

Exam Questions

TEACHING ASSISTANT: DAVID TRABISH

Question

The program contains a string constant.

compiler construction

compiling

linking

runtime

Question

The program contains a string constant.

compiler construction

compiling

linking

runtime

Question

Every time the command $x = y + 42$ is executed, the value of y is 0.

compiler construction

compiling

linking

runtime

Question

Every time the command $x = y + 42$ is executed, the value of y is 0.

compiler construction

compiling

linking

runtime

Question

All the variable names start with x.

compiler construction

compiling

linking

runtime

Question

All the variable names start with x.

compiler construction

compiling

linking

runtime

Question

The program contains a nested loop.

compiler construction

compiling

linking

runtime

Question

The program contains a nested loop.

compiler construction

compiling

linking

runtime

Question

The program contains a string constant with at least 200 characters.

compiler construction

compiling

linking

runtime

Question

The program contains a string constant with at least 200 characters.

compiler construction

compiling

linking

runtime

Question

The size of the stack exceeds 400 bytes.

compiler construction

compiling

linking

runtime

Question

The size of the stack exceeds 400 bytes.

compiler construction

compiling

linking

runtime

Question

The only method invocations are of methods which are located at offset 4 in the virtual table.

compiler construction

compiling

linking

runtime

Question

The code contains only invocations of methods which located at offset 4 in the virtual table.

compiler construction

compiling

linking

runtime

Question

There is an addition operation which is never executed in any run.

compiler construction

compiling

linking

runtime

Question

There is an addition operation which is never executed in any run.

compiler construction

compiling

linking

runtime

LR(0) Item

An LR(0) item with the dot at the end is called **reduce** item:

- $N \rightarrow \alpha\beta.$

Otherwise, it's a **shift** item:

- $N \rightarrow .\alpha\beta$
- $N \rightarrow \alpha.\beta$

LR(0) Item Closure Set

The LR(0) closure set of an LR(0) item i is a set S such that:

- $i \in S$
- If $A \rightarrow \alpha.N\beta \in S$ then for each rule $N \rightarrow \gamma$:
 - $N \rightarrow.\gamma \in S$

SLR(1)

- Same push-down automaton as in LR(0)
- But reduce items has a look-ahead set
 - $A \rightarrow \alpha. \{t_1, t_2, \dots\}$
 - where $Follow(A) = \{t_1, t_2, \dots\}$

LR(1)

An LR(1) item is of the form:

- $N \rightarrow \alpha.\beta \{\sigma\}$
- where $\sigma = t_1, t_2, \dots$ (terminals)

LR(1) Item Closure Set

The **LR(1) closure set** of an LR(1) item i is a set S such that:

- $i \in S$
- If $A \rightarrow \alpha.N\beta \{ \sigma \} \in S$ then for each rule $N \rightarrow \gamma$:
 - $N \rightarrow .\gamma \{ \tau \} \in S$, where $\tau = First(\beta, \{ \sigma \})$

Definition for $First(\beta, \{ \sigma \})$:

- If β is not nullable:
 - $First(\beta)$
- Otherwise:
 - $(First(\beta) \cup \{ \sigma \}) \setminus \{ \epsilon \}$

Question

Is the following CFG LR(0) / SLR(1) / LR(1)?

- $S \rightarrow A\$$
- $A \rightarrow Axx$
- $A \rightarrow x$

s_0 :

$S \rightarrow \cdot A \$$

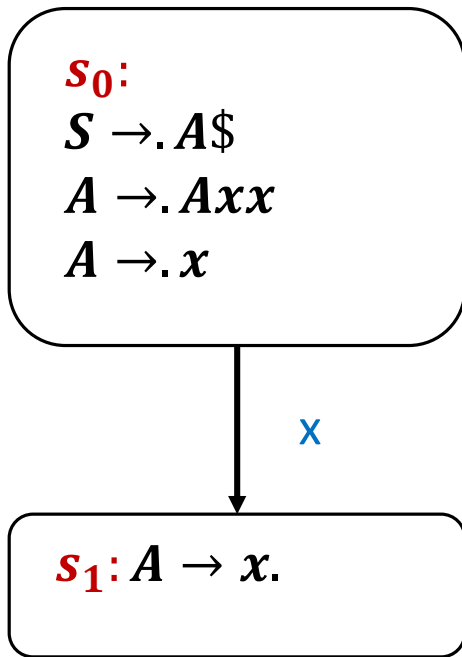
$A \rightarrow \cdot A x x$

$A \rightarrow \cdot x$

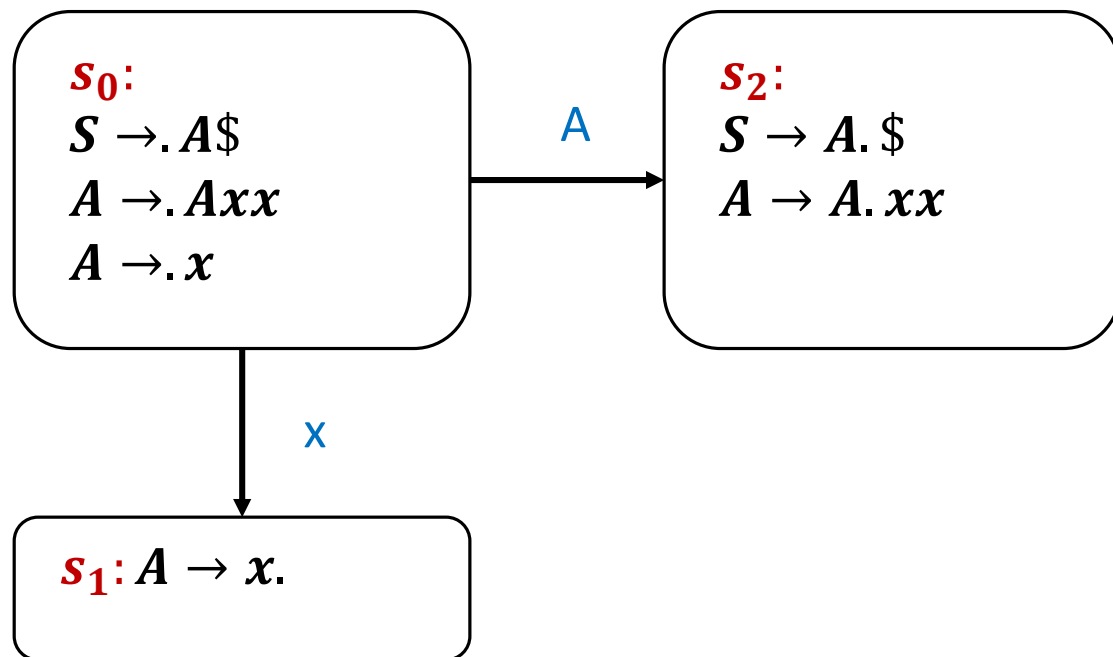
$S \rightarrow A \$$

$A \rightarrow A x x$

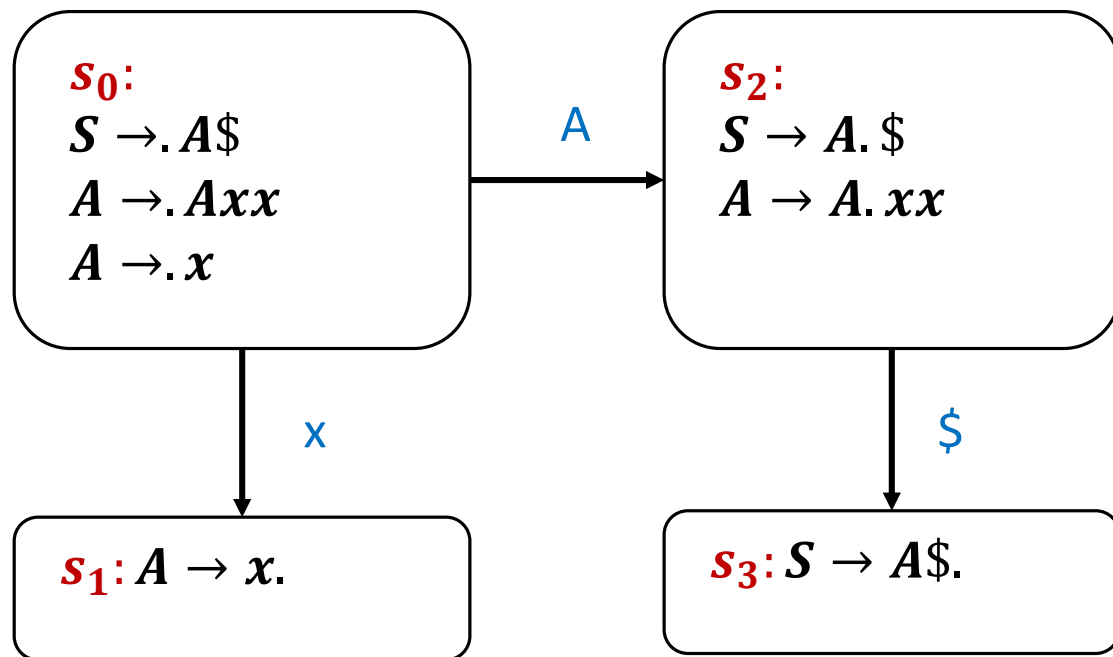
$A \rightarrow x$



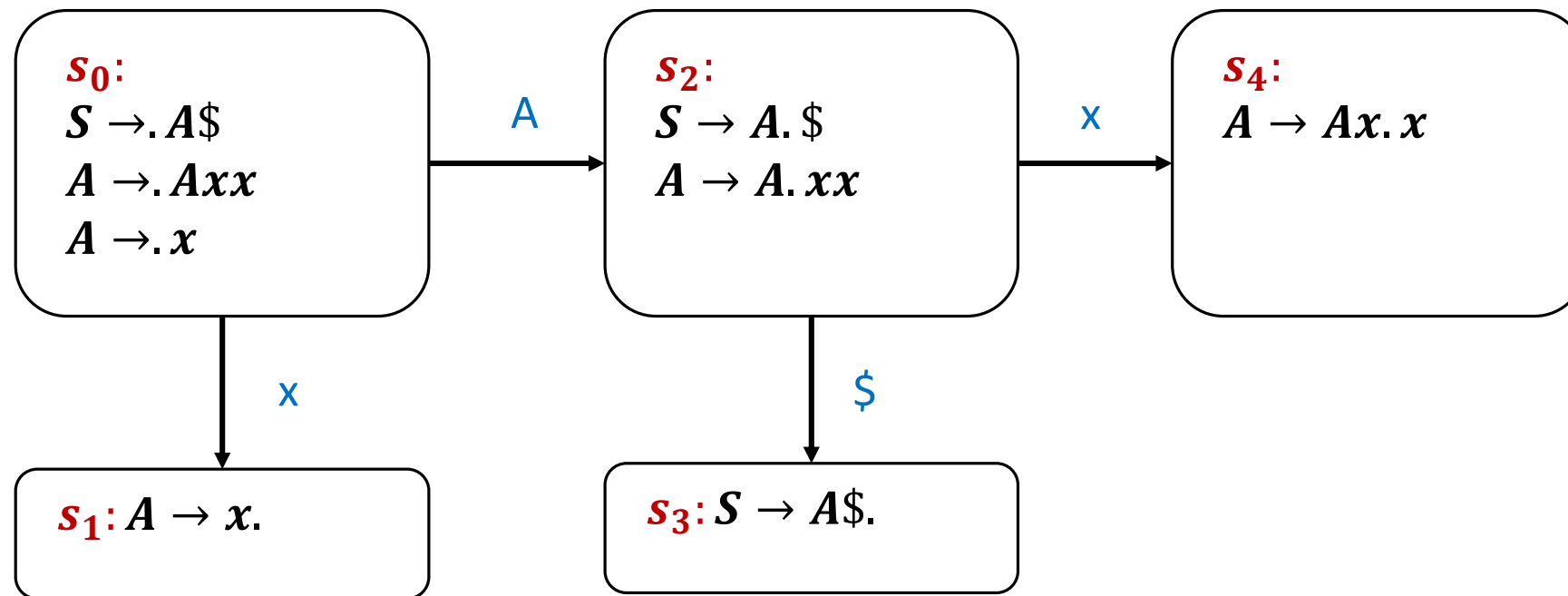
$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$



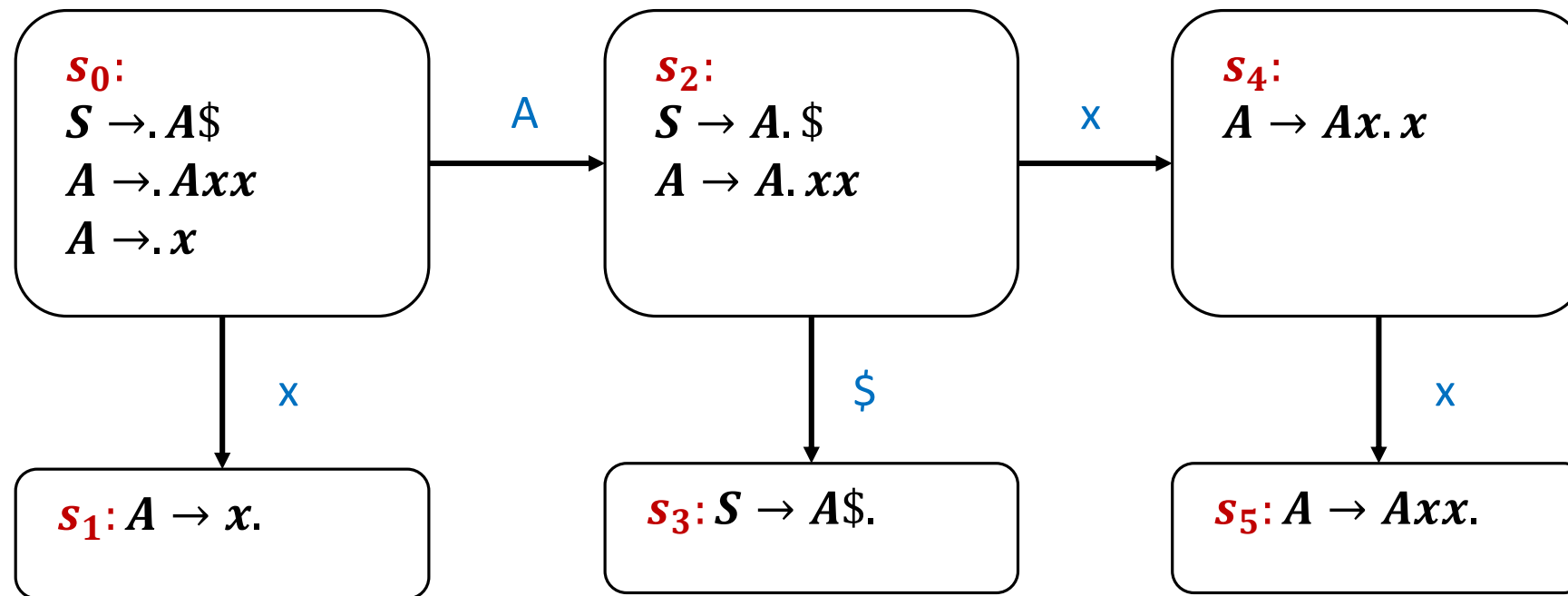
$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$

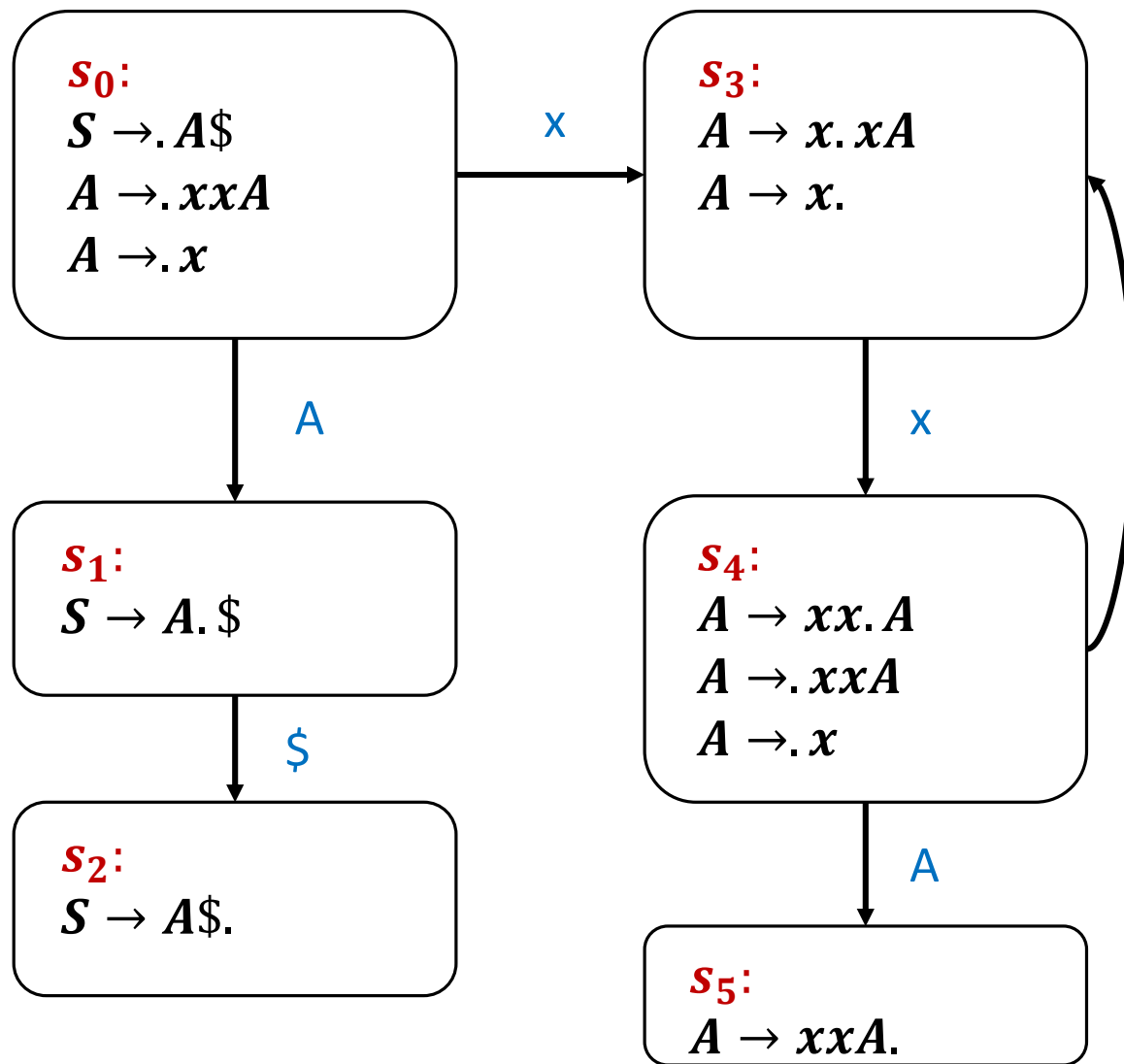


$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$

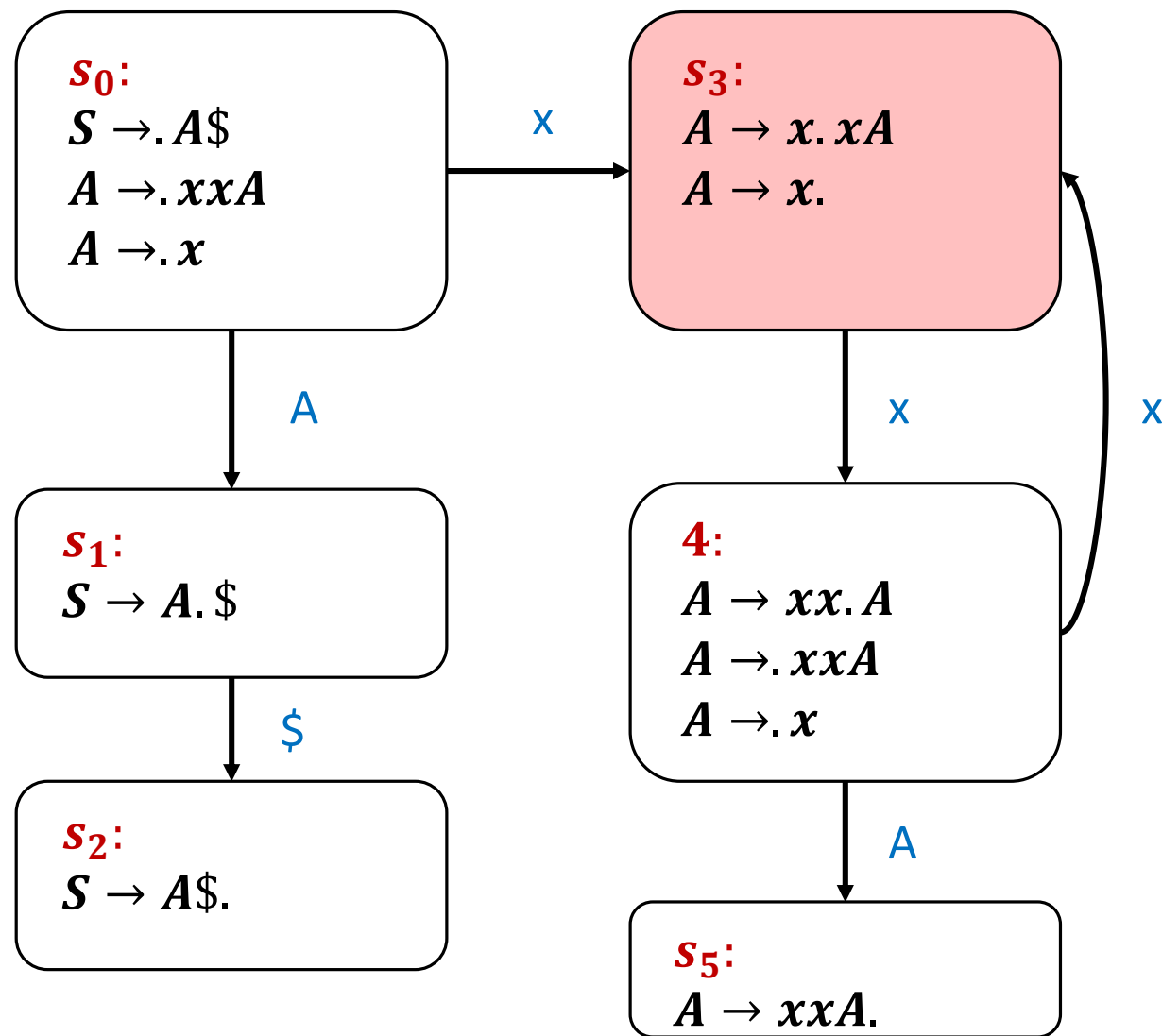
Question

Is the following CFG LR(0) / SLR(1) / LR(1)?

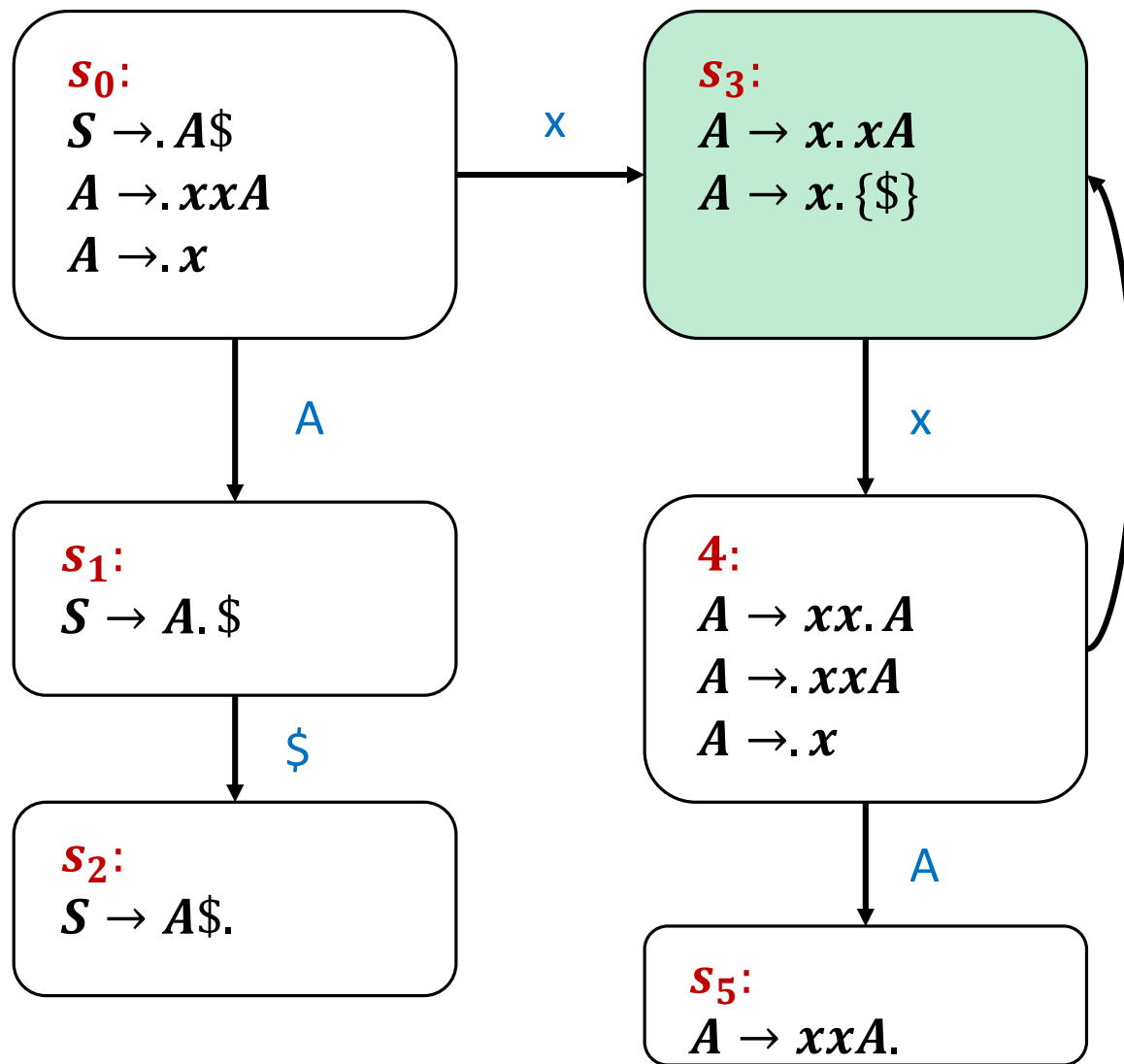
- $S \rightarrow A\$$
- $A \rightarrow xxA$
- $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow x x A$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow xx A$
 $A \rightarrow x$



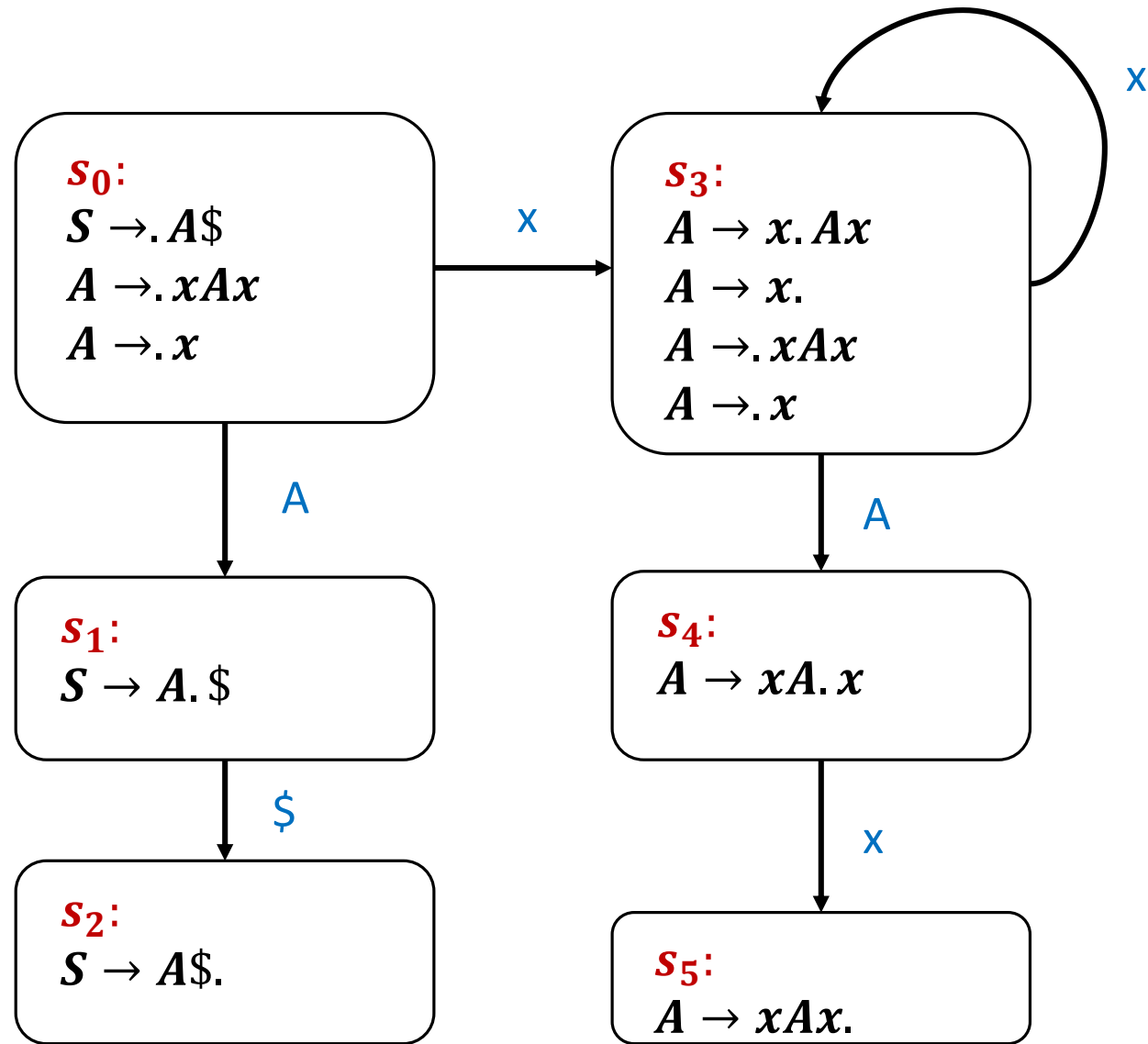
$Follow(A) = \{ \$ \}$

$S \rightarrow A\$$
 $A \rightarrow xxA$
 $A \rightarrow x$

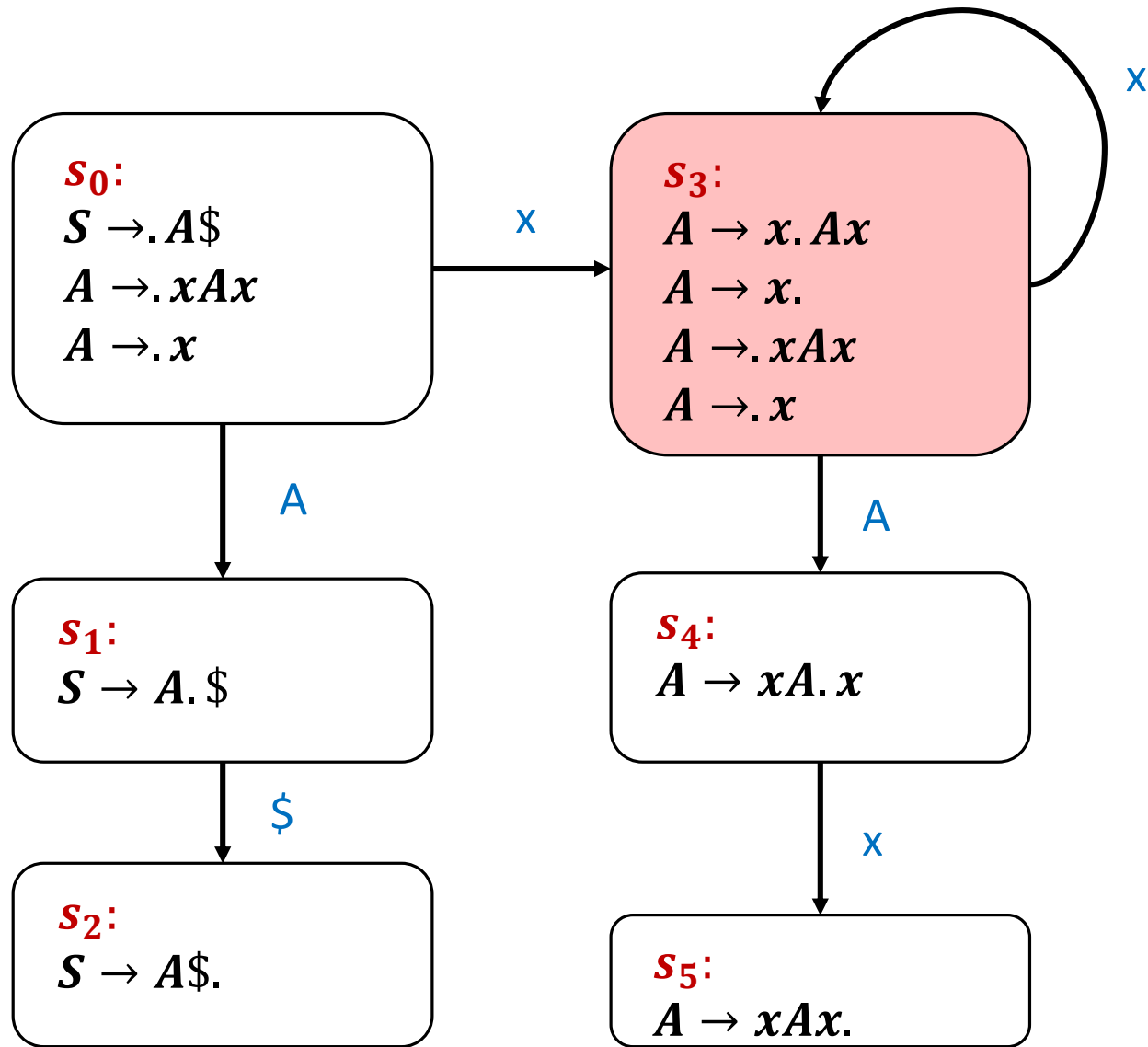
Question

Is the following CFG LR(0) / SLR(1) / LR(1)?

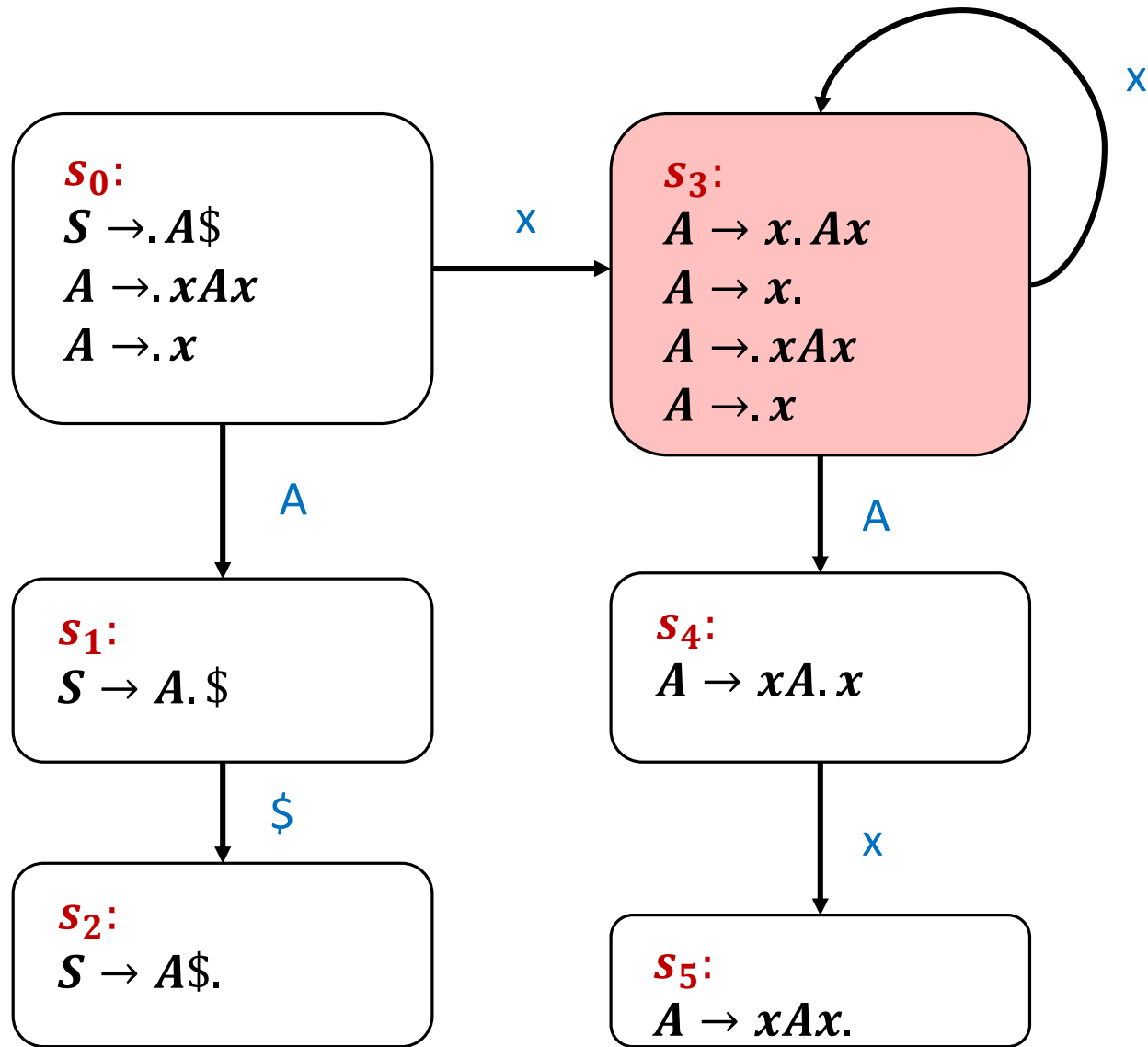
- $S \rightarrow A\$$
- $A \rightarrow xAx$
- $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



$$\text{Follow}(A) = \{\$, x\}$$

$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$

s_0 :

$S \rightarrow \cdot A \$ \{ \$ \}$

$A \rightarrow \cdot x A x \{ \$ \}$

$A \rightarrow \cdot x \{ \$ \}$

$S \rightarrow A \$$

$A \rightarrow x A x$

$A \rightarrow x$

s_0 :

$S \rightarrow \cdot A \$ \{ \$ \}$

$A \rightarrow \cdot x A x \{ \$ \}$

$A \rightarrow \cdot x \{ \$ \}$

A

s_1 :

$S \rightarrow A \cdot \$ \{ \$ \}$

$S \rightarrow A \$$

$A \rightarrow x A x$

$A \rightarrow x$

s_0 :
 $S \rightarrow \cdot A \$ \{ \$ \}$
 $A \rightarrow \cdot x A x \{ \$ \}$
 $A \rightarrow \cdot x \{ \$ \}$



A

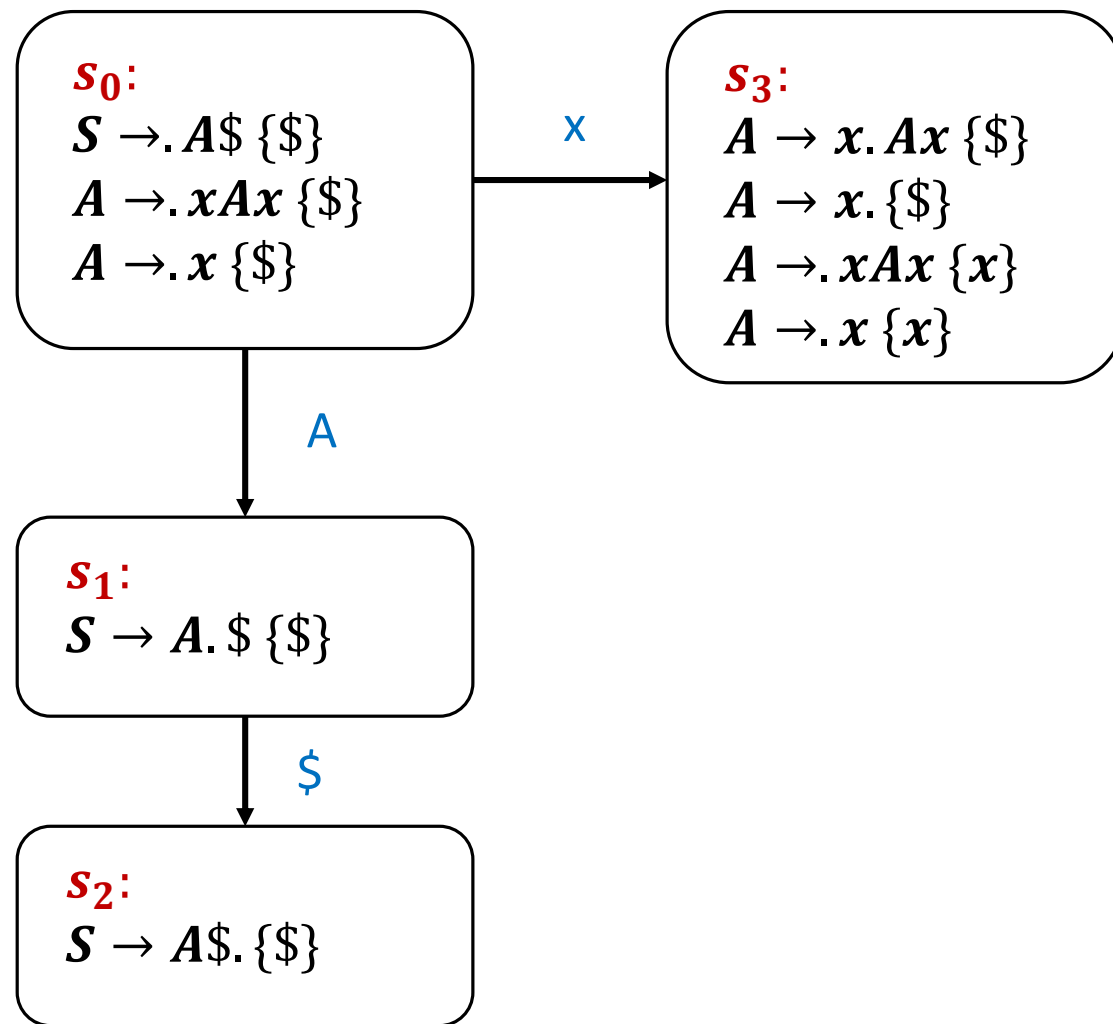
s_1 :
 $S \rightarrow A \cdot \$ \{ \$ \}$



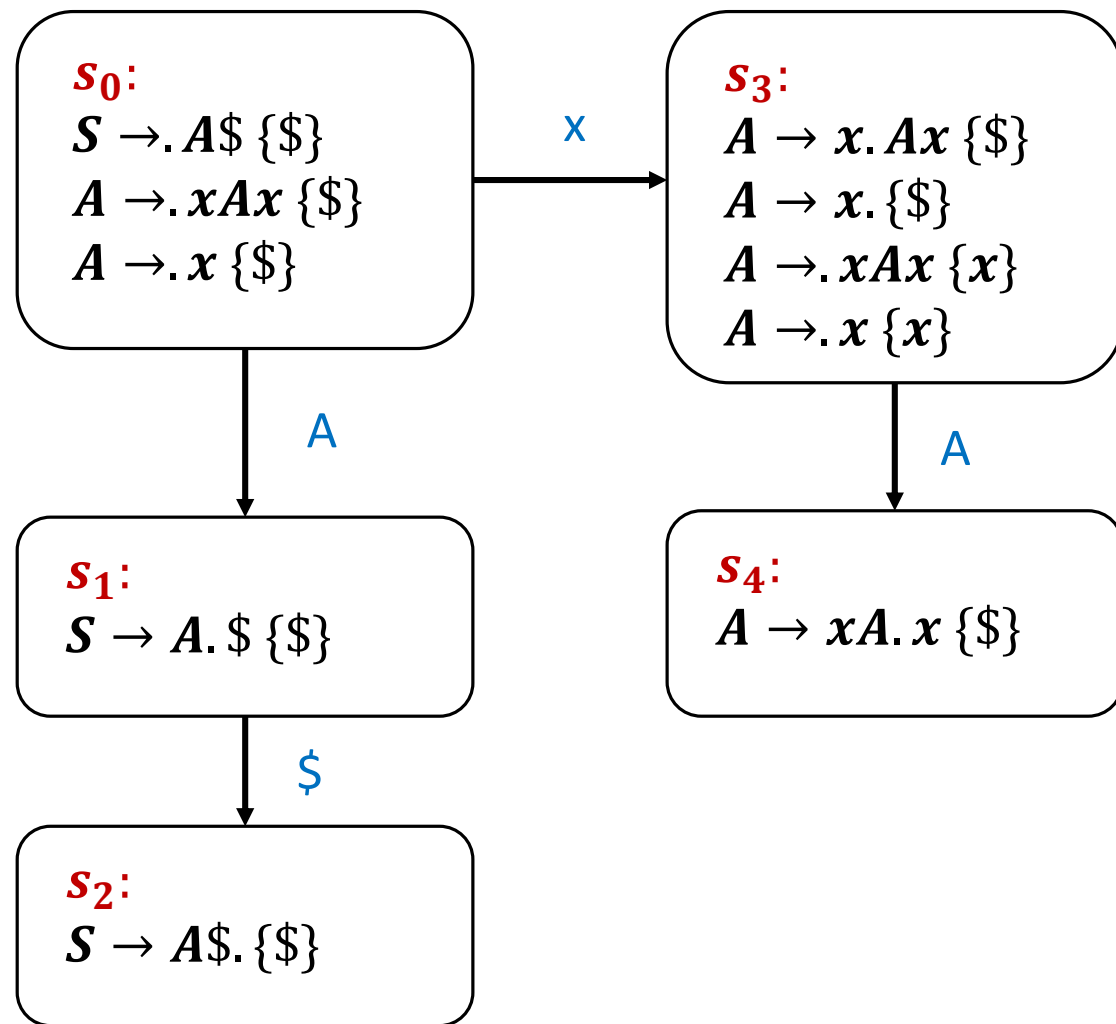
$\$$

s_2 :
 $S \rightarrow A \$ \cdot \{ \$ \}$

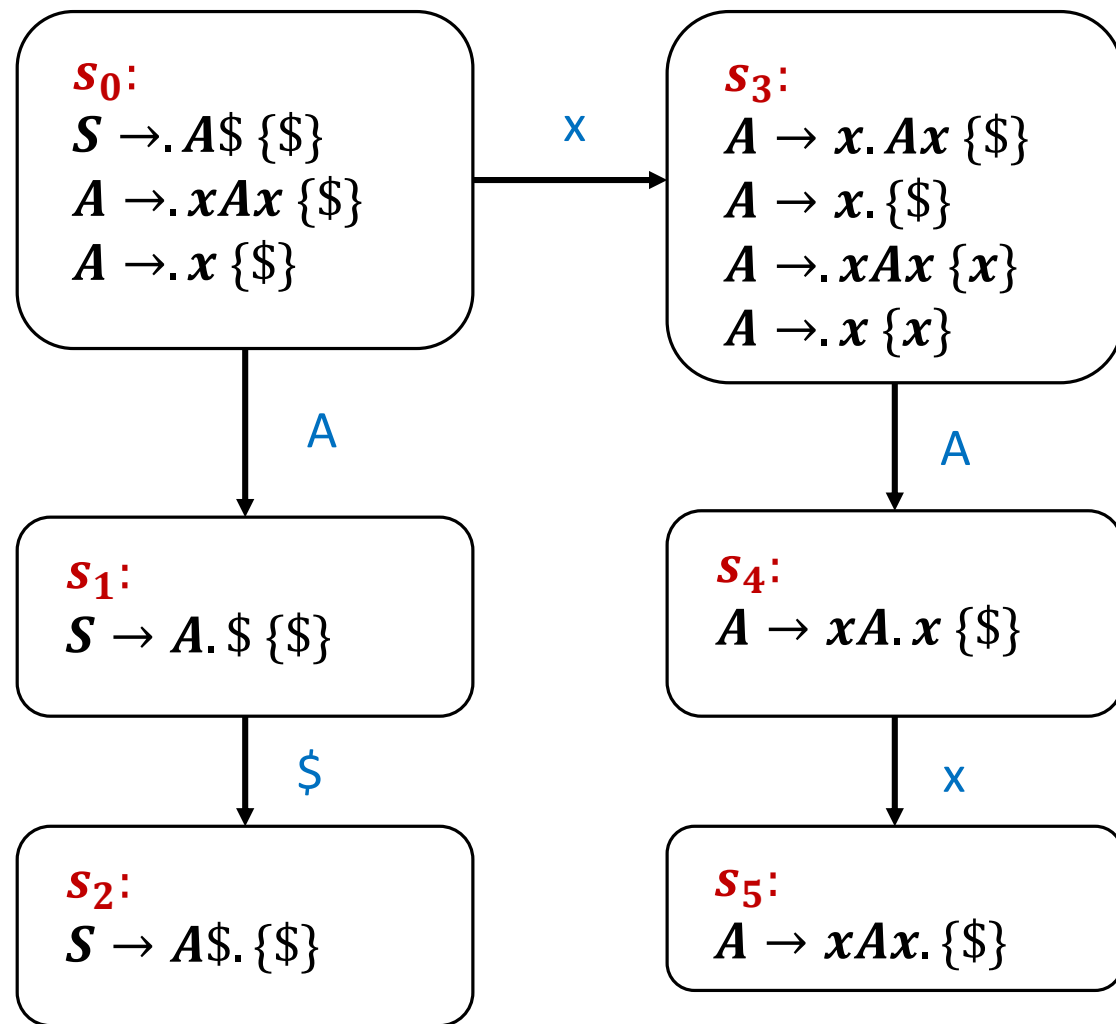
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



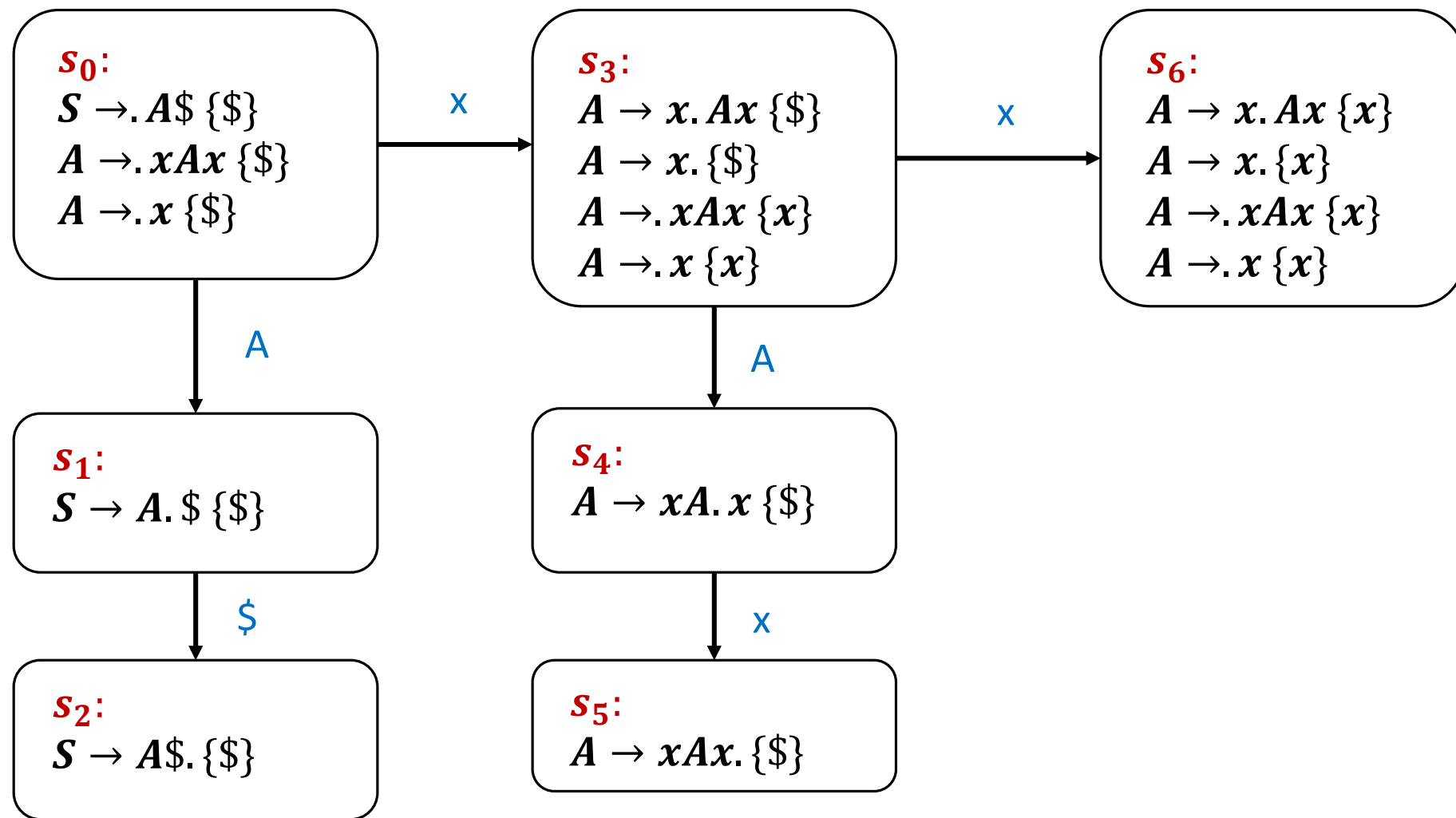
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



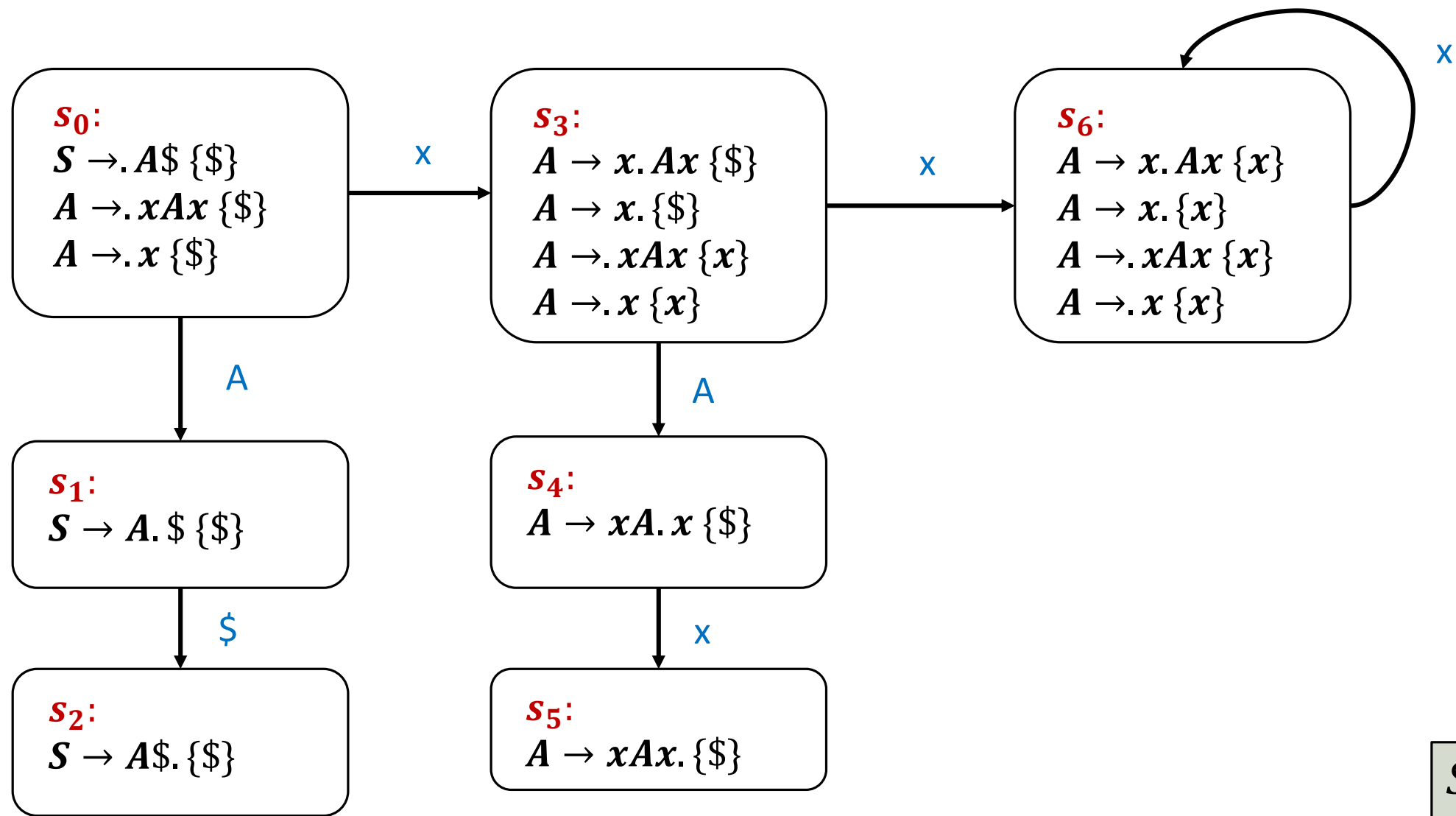
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



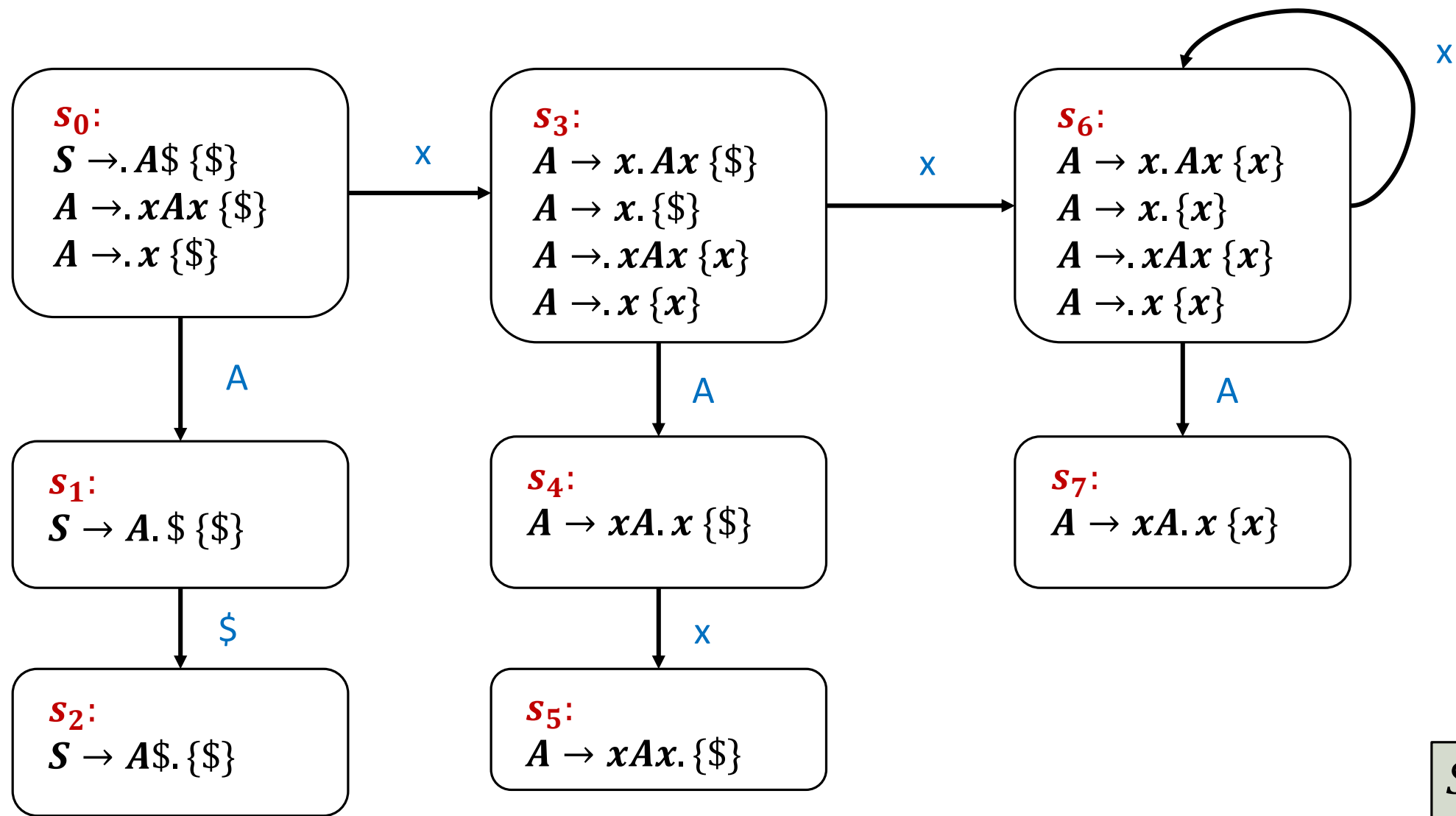
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



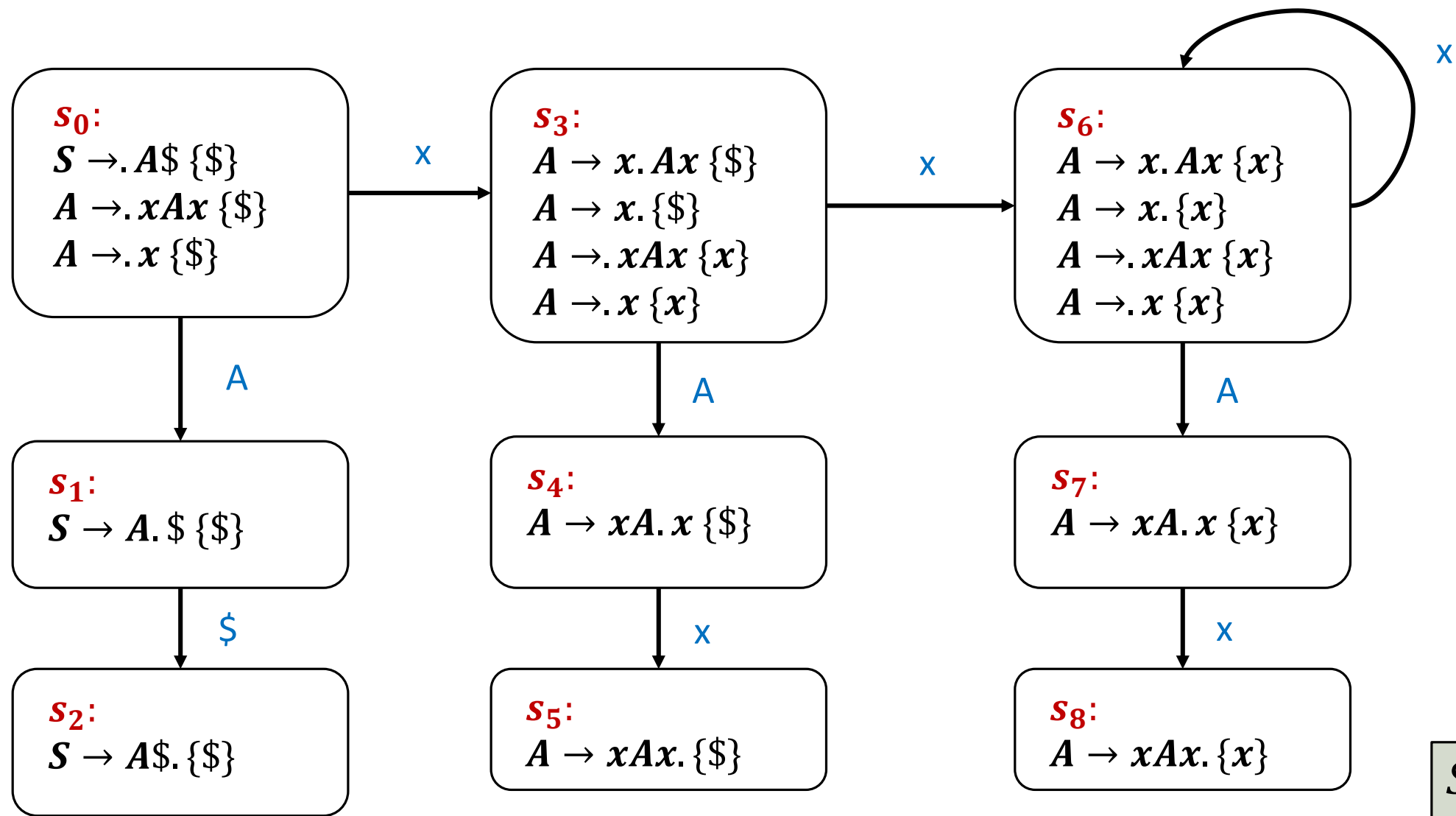
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



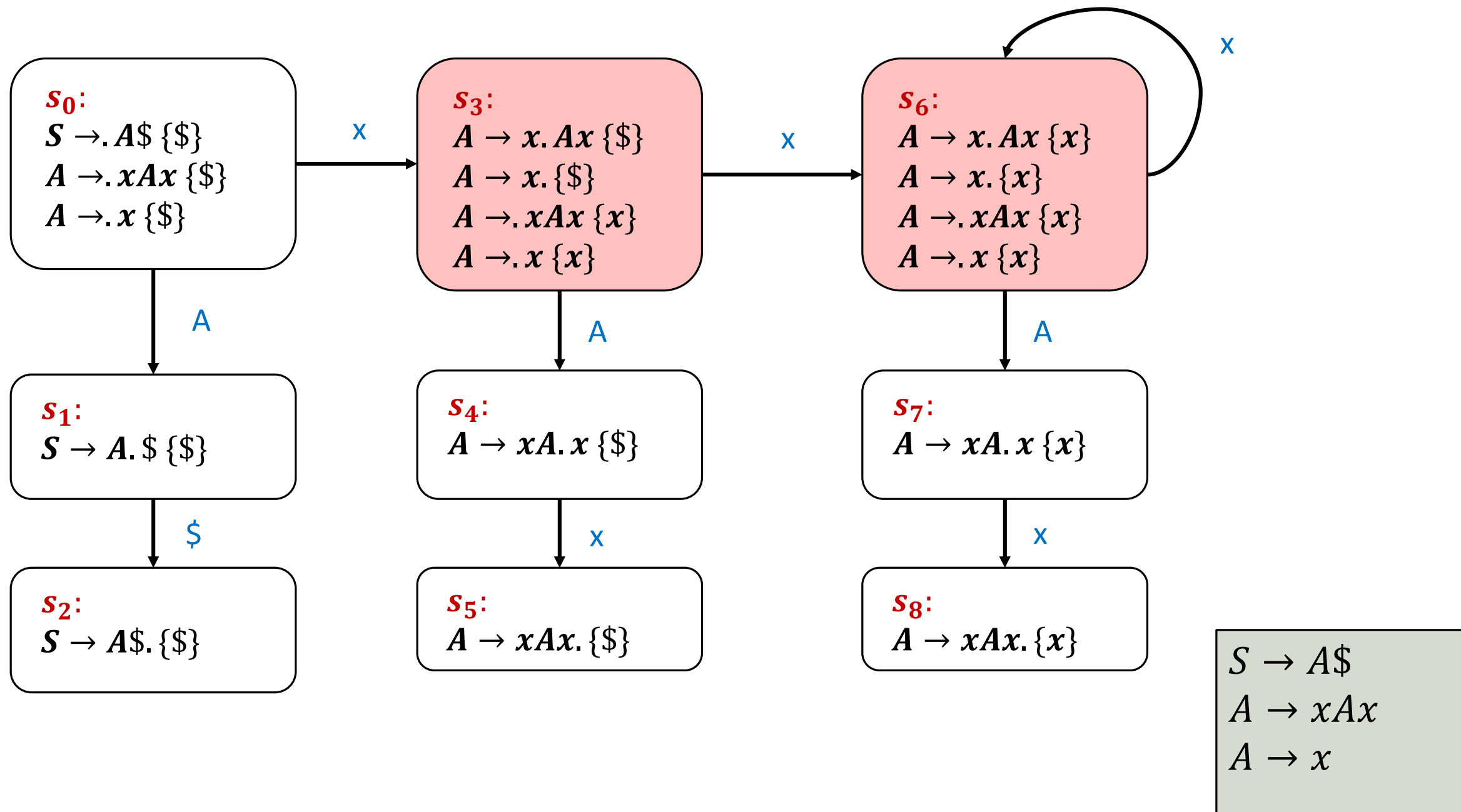
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



$S \rightarrow A\$$
 $A \rightarrow xAx$
 $A \rightarrow x$



$S \rightarrow A\$$
 $A \rightarrow xAx$
 $A \rightarrow x$



Question

We extend the language with automatic type inference:

- Can use **auto** when the declaration has an initial value

Describe the changes required in:

- Lexical analysis
- Syntactic analysis
- Semantic analysis

```
auto i := 8 + 100;  
auto s := "1234";  
class A {}  
A a := new A;  
auto b := a;
```

Question

A variable x **depends** on a variable y if y is used (directly or indirectly) to compute x . For example, c depends on x, y, b, z but not on t .

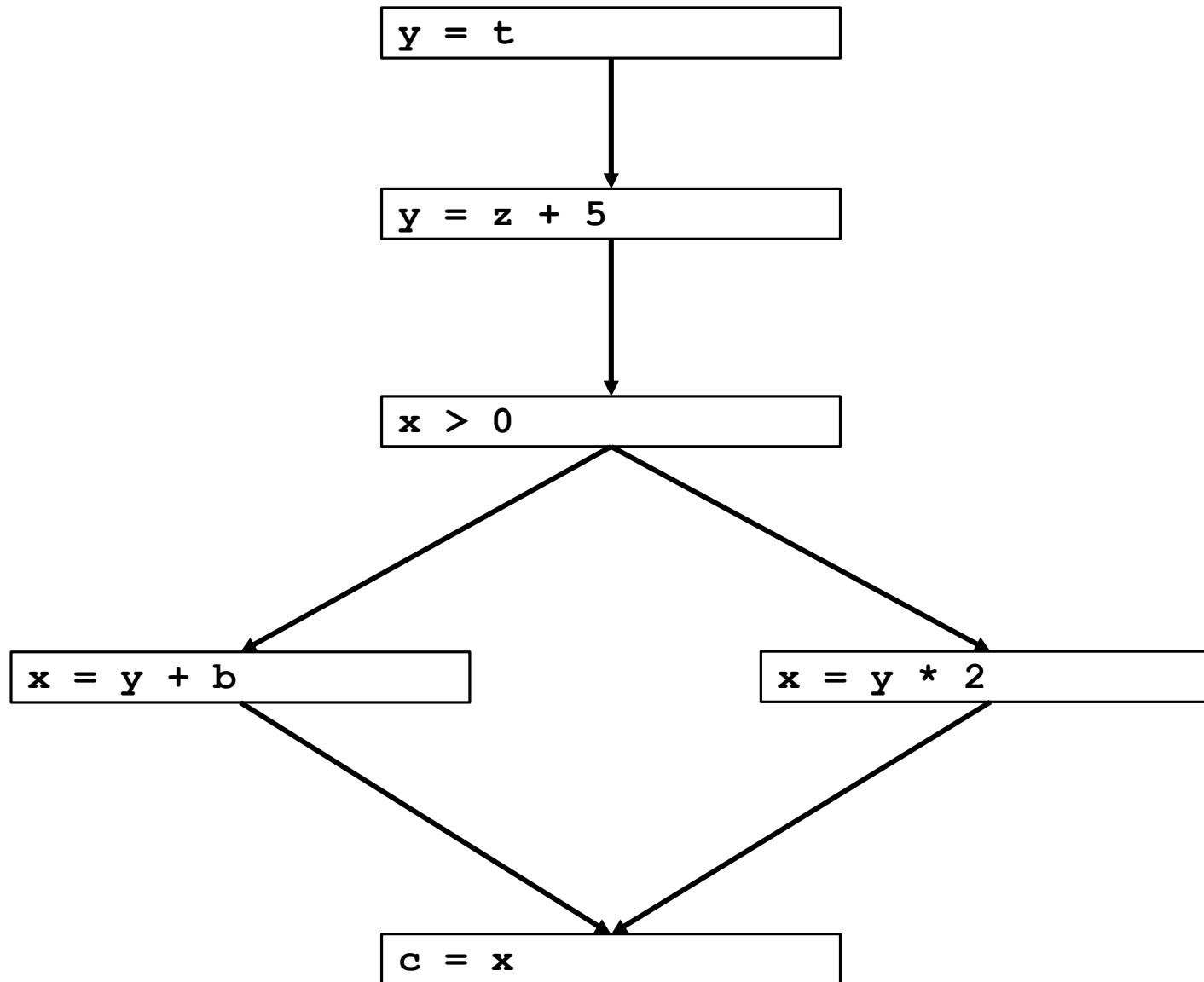
- Define a static analysis in terms of (D, V, \sqcup, F, I)
- Run on the example

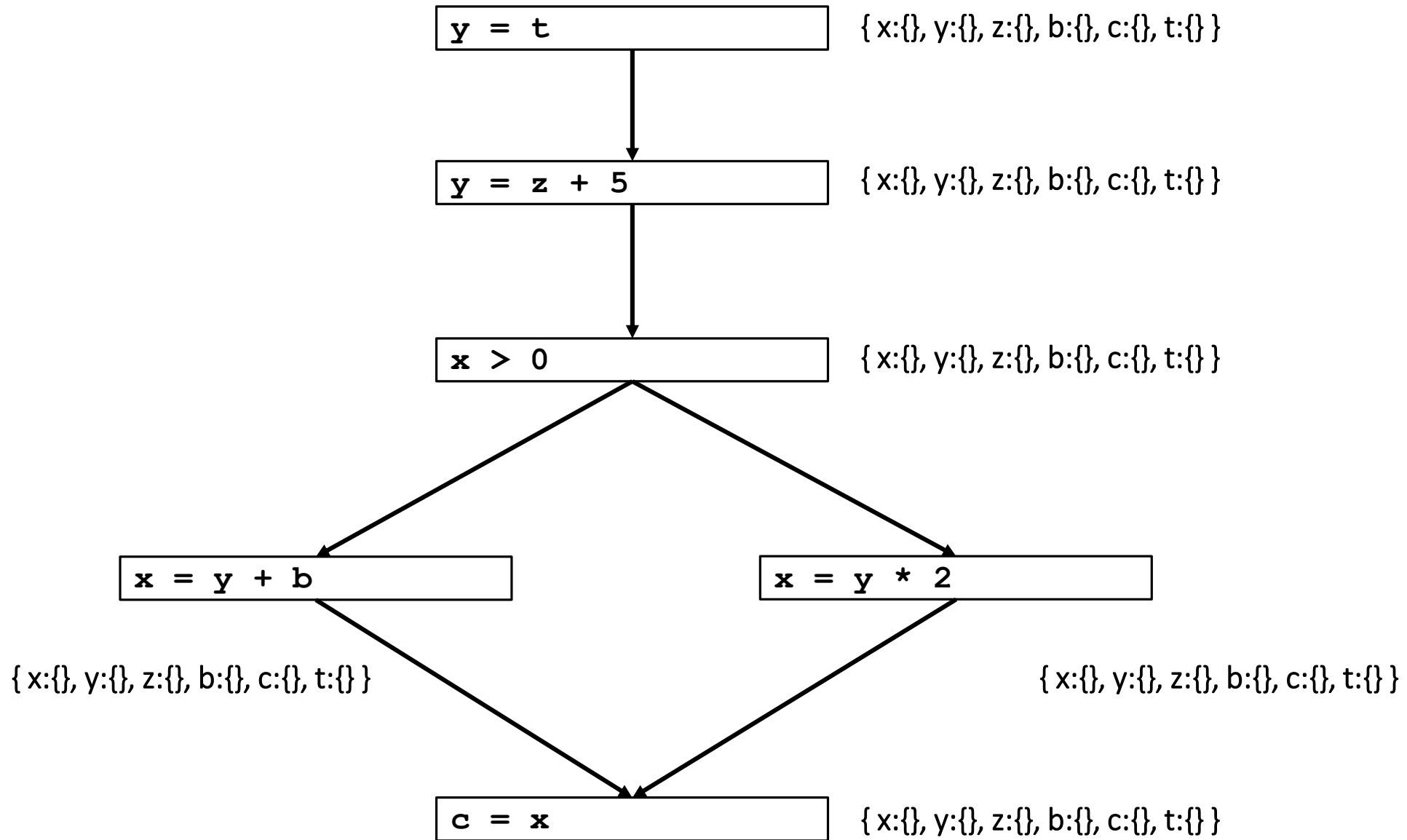
```
y := t;  
y := z + 5;  
if (x > 0) {  
    x := y * 2;  
} else {  
    x := y + b;  
}  
c := x;
```

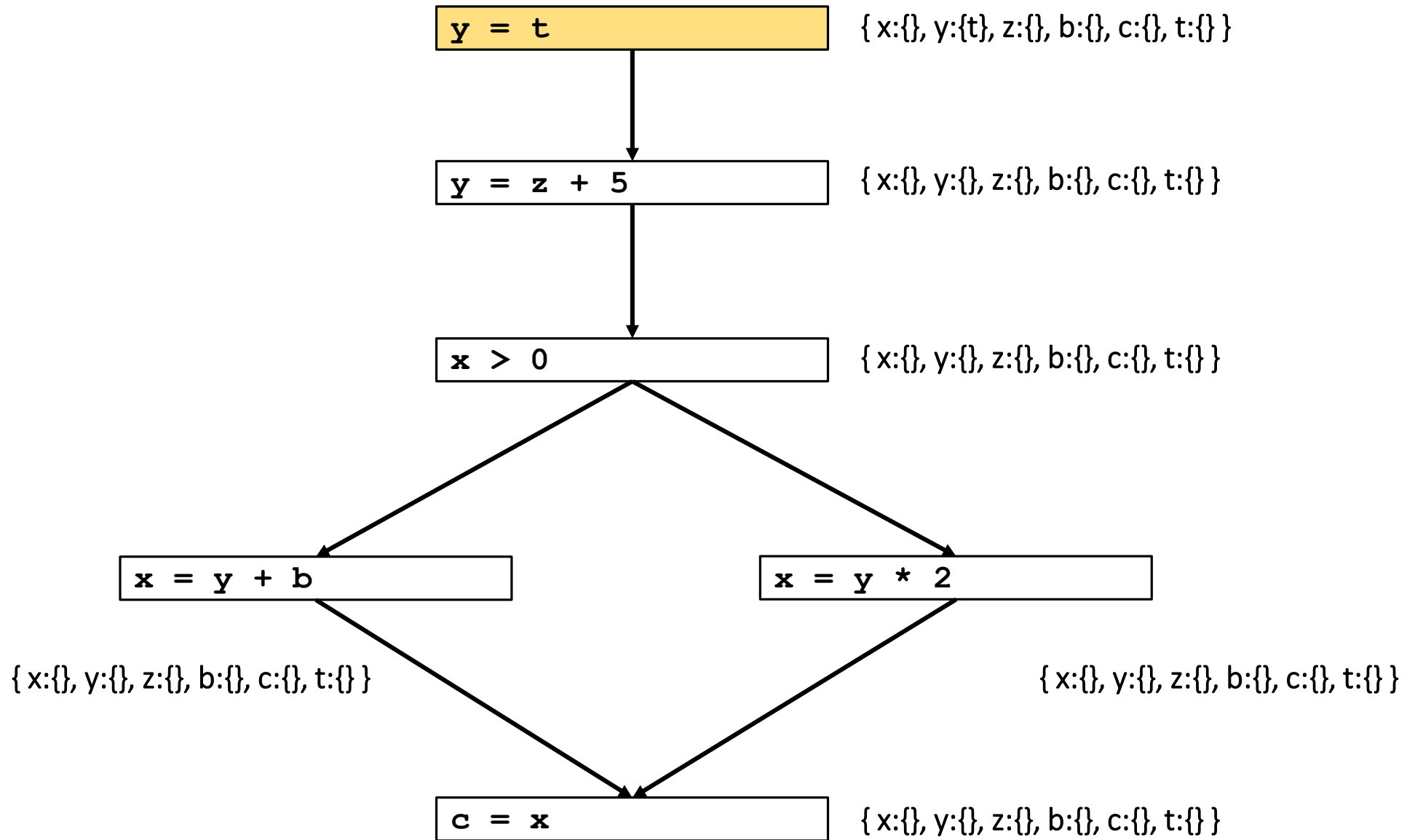
Abstract Domain

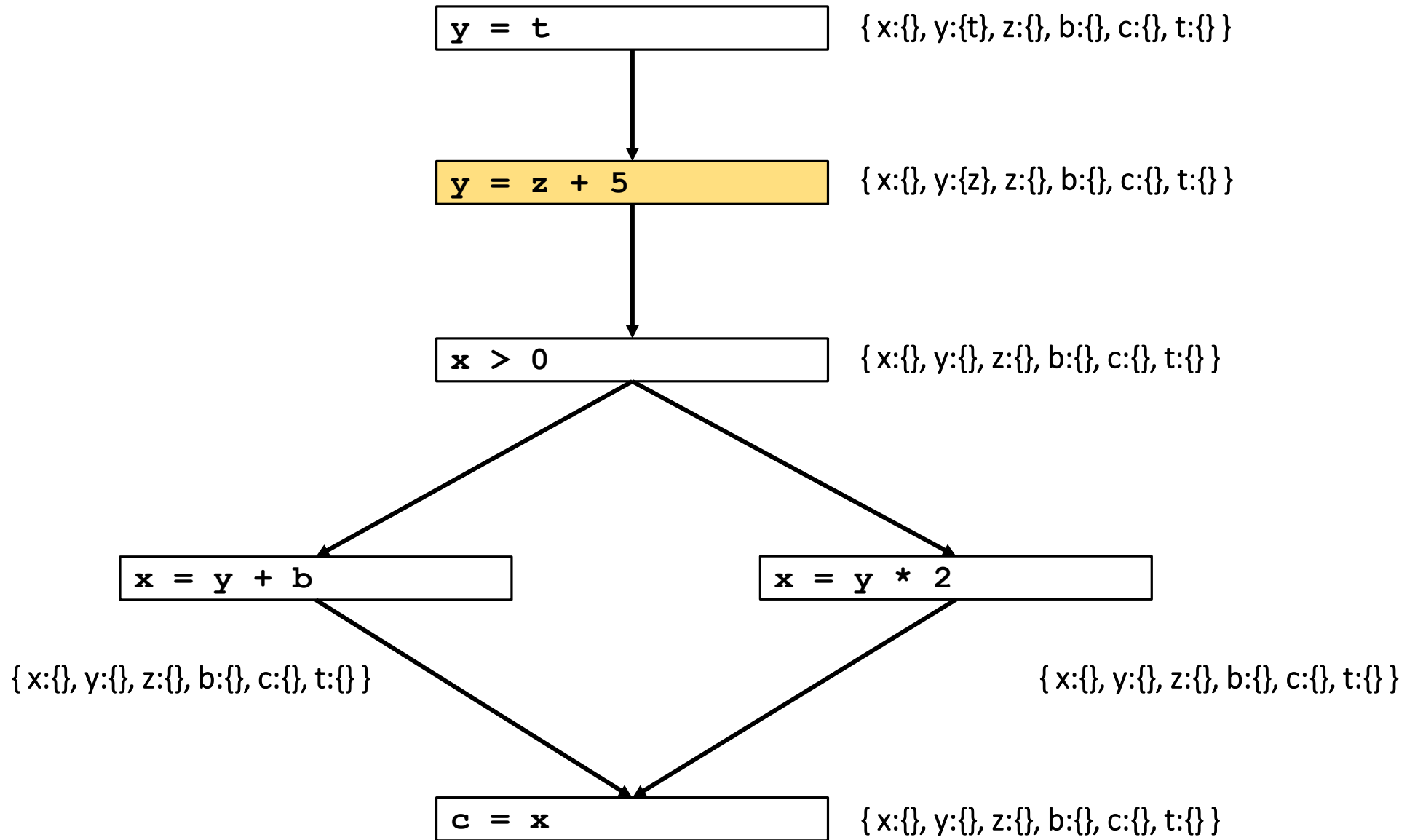
We define (D, V, \sqcup, F, I) :

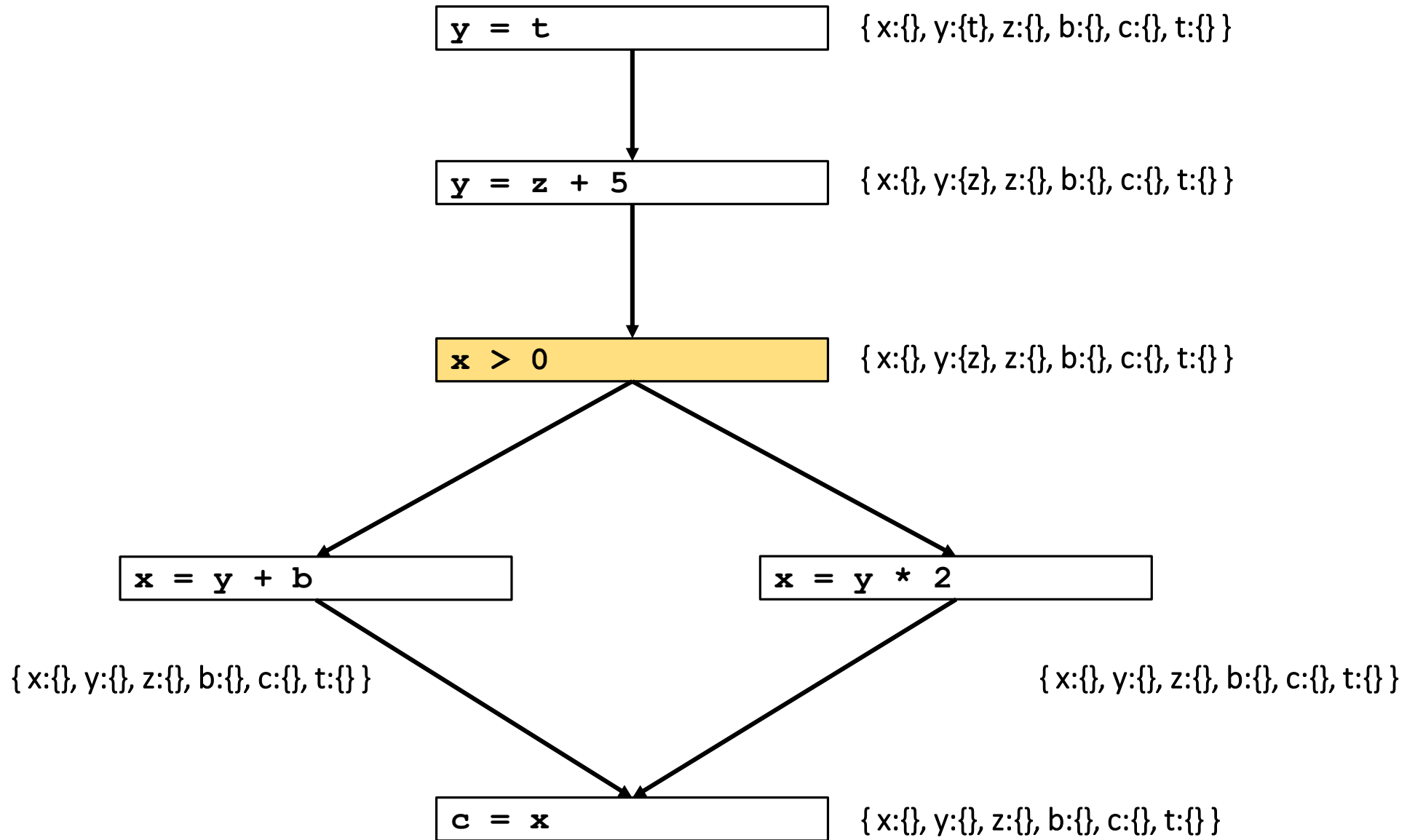
- Forward analysis
- V contains maps of the form:
 - $Var \mapsto P(Var)$ (e.g., $\{a : \{b, c\}\}$)
- Join operator:
 - $m_1 \sqcup m_2 := \lambda v. m_1[v] \cup m_2[v]$
 - $\{a : \{b\}\} \sqcup \{a : \{c\}, d : \{e\}\} = \{a : \{b, c\}, d : \{e\}\}$
- On $a = b + c$:
 - $\{a : s_a, b : s_b, c : s_c, \dots\} \rightarrow \{a : \{b, c\} \cup s_b \cup s_c, b : s_b, c : s_c, \dots\}$
- Initialize with:
 - $\lambda v. \{\}$

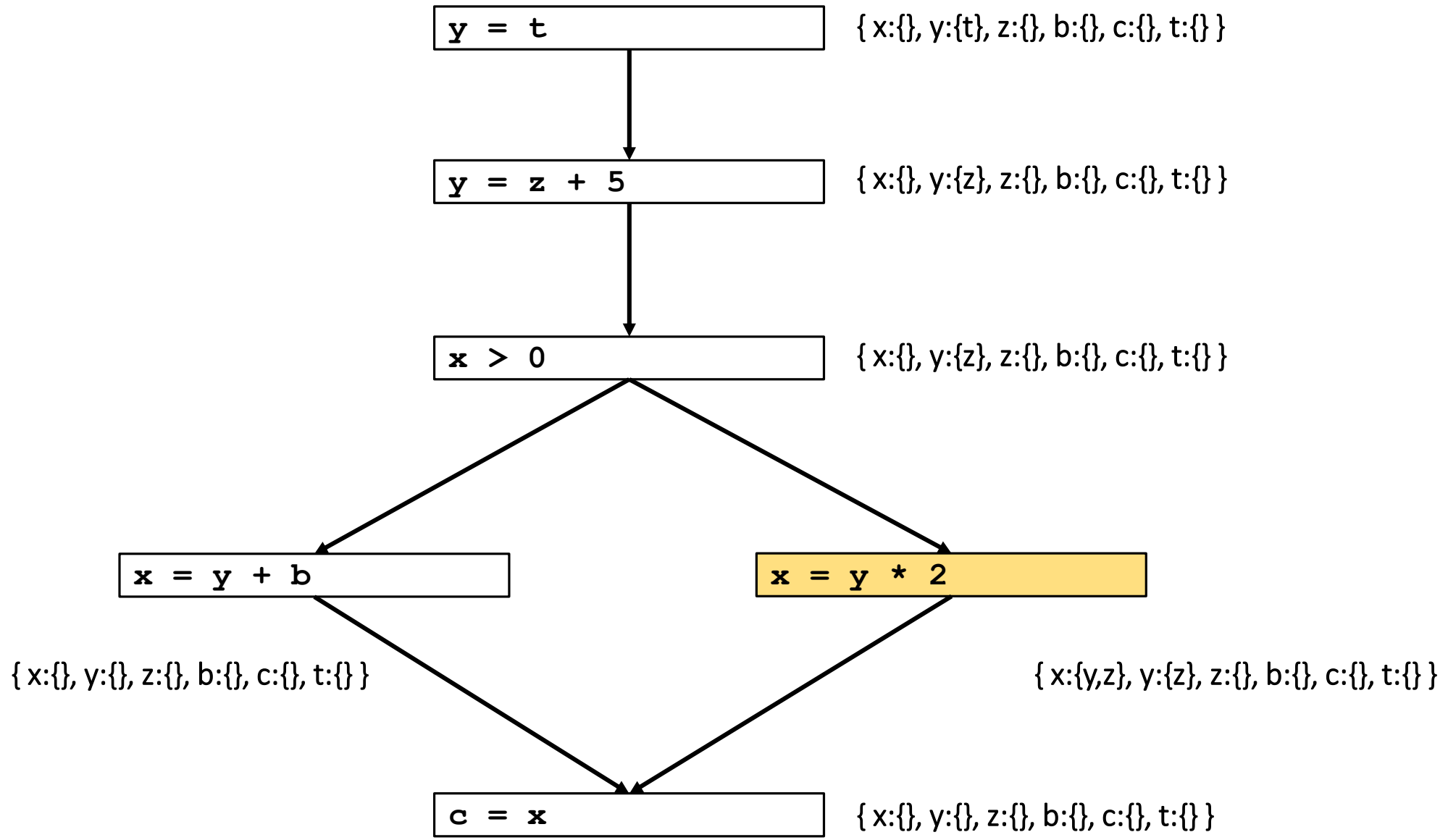


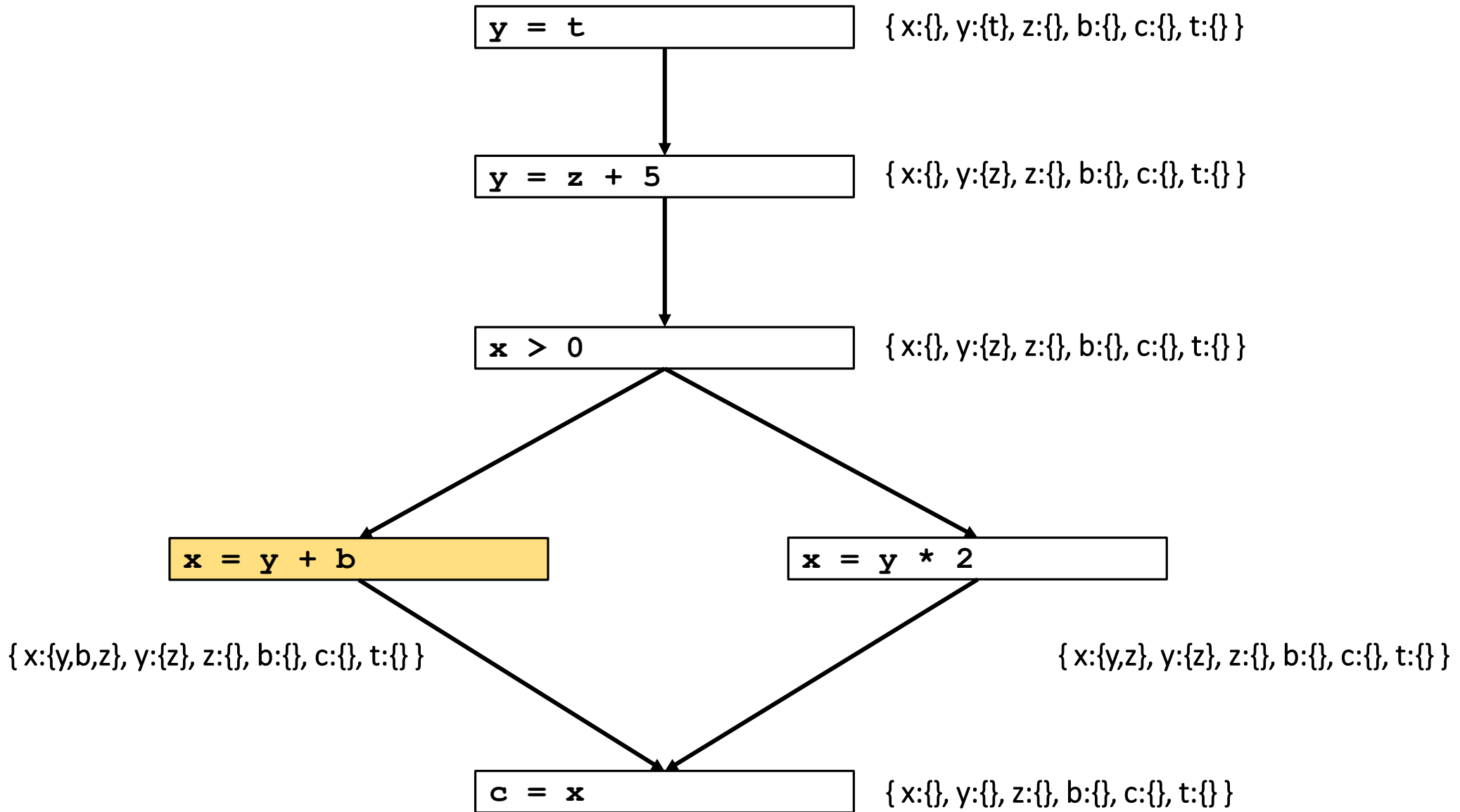


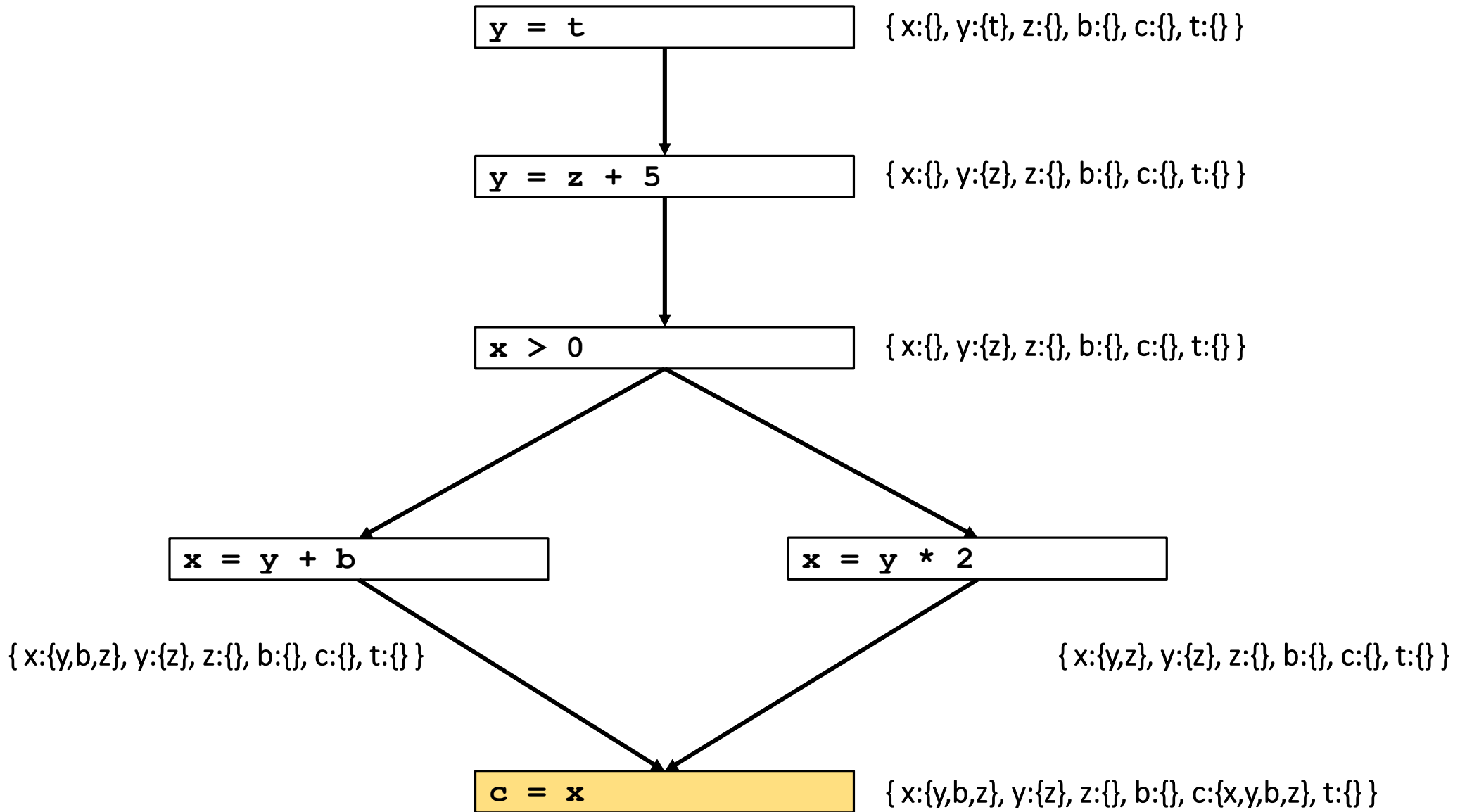












Question

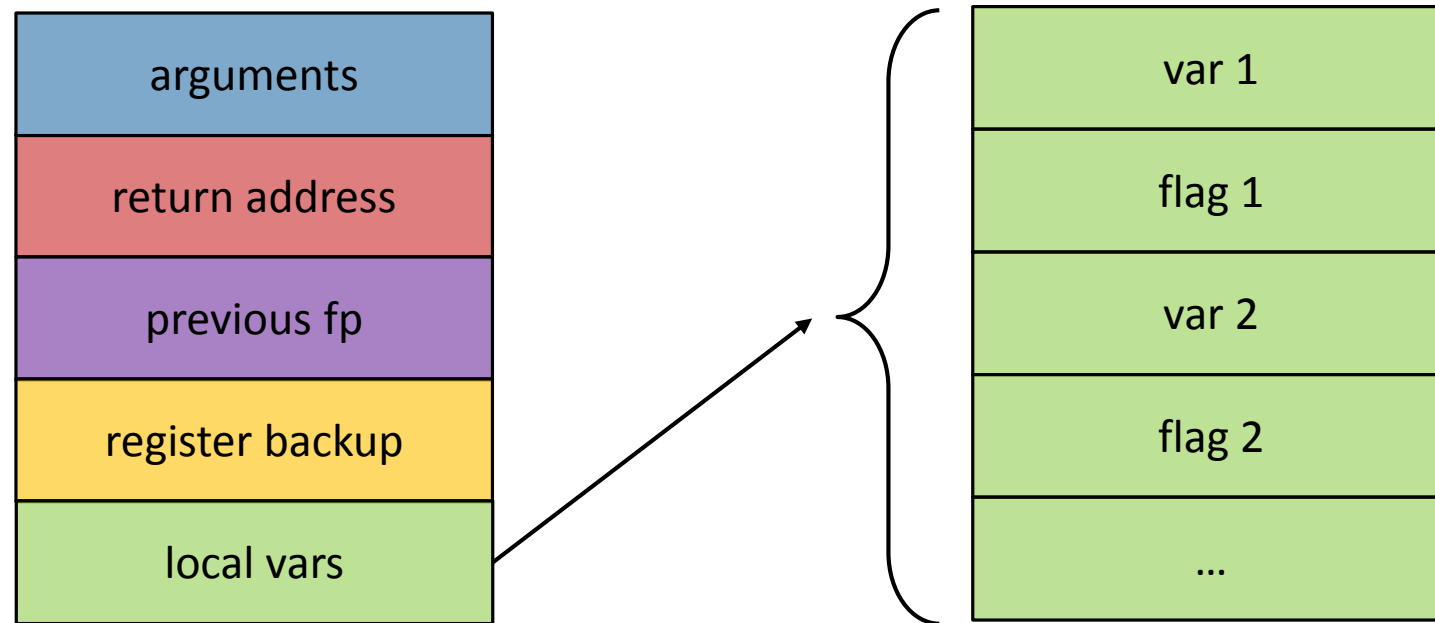
Add support for detecting accesses to uninitialized local variables.
Describe the required changes in the code generation step.

For example:

```
void f() {  
    int x;  
    int y := 7;  
    if (y > 10) {  
        x := 100;  
    }  
    int z := x + 1;  
}
```

Solution

High level idea:



Solution

- Initialize each variable flag to zero on function entry
- When writing to a local variable, set its flag to 1
- When reading a local variable, check if its flag is 1

var 1
flag 1
var 2
flag 2
...

Solution

- **Initialize each variable flag to zero on function entry**
- When writing to a local variable, set its flag to 1
- When reading a local variable, check if its flag is 1

prologue:

```
...  
li $s0, 0  
sw $s0, local_1_flag_offset($fp)  
li $s0, 0  
sw $s0, local_2_flag_offset($fp)  
...
```

var 1
flag 1
var 2
flag 2
...

Solution

- Initialize each variable flag to zero on function entry
- **When writing to a local variable, set its flag to 1**
- When reading a local variable, check if its flag is 1

x = t0

```
sw $t0, x_offset($fp)
li $s0, 1
sw $s0, x_flag_offset($fp)
```

var 1
flag 1
var 2
flag 2
...

Solution

- Initialize each variable flag to zero on function entry
- When writing to a local variable, set its flag to 1
- **When reading a local variable, check if its flag is 1**

`t0 = x`

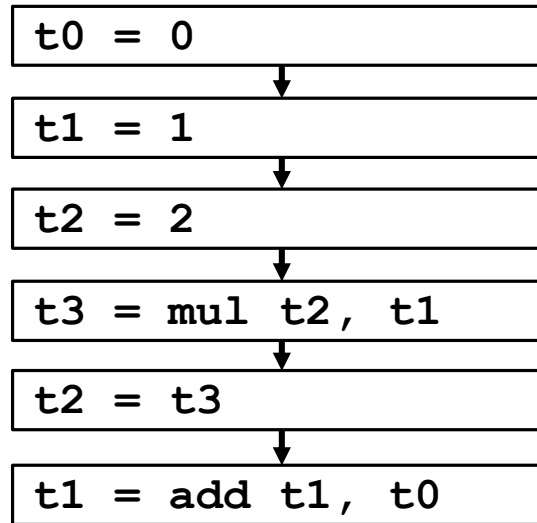
```
lw $s0, x_flag_offset($fp)
beq $s0, 0, abort
lw $t0, x_offset($fp)
```

var 1
flag 1
var 2
flag 2
...

Question

Apply the register allocation algorithm with 3 registers (R1,R2,R3)
R1 can't hold a result of a multiplication operation.

```
t0 = 0
t1 = 1
t2 = 2
t3 = t2 * t1
t2 = t3
t1 = t1 + t0
```



IN

{ }

{ }

{ }

{ }

{ }

{ }

OUT

{ }

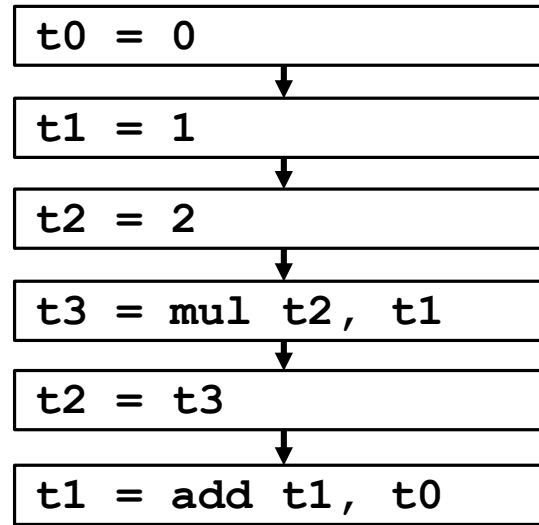
{ }

{ }

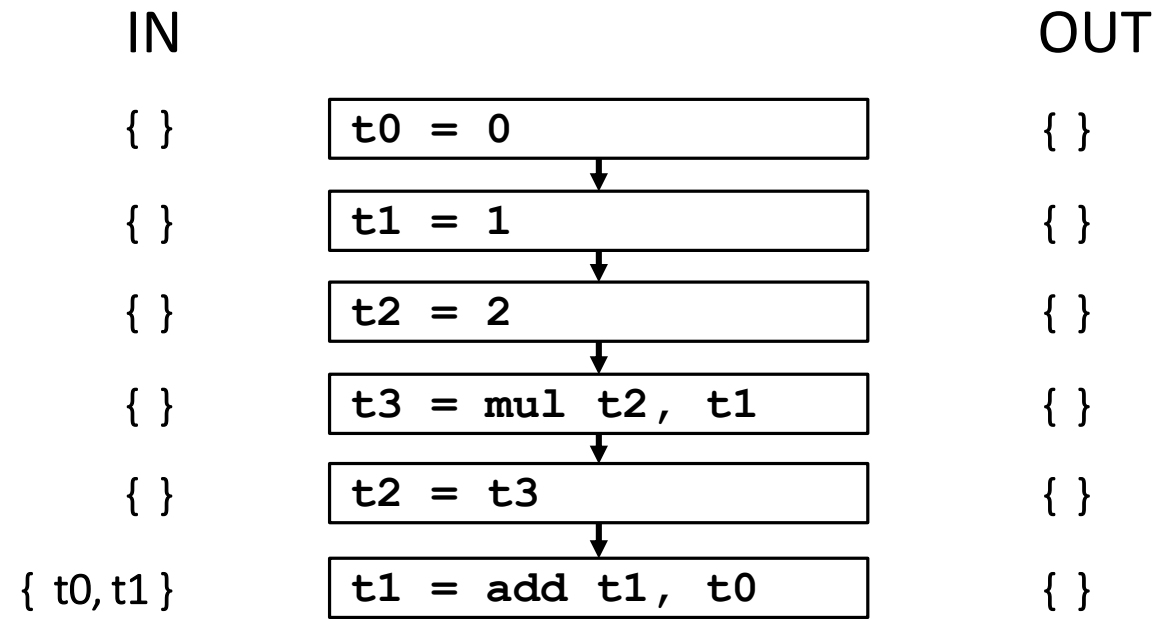
{ }

{ }

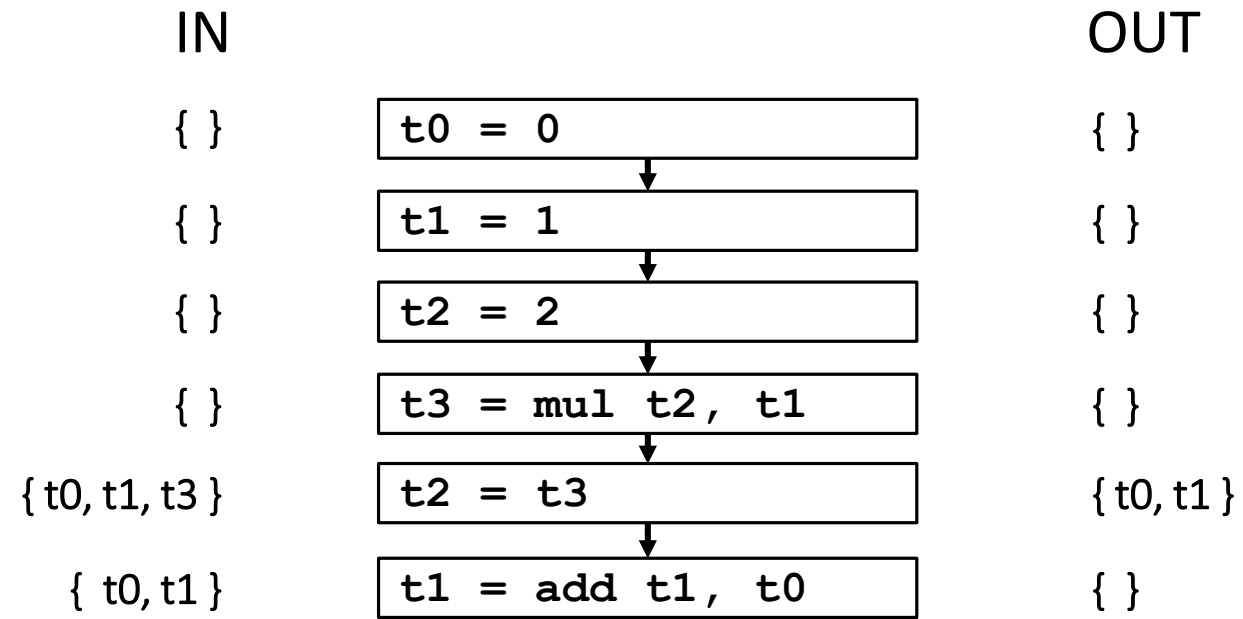
{ }



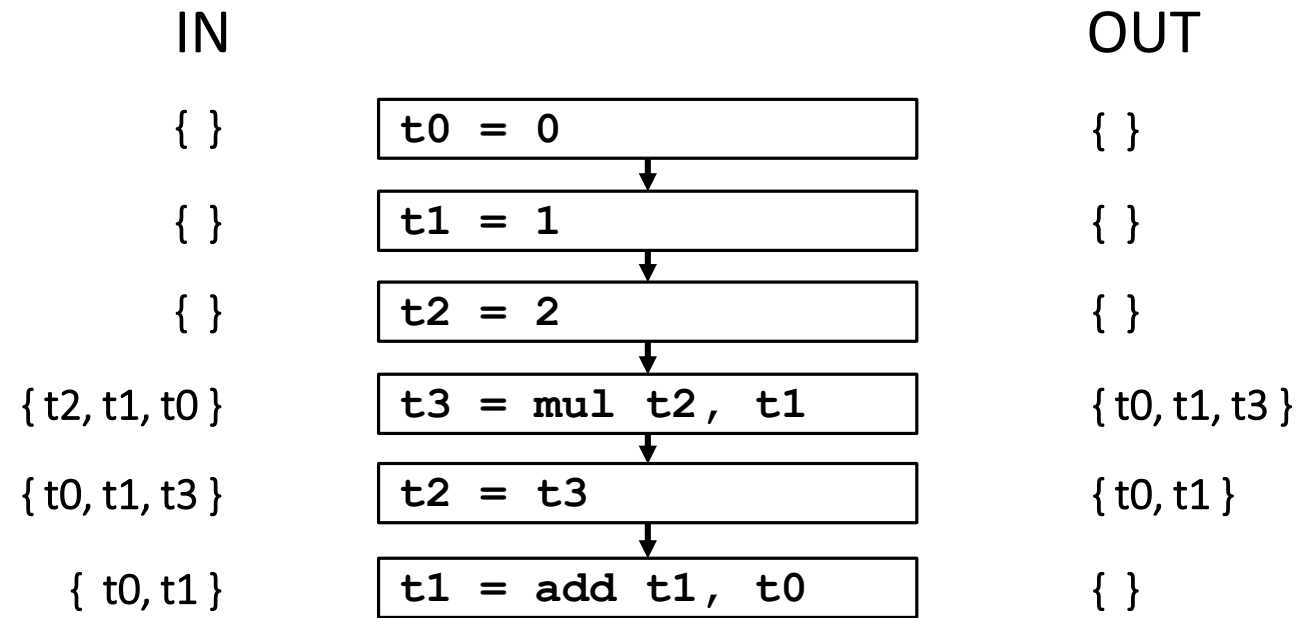
initialization



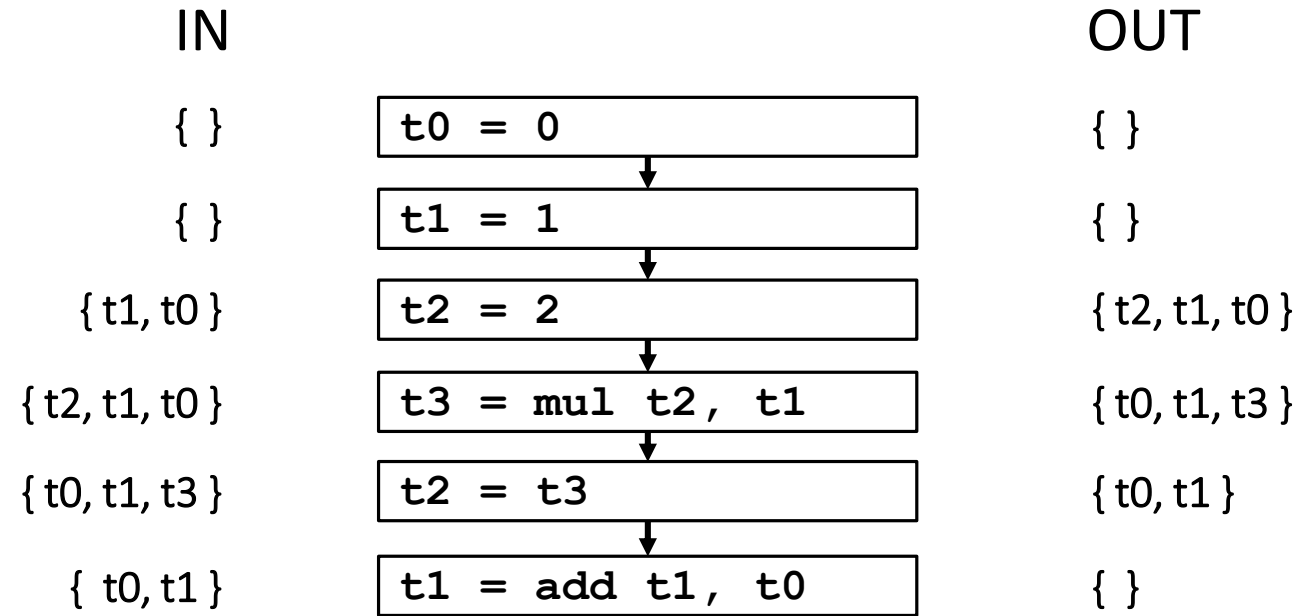
first iteration



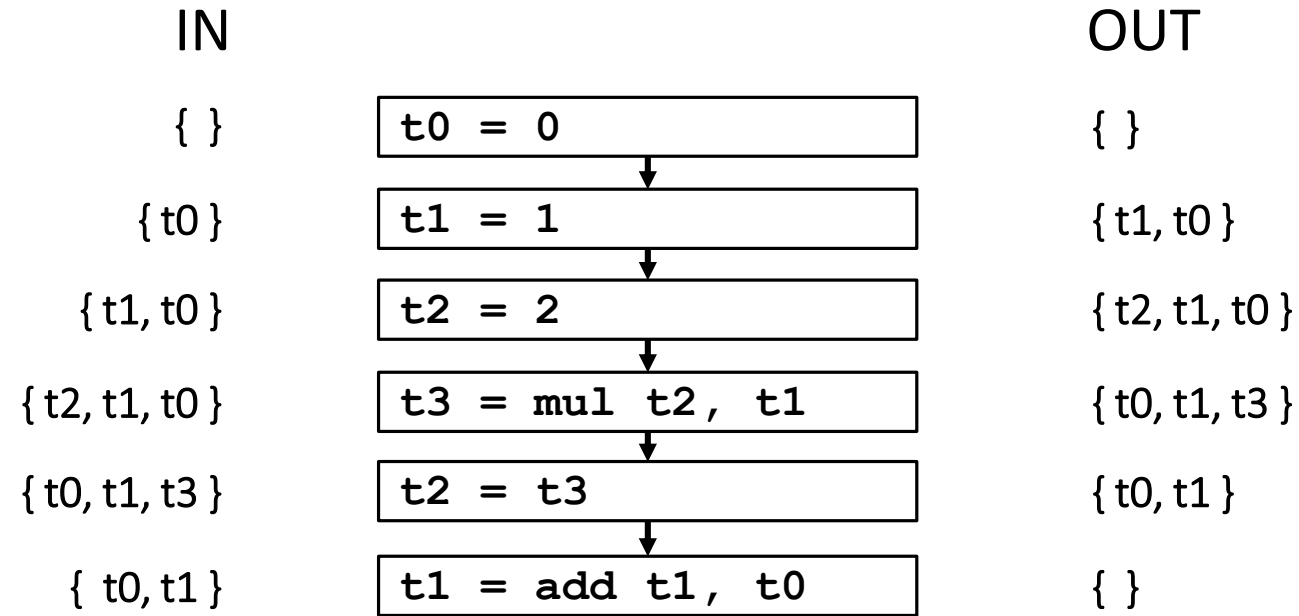
first iteration



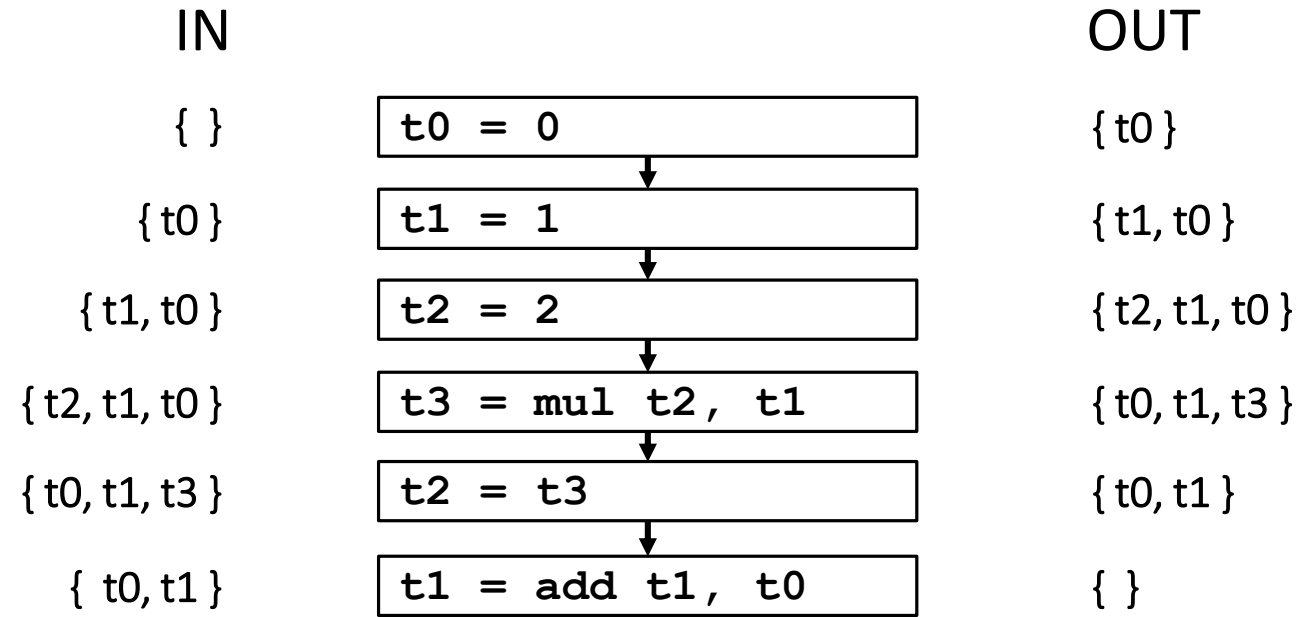
first iteration



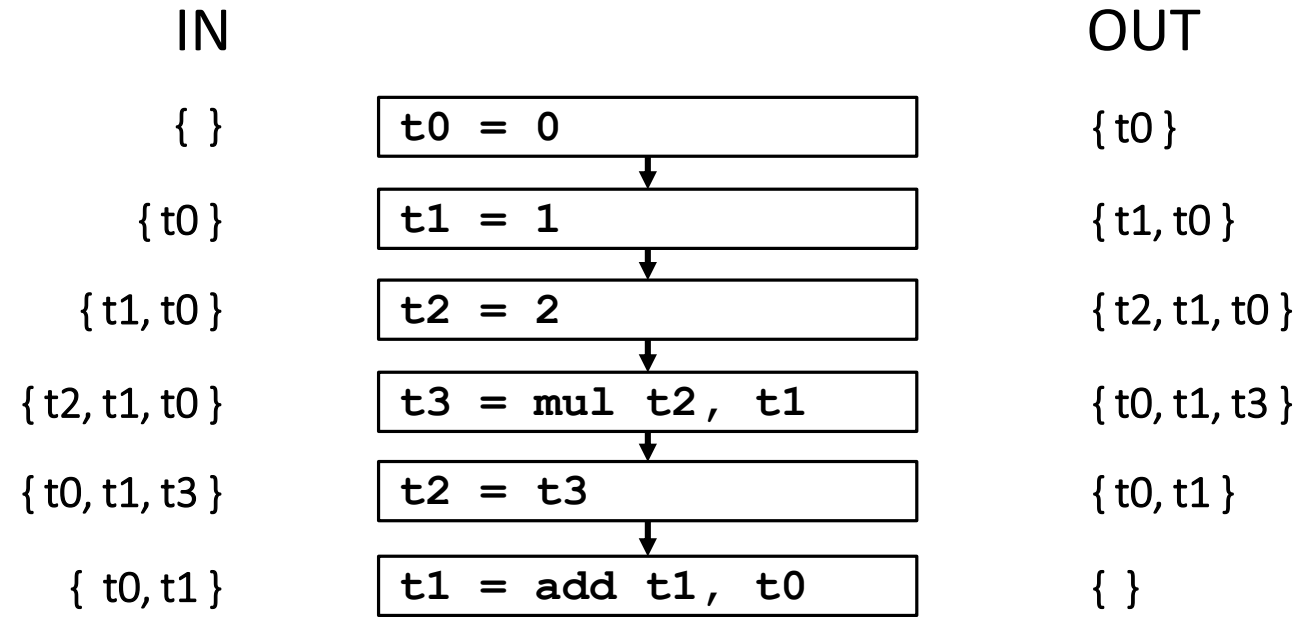
first iteration



first iteration



first iteration



second iteration...

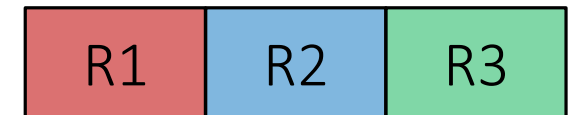
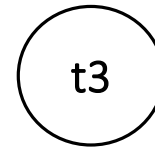
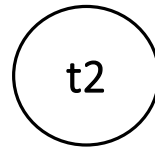
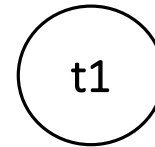
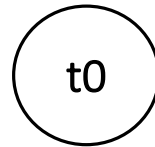
Interference Graph

$\{t_0\}$

$\{t_0, t_1\}$

$\{t_0, t_2, t_1\}$

$\{t_0, t_3\}$



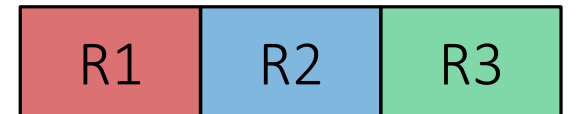
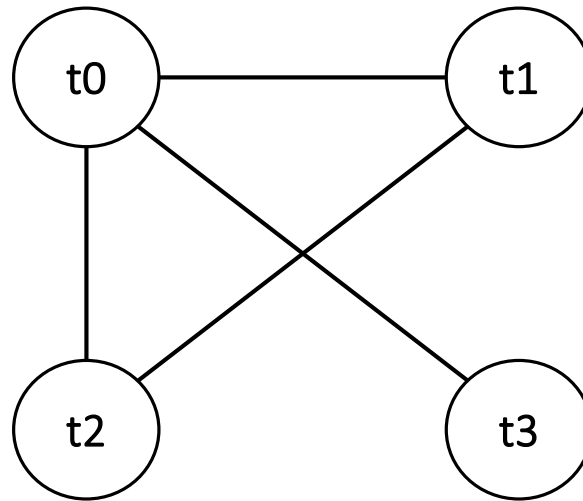
Interference Graph

$\{t_0\}$

$\{t_0, t_1\}$

$\{t_0, t_2, t_1\}$

$\{t_0, t_3\}$



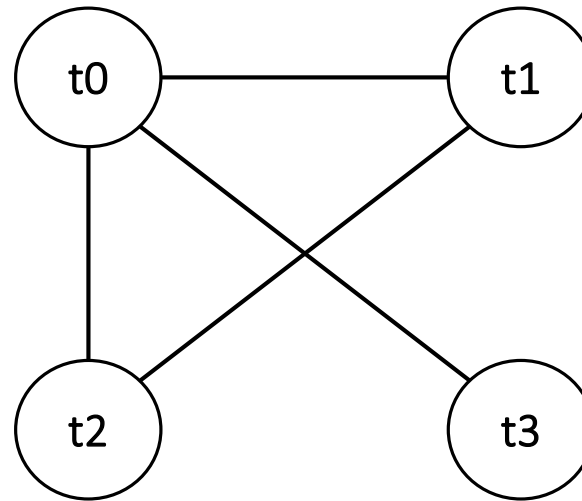
Interference Graph

{ t0 }

{ t0, t1 }

{ t0, t2, t1 }

{ t0, t3 }



t0 = 0

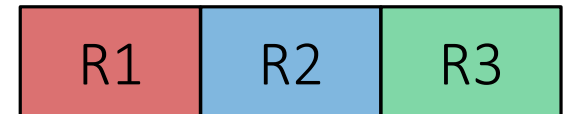
t1 = 1

t2 = 2

t3 = t2 * t1

t2 = t3

t1 = t1 + t0



Interference Graph

{ t0 }

{ t0, t1 }

{ t0, t2, t1 }

{ t0, t3 }

t0 = 0

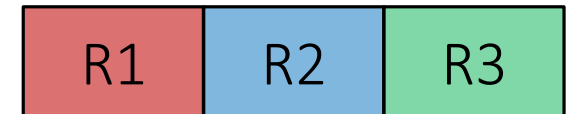
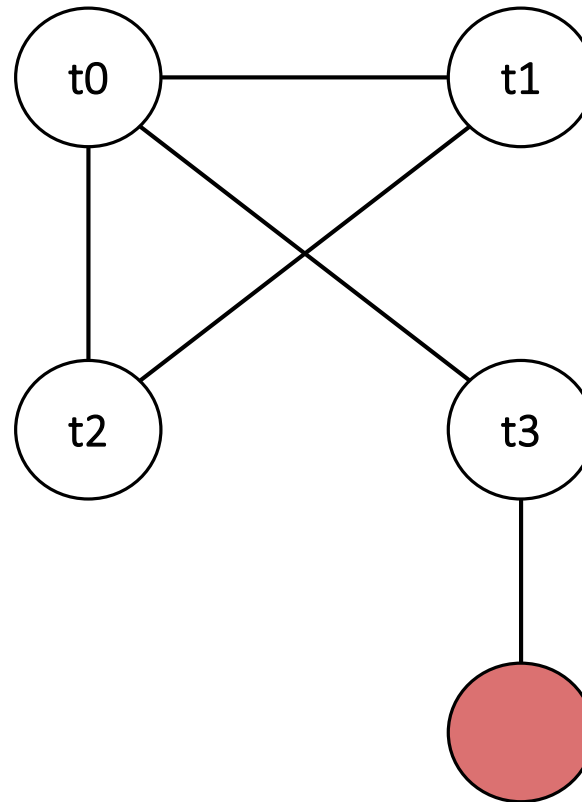
t1 = 1

t2 = 2

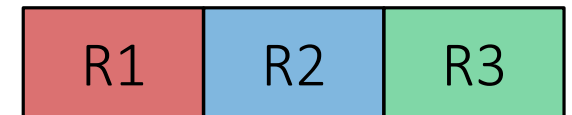
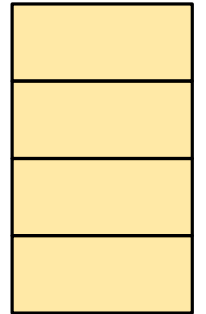
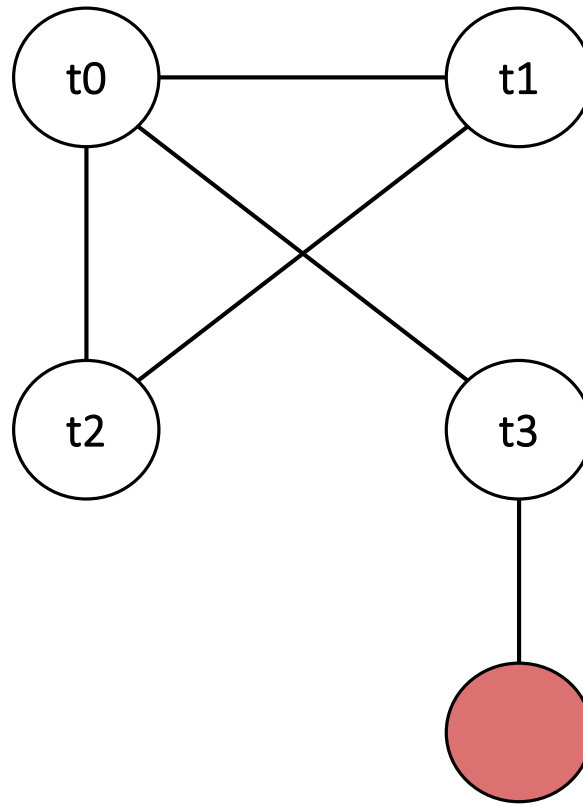
t3 = t2 * t1

t2 = t3

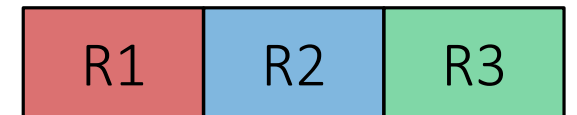
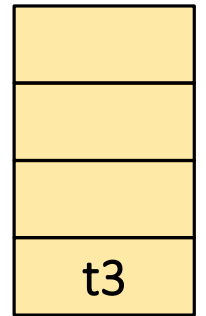
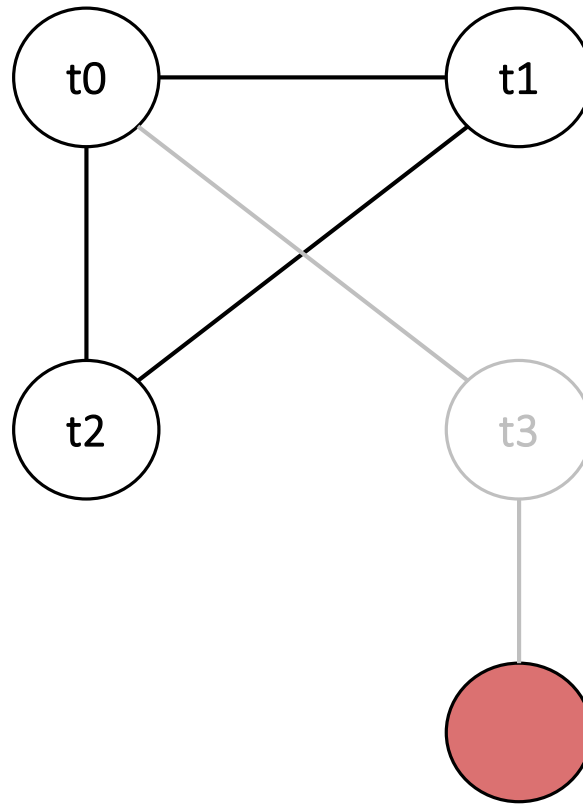
t1 = t1 + t0



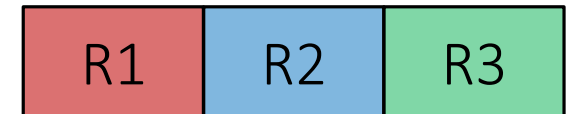
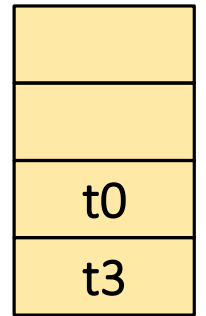
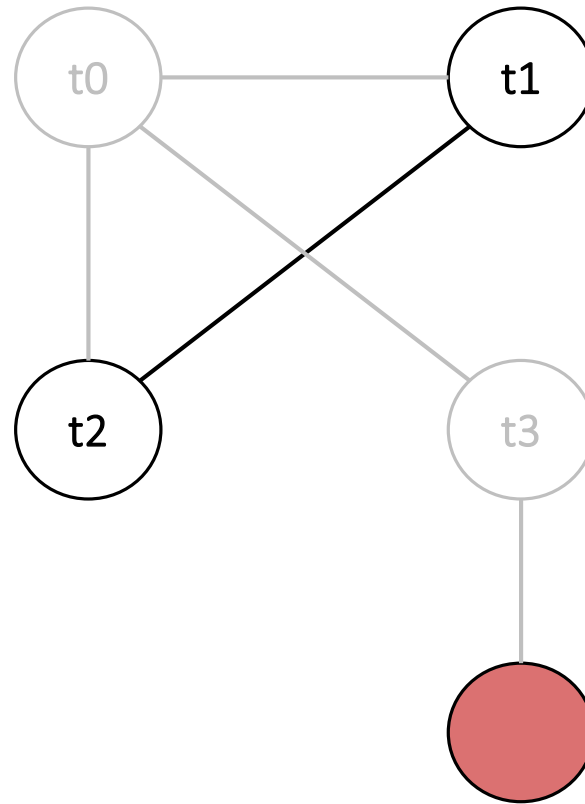
Graph Coloring



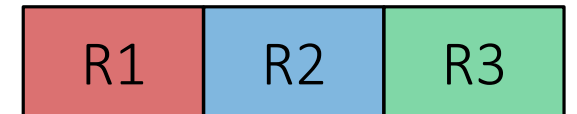
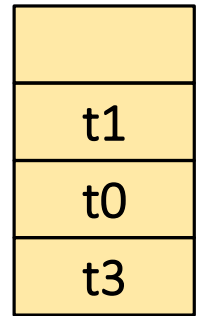
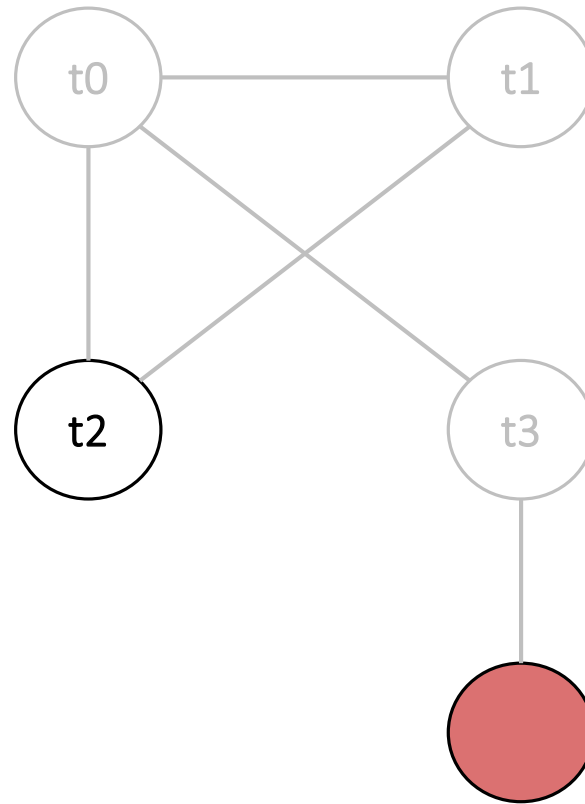
Graph Coloring



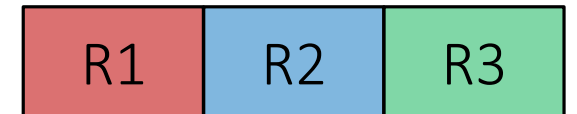
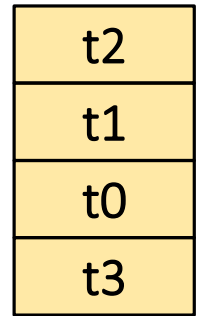
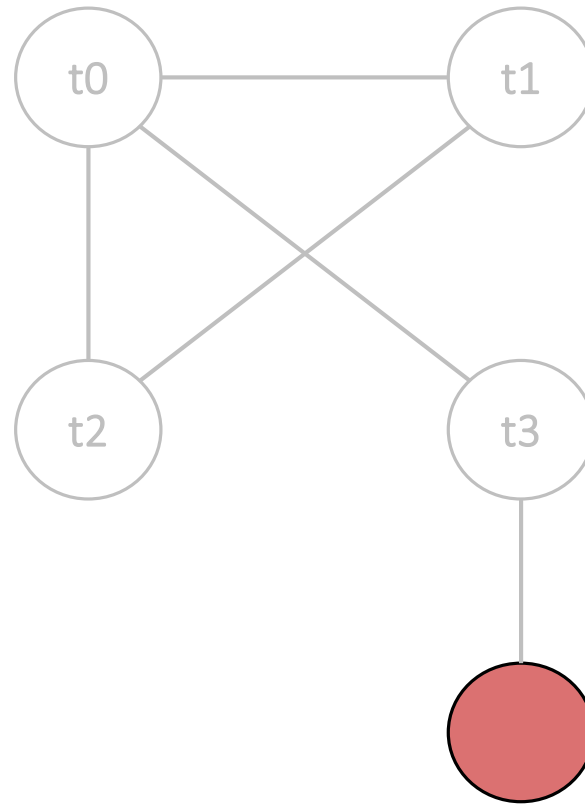
Graph Coloring



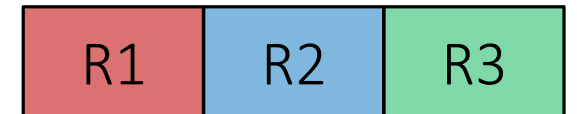
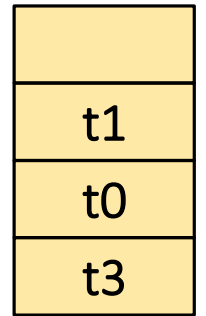
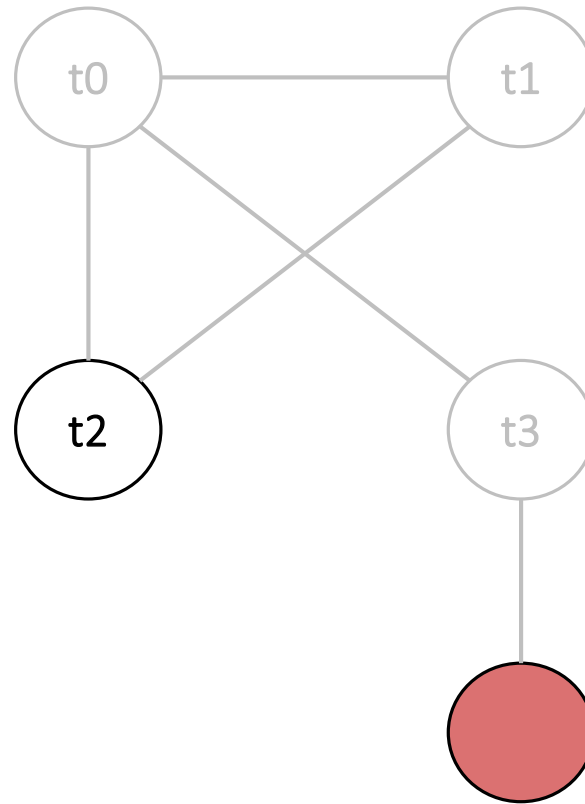
Graph Coloring



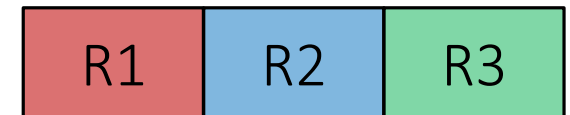
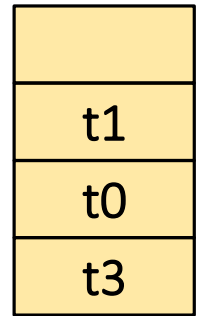
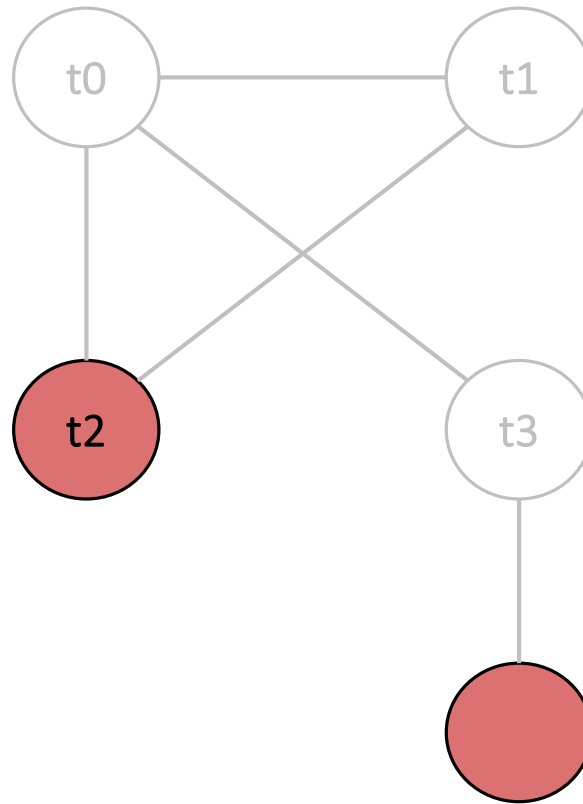
Graph Coloring



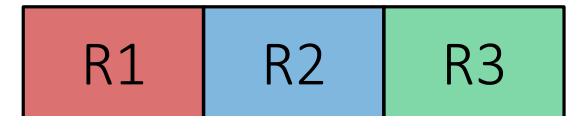
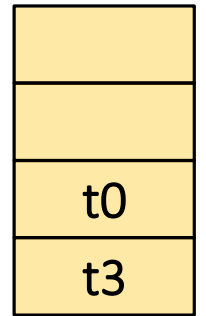
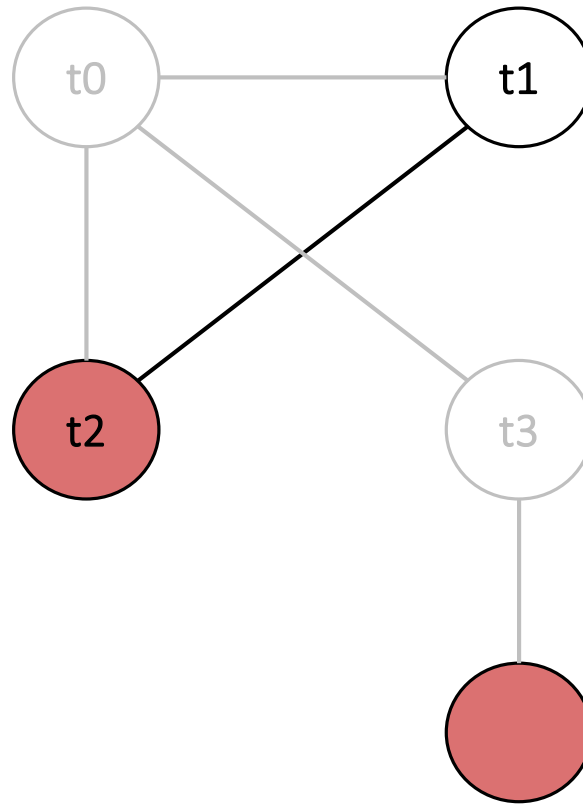
Graph Coloring



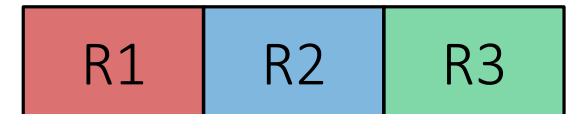
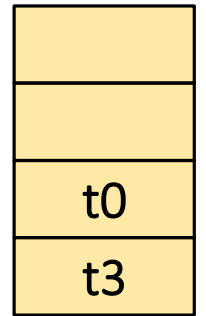
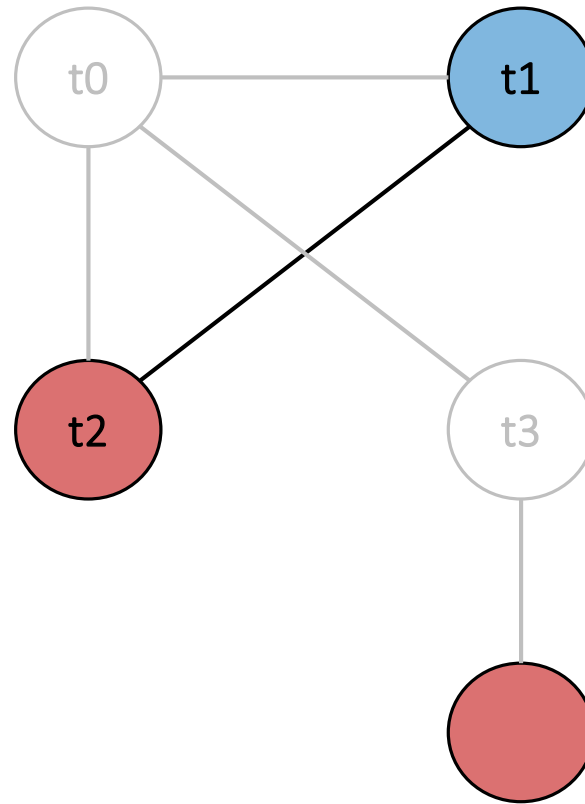
Graph Coloring



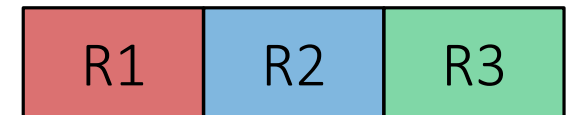
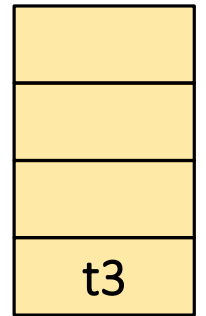
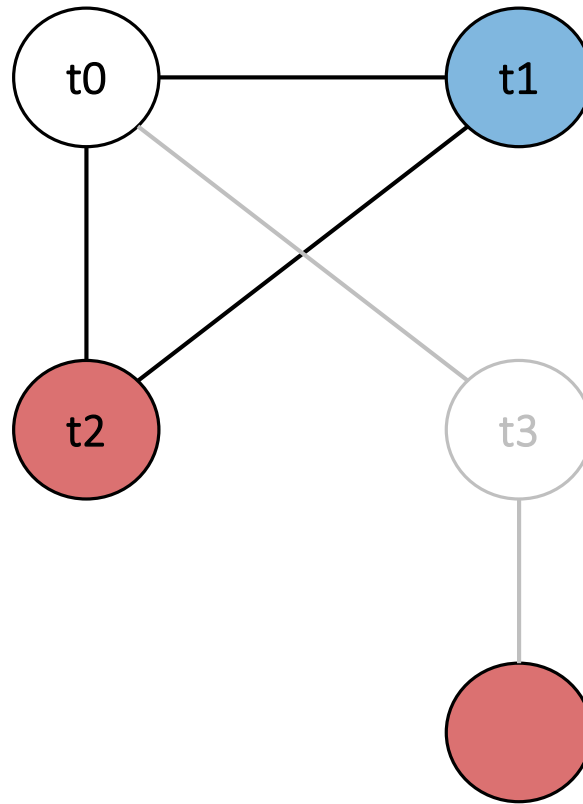
Graph Coloring



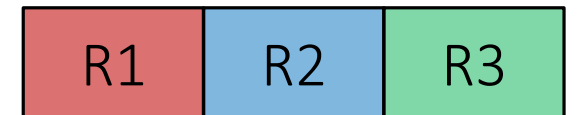
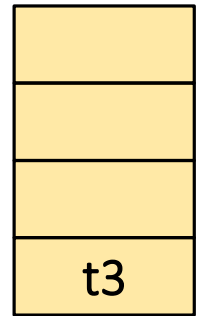
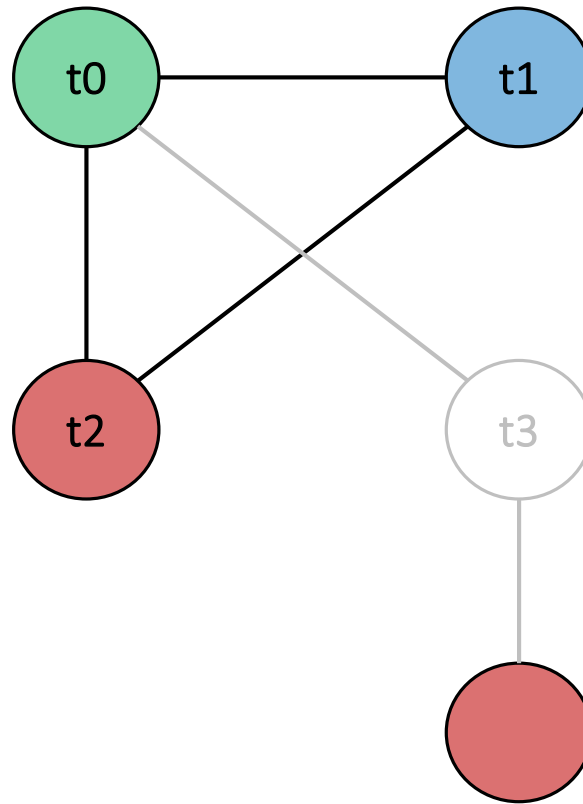
Graph Coloring



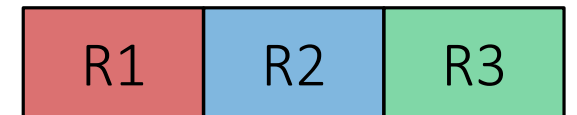
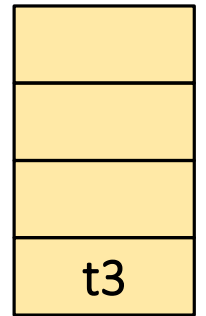
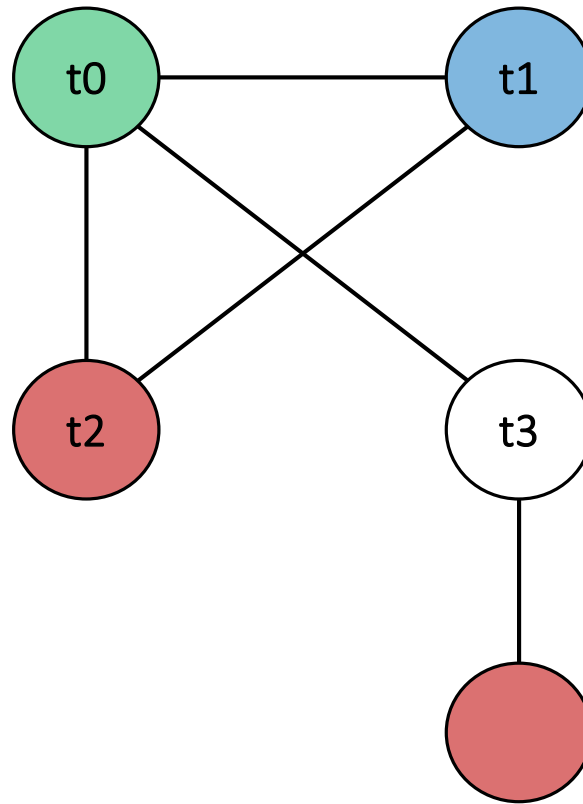
Graph Coloring



Graph Coloring



Graph Coloring



Graph Coloring

