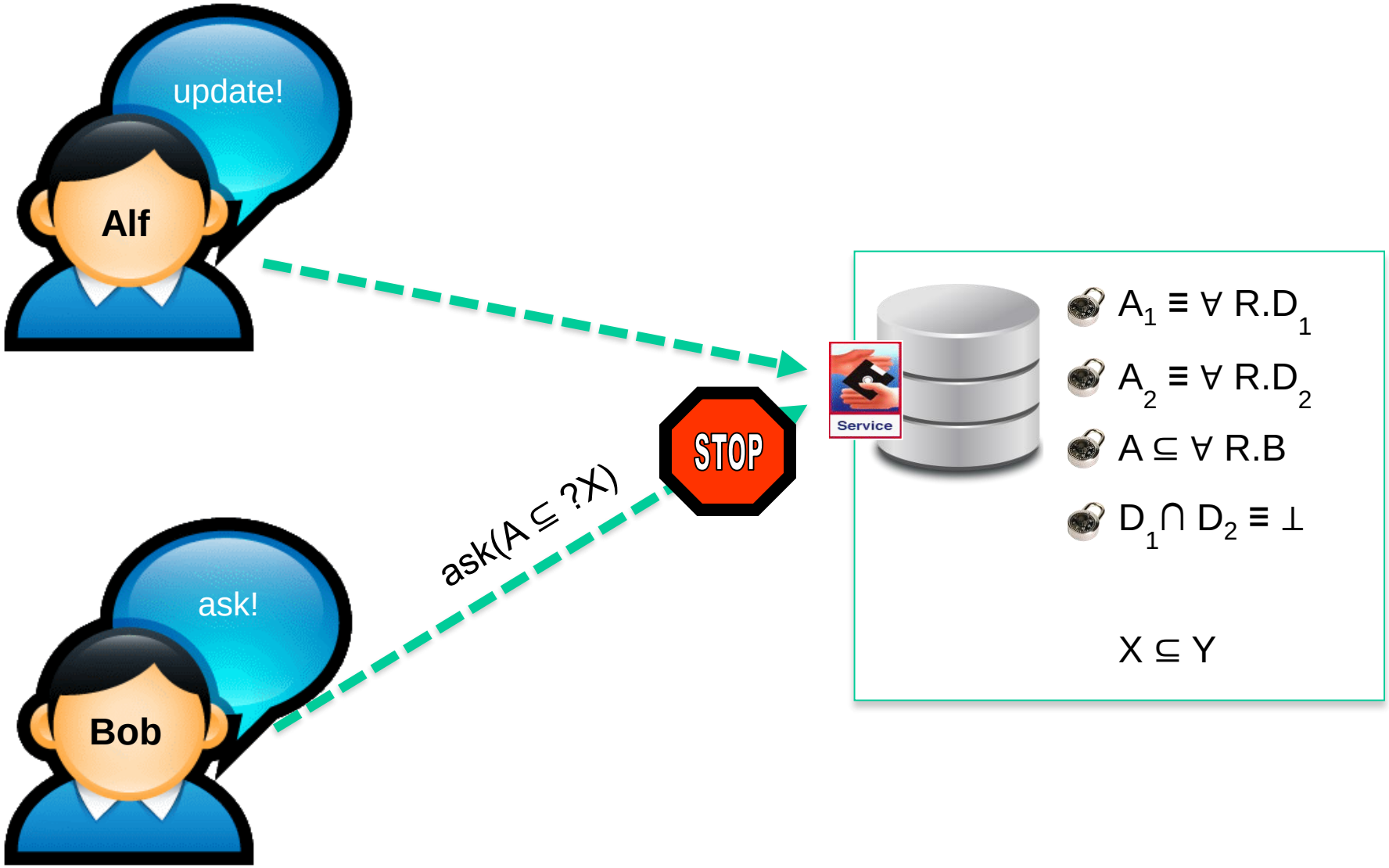
Transaction Processing II



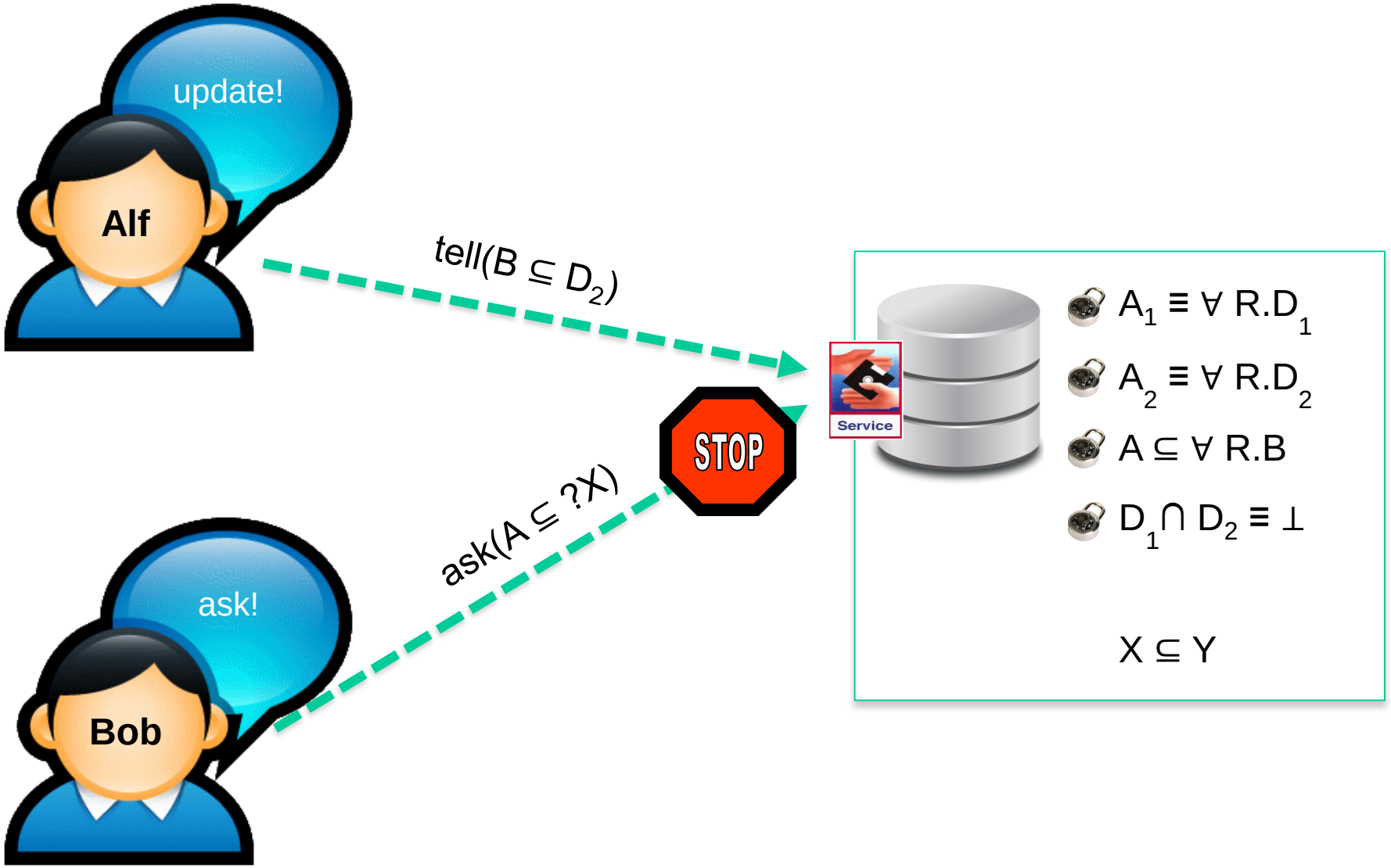
Transaction Processing II



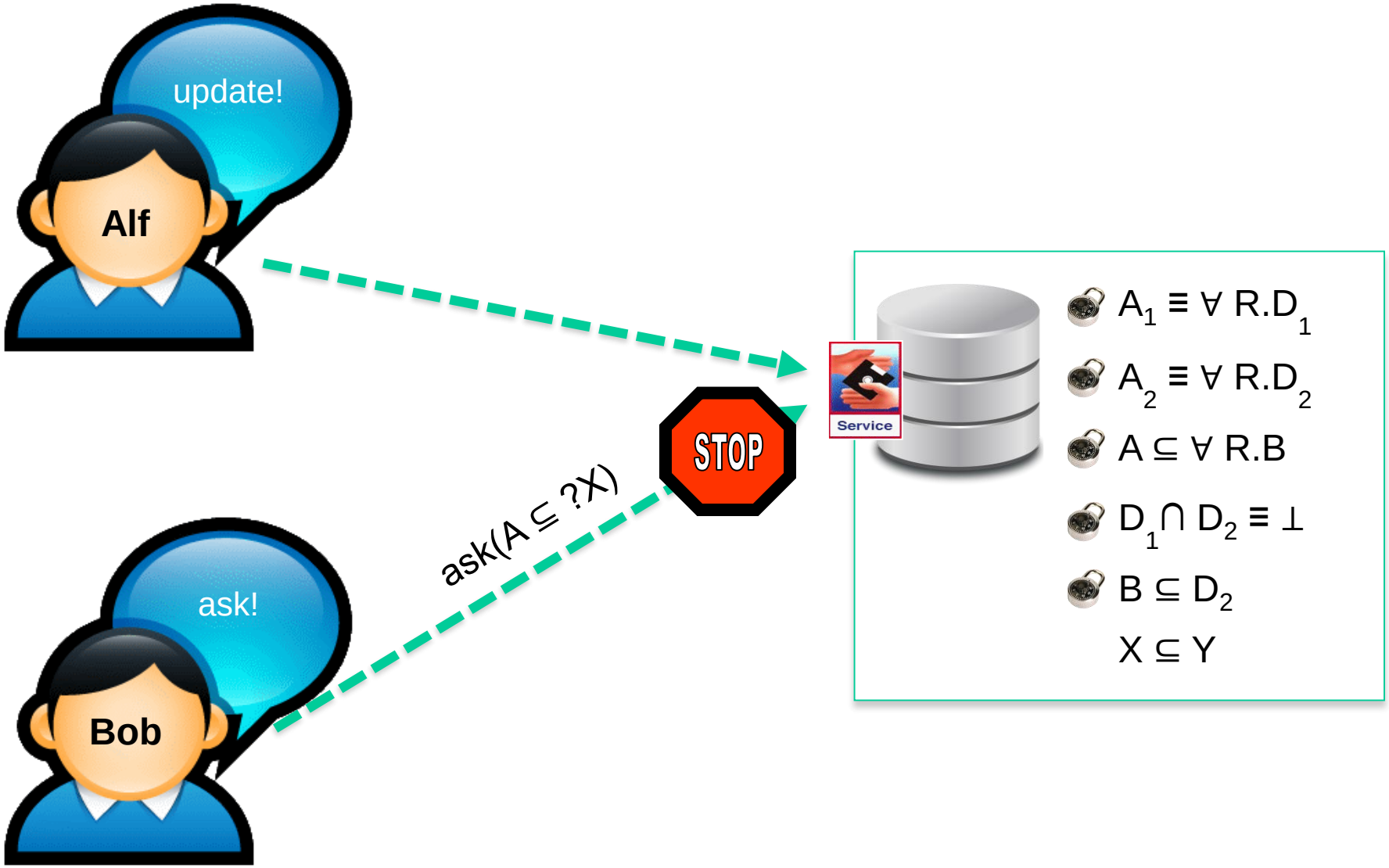
Transaction Processing II



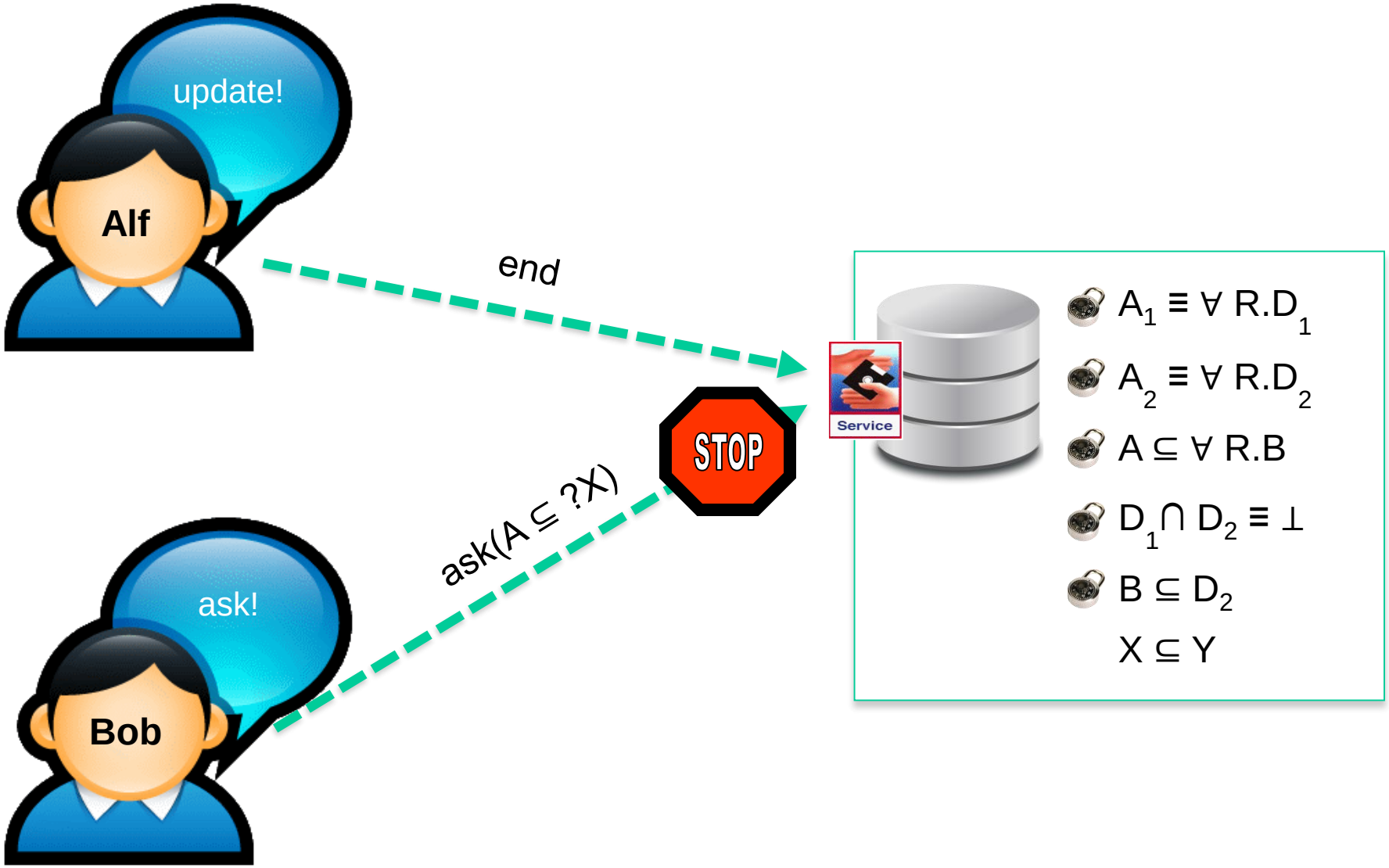
Transaction Processing II



Transaction Processing II



Transaction Processing II



Transaction Processing II

ask(A ⊆ ?X)

$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

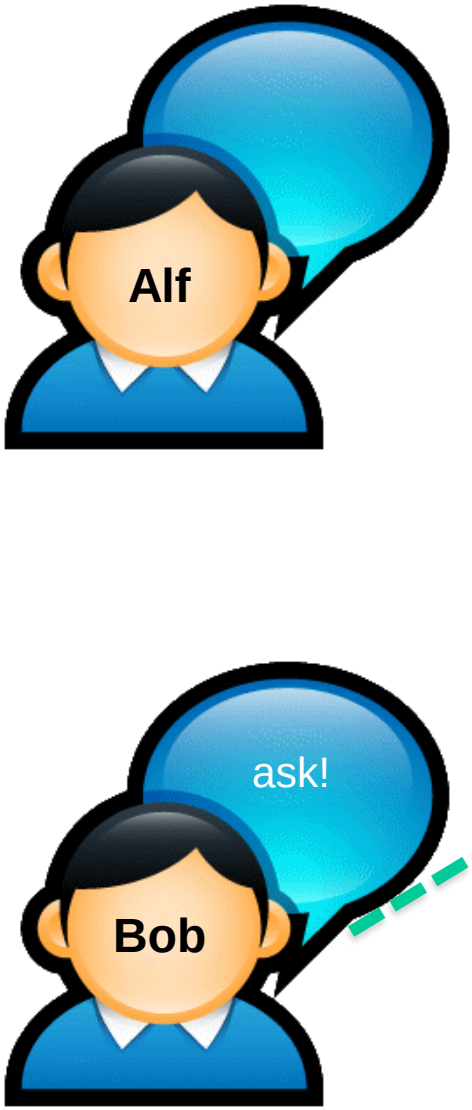
$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

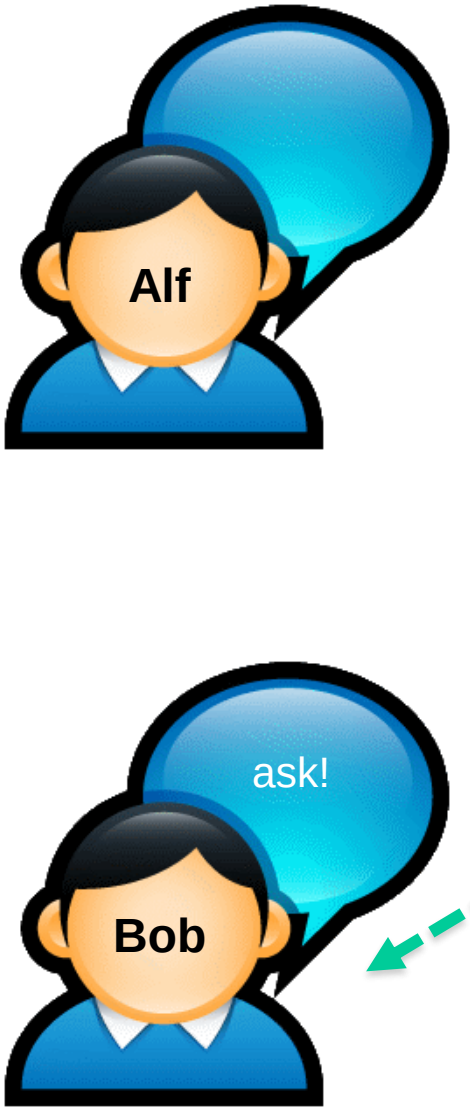
$B \subseteq D_2$

$X \subseteq Y$

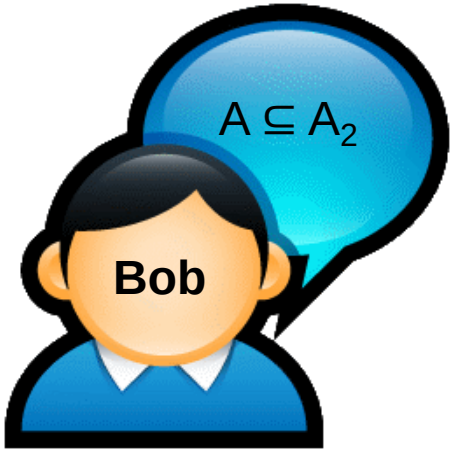
Transaction Processing II

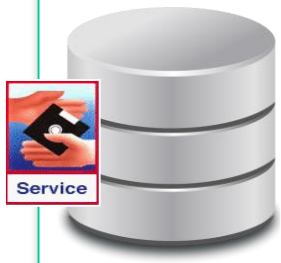


Transaction Processing II



Transaction Processing II

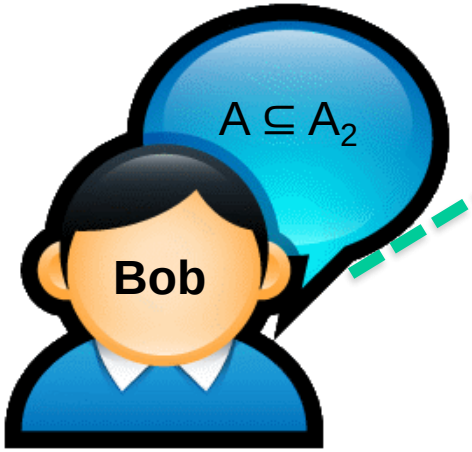




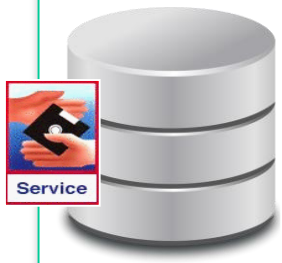
- $A_1 \equiv \forall R.D_1$
- $A_2 \equiv \forall R.D_2$
- $A \subseteq \forall R.B$
- $D_1 \cap D_2 \equiv \bot$
- $B \subseteq D_2$

$X \subseteq Y$

Transaction Processing II



end



$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

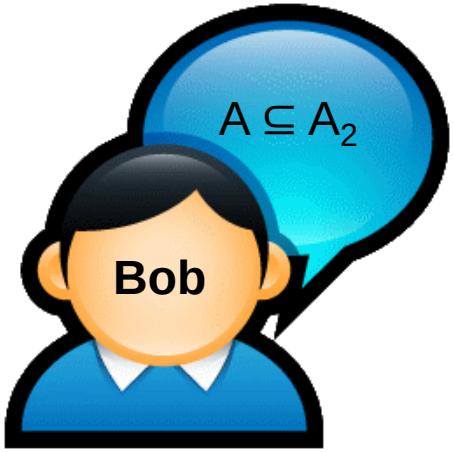
$A \subseteq \forall R.B$

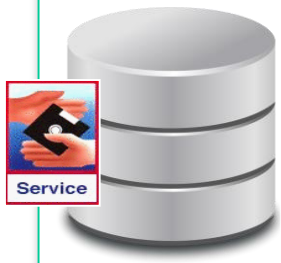
$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

$X \subseteq Y$

Transaction Processing II





$A_1 \equiv \forall R.D_1$

$A_2 \equiv \forall R.D_2$

$A \subseteq \forall R.B$

$D_1 \cap D_2 \equiv \bot$

$B \subseteq D_2$

$X \subseteq Y$

Evaluation: Construction of Histories

Evaluation: Construction of Histories

Input:

- National Cancer Thesaurus (NCIt)
  - OWL EL++ Ontology
  - 4 consecutive version
  - ~600K Axioms,
    - 500K annotation, 38K classes, 90 object properties

Evaluation: Construction of Histories

Input:

- National Cancer Thesaurus (NCIt)
  - OWL EL++ Ontology
  - 4 consecutive version
  - ~600K Axioms,
    - 500K annotation, 38K classes, 90 object properties

Steps:

1. Identifying 420 Transactions of 6-12 operations
   - How: From syntactic diffs of consecutive versions
2. Each critical operation followed by non-critical with same duration
3. Constructing Histories from 2-4 Transactions

Evaluation: Construction of Histories

Input:

- National Cancer Thesaurus (NCIt)
  - OWL EL++ Ontology
  - 4 consecutive version
  - ~600K Axioms,
    - 500K annotation, 38K classes, 90 object properties

Steps:

1. Identifying 420 Transactions of 6-12 operations
   - How: From syntactic diffs of consecutive versions
2. Each critical operation followed by non-critical with same duration
3. Constructing Histories from 2-4 Transactions

Output:

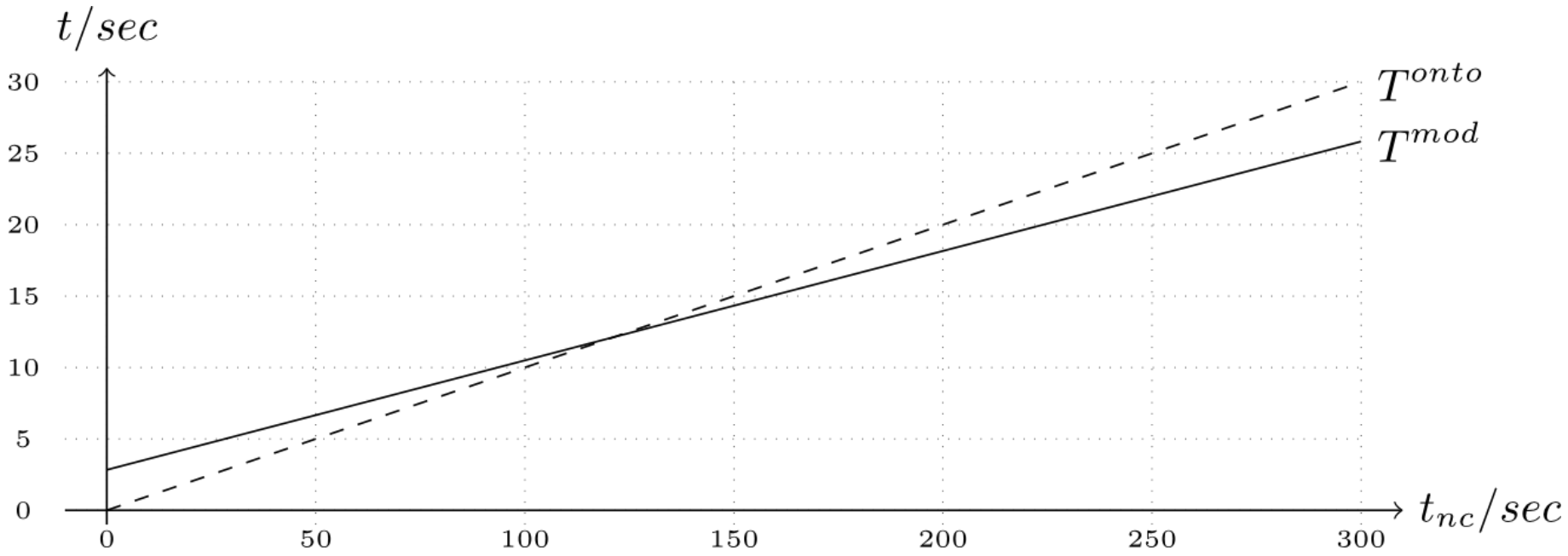
1200 Histories consisting of 24 – 96 atomic operations each

Evaluation Results

- 30% (~240) of the histories are serializable
  - Due to random generation of transactions
- Average serializable history 76,6% of the steps of serial execution
- In average 2.832 sec for a single lock calculation

- Linux Virtual Machine 8Gig Ram, 1 Core
  (Dual Xeon Hexacore, 2.9Ghz, 96 Gig Ram running ~20 VMs)

Results



- 10% of module calculation time for the module of the upcoming operation
- 90% to recalculate the lock

Incremantal module calculation methods would lead to a downscale

Conclusion & Further Work

- Incremental module calculation
- Pre-computation strategies
- Real world Evaluation
- Integration into ontology development tool

Thank You