Lab Basic Blocks

J. Nelson Amaral

A Basic Block

Only the first instruction of a basic block can be the target of a branch.

If any instruction of the basic block is executed, then all of them must be executed.

Execution can only start here

```
TARGET:   andi  $t2,  $t0, 0x1
          add   $t2,  $t2, $t4
          or    $t2,  $t3, $t0
          bnez  $t2,  ODD
```

Only the last instruction of the basic block can be a branch or a jump.

Execution can only stop here

A Program Example

```c
int odd_series(int p){
int j=0;
 for (int i=0 ; i<p; i++){
   if(i%2)
     j += i;
   else
     j++;
 }
 return j;
}
```

```
odd_series:
        li      $t0, 0          # i <-- 0
        li      $v0, 0          # j <-- 0
        blez    $a0, DONE       # if (p <= 0) goto DONE
LOOP:
        andi    $t2, $t0, 0x1   # $t2 <-- bit0 of i
        bnez    $t2 ODD         # if i is odd goto ODD
        add     $v0, $v0, $t0   # j <-- j+i
        j       REINIT
ODD:
        add     $v0, $v0, 1     # j <-- j+1
REINIT:
        add     $t0, $t0, 1     # i <-- i+1
        blt     $t0, $a0, LOOP # if i<p goto LOOP
DONE:
        jr      $ra
```

Finding Leaders

Rule 1: The first statement of a procedure is a leader.

```
odd_series:
        li      $t0, 0          # i <-- 0
        li      $v0, 0          # j <-- 0
        blez    $a0, DONE       # if (p <= 0) goto DONE
LOOP:
        andi    $t2, $t0, 0x1   # $t2 <-- bit0 of i
        bnez    $t2 ODD         # if i is odd goto ODD
        add     $v0, $v0, $t0   # j <-- j+i
        j       REINIT
ODD:
        add     $v0, $v0, 1     # j <-- j+1
REINIT:
        add     $t0, $t0, 1     # i <-- i+1
        blt     $t0, $a0, LOOP # if i<p goto LOOP
DONE:
        jr      $ra
```

Rule 2: Any target of a branch or jump is a leader.

```
odd_series:
        li      $t0, 0          # i <-- 0
        li      $v0, 0          # j <-- 0
        blez    $a0, DONE       # if (p <= 0) goto DONE
LOOP:
        andi    $t2, $t0, 0x1   # $t2 <-- bit0 of i
        bnez    $t2 ODD         # if i is odd goto ODD
        add     $v0, $v0, $t0   # j <-- j+i
        j       REINIT
ODD:
        add     $v0, $v0, 1     # j <-- j+1
REINIT:
        add     $t0, $t0, 1     # i <-- i+1
        blt     $t0, $a0, LOOP  # if i<p goto LOOP
DONE:
        jr      $ra
```

Rule 3: Any instruction that follows a branch or jump is a leader.

```
odd_series:
        li      $t0, 0              # i <-- 0
        li      $v0, 0              # j <-- 0
        blez    $a0, DONE           # if (p <= 0) goto DONE
LOOP:
        andi    $t2, $t0, 0x1       # $t2 <-- bit0 of i
        bnez    $t2 ODD             # if i is odd goto ODD
        add     $v0, $v0, $t0       # j <-- j+i
        j       REINIT
ODD:
        add     $v0, $v0, 1         # j <-- j+1
REINIT:
        add     $t0, $t0, 1         # i <-- i+1
        blt     $t0, $a0, LOOP # if i<p goto LOOP
DONE:
        jr      $ra
```

Instruction	Encoding
`beq $s, $t, offset`	`0001 00ss ssst tttt oooo oooo oooo oooo`
`bgez $s, offset`	`0000 01ss sss0 0001 oooo oooo oooo oooo`
`bgezal $s, offset`	`0000 01ss sss1 0001 oooo oooo oooo oooo`
`bgtz $s, offset`	`0001 11ss sss0 0000 oooo oooo oooo oooo`
`blez $s, offset`	`0001 10ss sss0 0000 oooo oooo oooo oooo`
`bltz $s, offset`	`0000 01ss sss0 0000 oooo oooo oooo oooo`
`bltzal $s, offset`	`0000 01ss sss1 0000 oooo oooo oooo oooo`
`bne $s, $t, offset`	`0001 01ss ssst tttt oooo oooo oooo oooo`
`j target`	`0000 10aa aaaa aaaa aaaa aaaa aaaa aaaa`
`jal target`	`0000 11aa aaaa aaaa aaaa aaaa aaaa aaaa`
`jr $s`	`0000 00ss sss0 0000 0000 0000 0000 1000`

Finding the Leaders – Lab #2

Instruction	**Encoding**
`beq $s, $t, offset`	`0001 00ss ssst tttt oooo oooo oooo oooo`
`bgez $s, offset`	`0000 01ss sss0 0001 oooo oooo oooo oooo`
`bgezal $s, offset`	`0000 01ss sss1 0001 oooo oooo oooo oooo`
`bgtz $s, offset`	`0001 11ss sss0 0000 oooo oooo oooo oooo`
`blez $s, offset`	`0001 10ss sss0 0000 oooo oooo oooo oooo`
`bltz $s, offset`	`0001 10ss sss0 0000 oooo oooo oooo oooo`
`bne $s, $t, offset`	`0001 01ss ssst tttt oooo oooo oooo oooo`
`j target`	`0000 10aa aaaa aaaa aaaa aaaa aaaa aaaa`
`jal target`	`0000 11aa aaaa aaaa aaaa aaaa aaaa aaaa`
`jr $s`	`0000 00ss sss0 0000 0000 0000 0000 1000`

Given the Leaders,
How do we get the Basic Blocks?

A basic block is the leader followed by all subsequent instructions up to, but not including, the next leader.

```
odd_series:
        li      $t0, 0              # i <-- 0
        li      $v0, 0              # j <-- 0
        blez    $a0, DONE           # if (p <= 0) goto DONE
LOOP:
        andi    $t2, $t0, 0x1       # $t2 <-- bit0 of i
        bnez    $t2 ODD             # if i is odd goto ODD
        add     $v0, $v0, $t0       # j <-- j+i
        j       REINIT
ODD:
        add     $v0, $v0, 1         # j <-- j+1
REINIT:
        add     $t0, $t0, 1         # i <-- i+1
        blt     $t0, $a0, LOOP      # if i<p goto LOOP
DONE:
        jr      $ra
```

A basic block is the leader followed by all subsequent instructions up to, but not including, the next leader.

```
odd_series:
        li      $t0, 0              # i <-- 0
        li      $v0, 0              # j <-- 0
        blez    $a0, DONE           # if (p <= 0) goto DONE
LOOP:
        andi    $t2, $t0, 0x1       # $t2 <-- bit0 of i
        bnez    $t2 ODD             # if i is odd goto ODD
        add     $v0, $v0, $t0       # j <-- j+i
        j       REINIT
ODD:
        add     $v0, $v0, 1         # j <-- j+1
REINIT:
        add     $t0, $t0, 1         # i <-- i+1
        blt     $t0, $a0, LOOP      # if i<p goto LOOP
DONE:
        jr      $ra
```

The Actual Code

0
```
[10010000] 34080000  ori $8, $0, 0              ; 52: li $t0, 0 # i
[10010004] 34020000  ori $2, $0, 0              ; 53: li $v0, 0 # j
[10010008] 18800009  blez $4 36 [DONE-0x10010008]; 54: blez $a0, DONE #
```

1
```
[1001000c] 310a0001  andi $10, $8, 1            ; 56: andi $t2, $t0, 0x1 #
[10010010] 15400003  bne $10, $
```

2
```
[10010014] 00481020  add $2, $2
[10010018] 08100029  j 0x100100
```

3
```
[1001001c] 20420001  addi $2, $
```

4
```
[10010020] 21080001  addi $8, $
[10010024] 0104082a  slt $1, $8
[10010028] 1420fff9  bne $1, $0
```

5
```
[1001002c] 03e00008  jr $31
```

6 block(s) found.

Block Leader: 0x10010000, Size: 3

Block Leader: 0x1001000C, Size: 2

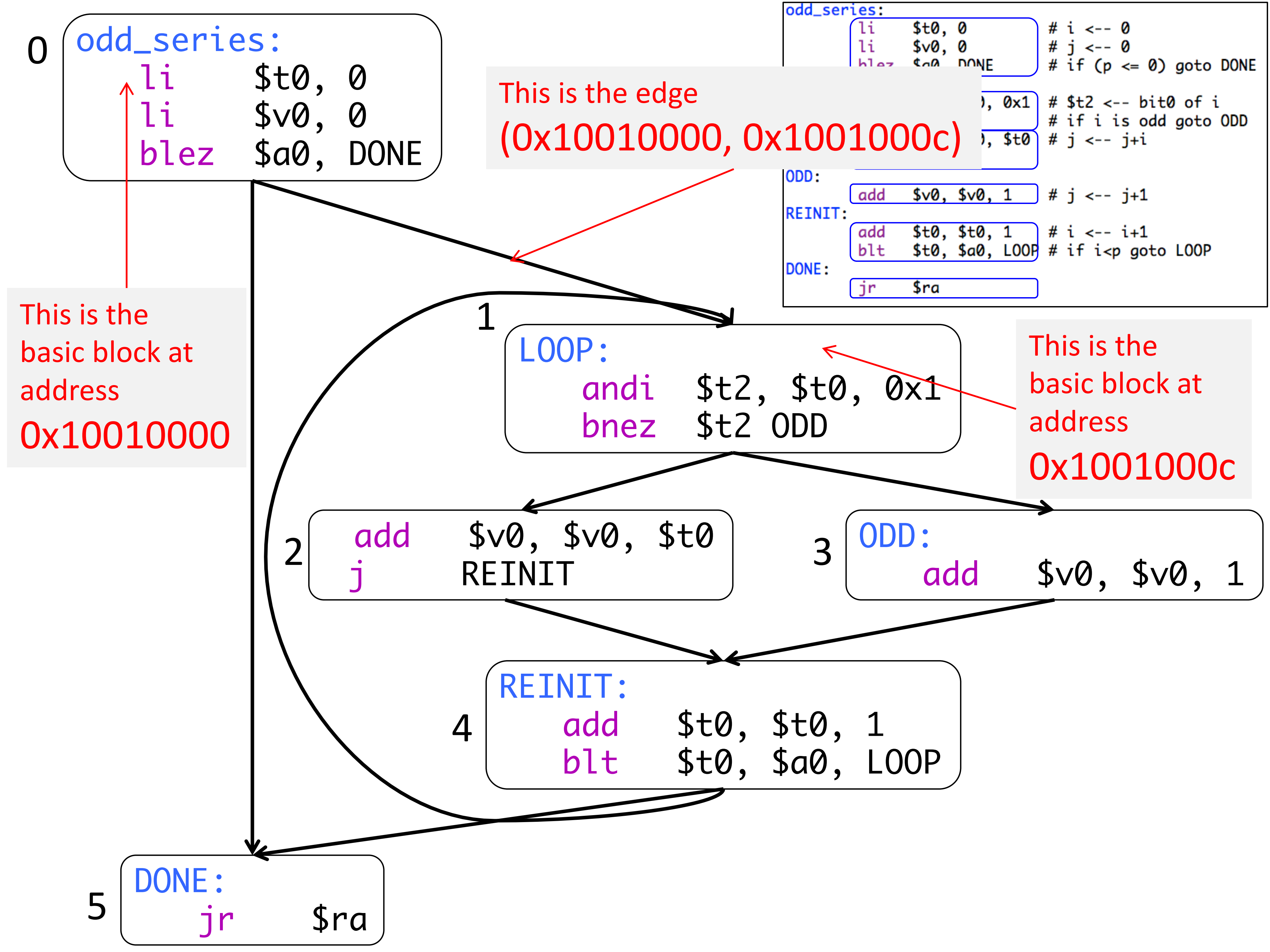
Block Leader: 0x10010014, Size: 2

Block Leader: 0x1001001C, Size: 1

Block Leader: 0x10010020, Size: 3

Block Leader: 0x1001002C, Size: 1

Control Flow Graphs



0
odd_series:
li $t0, 0
li $v0, 0
blez $a0, DONE
This is the edge
(0x10010000, 0x1001000c)
1
LOOP:
andi $t2, $t0, 0x1
bnez $t2 ODD
2
add $v0, $v0, $t0
j REINIT
3
ODD:
add $v0, $v0, 1
4
REINIT:
add $t0, $t0, 1
blt $t0, $a0, LOOP
5
DONE:
jr $ra
This is the basic block at address 0x10010000
This is the basic block at address 0x1001000c
odd_series:
li $t0, 0 # i <-- 0
li $v0, 0 # j <-- 0
if (p <= 0) goto DONE
$t2 <-- bit0 of i
if i is odd goto ODD
j <-- j+i
ODD:
add $v0, $v0, 1 # j <-- j+1
REINIT:
add $t0, $t0, 1 # i <-- i+1
blt $t0, $a0, LOOP # if i<p goto LOOP
DONE:
jr $ra

The Actual Code

```
0
[10010000] 34080000  ori $8, $0, 0                ; 52: li $t0, 0 # i
[10010004] 34020000  ori $2, $0, 0                ; 53: li $v0, 0 # j
[10010008] 18800009  blez $4 36 [DONE-0x10010008]; 54: blez $a0, DONE #

1
[1001000c] 310a0001  andi $10, $8, 1              ; 56: andi $t2, $t0, 0x1 #
[10010010] 15400003  bne $10, $0, 12

2
[10010014] 00481020  add $2, $2, $8
[10010018] 08100029  j 0x10010020 [R

3
[1001001c] 20420001  addi $2, $2, 1

4
[10010020] 21080001  addi $8, $8, 1
[10010024] 0104082a  slt $1, $8, $4
[10010028] 1420fff9  bne $1, $0, -28

5
[1001002c] 03e00008  jr $31
```

Edges:

0x10010000 --> 0x1001000C

0x10010000 --> 0x1001002C

0x1001000C --> 0x10010014

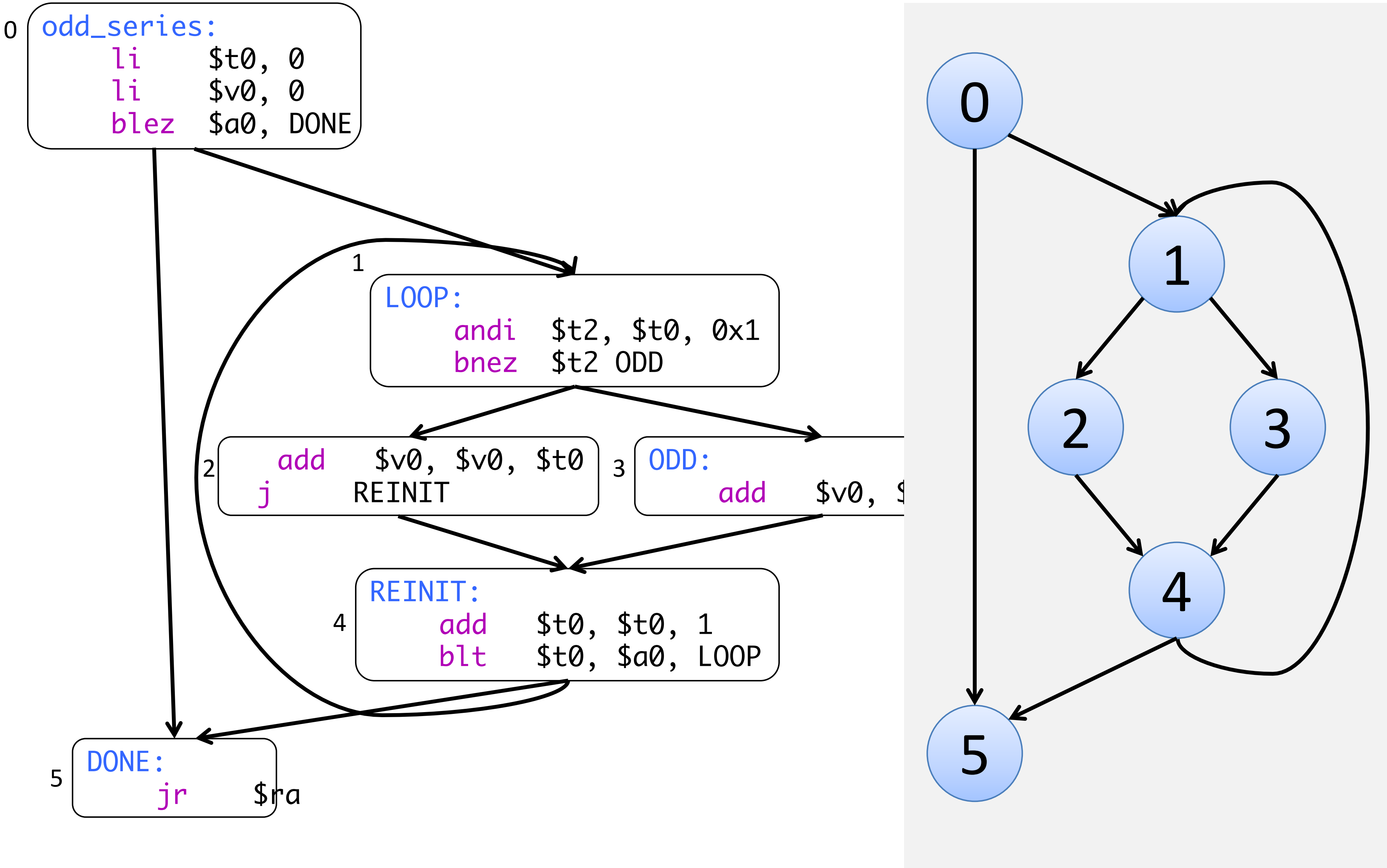
0x1001000C --> 0x1001001C

0x10010014 --> 0x10010020

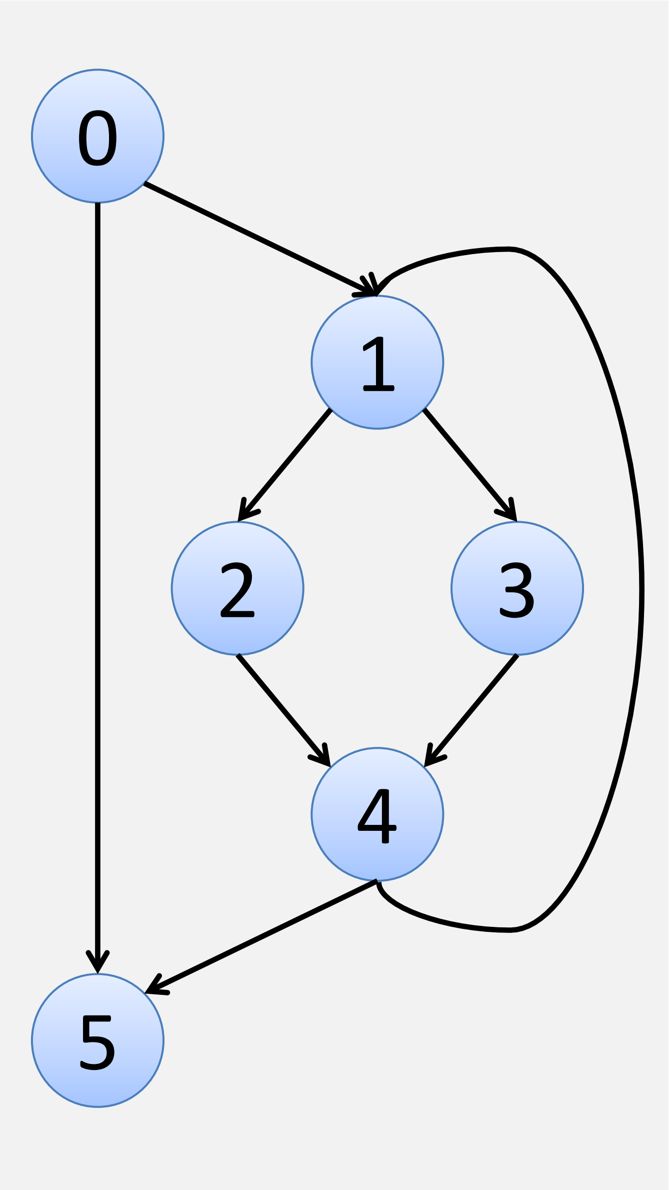
0x1001001C --> 0x10010020

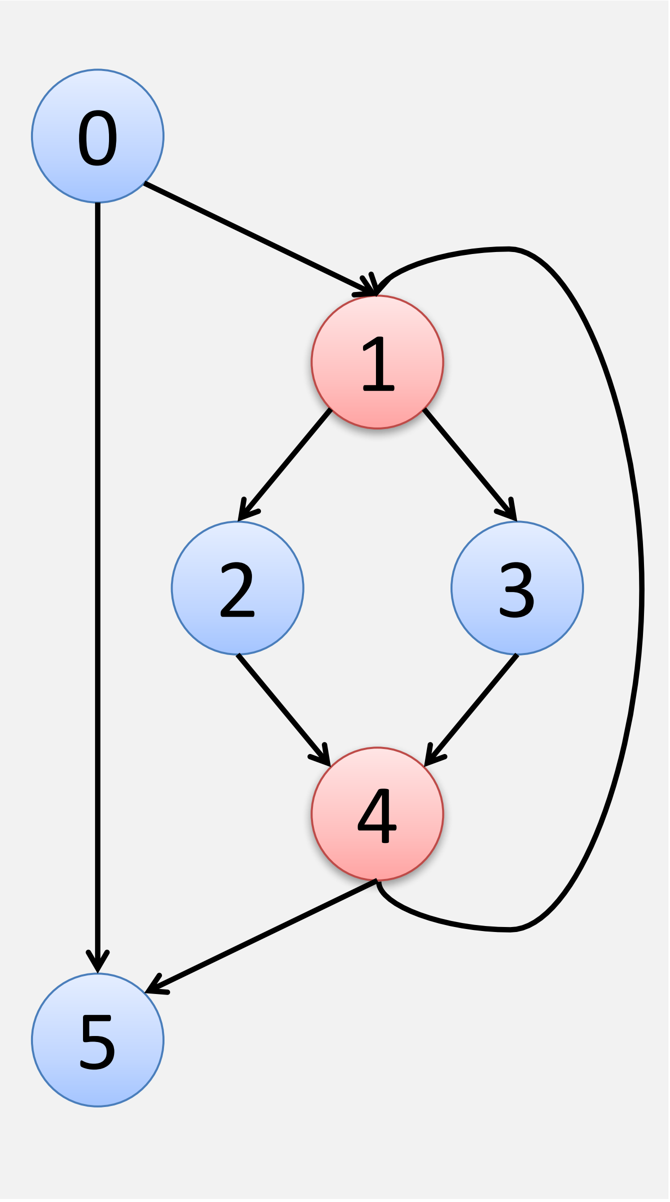
0x10010020 --> 0x1001000C

0x10010020 --> 0x1001002C

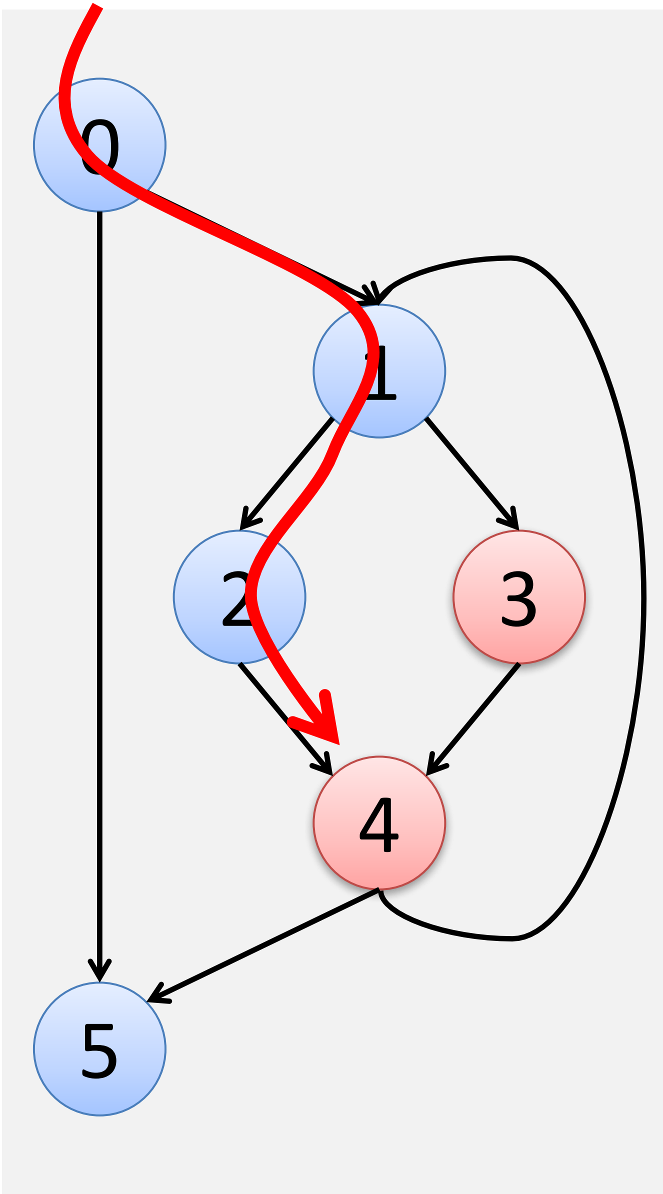

0
odd_series:
li $t0, 0
li $v0, 0
blez $a0, DONE
1
LOOP:
andi $t2, $t0, 0x1
bnez $t2 ODD
2
add $v0, $v0, $t0
j REINIT
3
ODD:
add $v0, $
4
REINIT:
add $t0, $t0, 1
blt $t0, $a0, LOOP
5
DONE:
jr $ra
0
1
2
3
4
5

Dominators


0
1
2
3
4
5

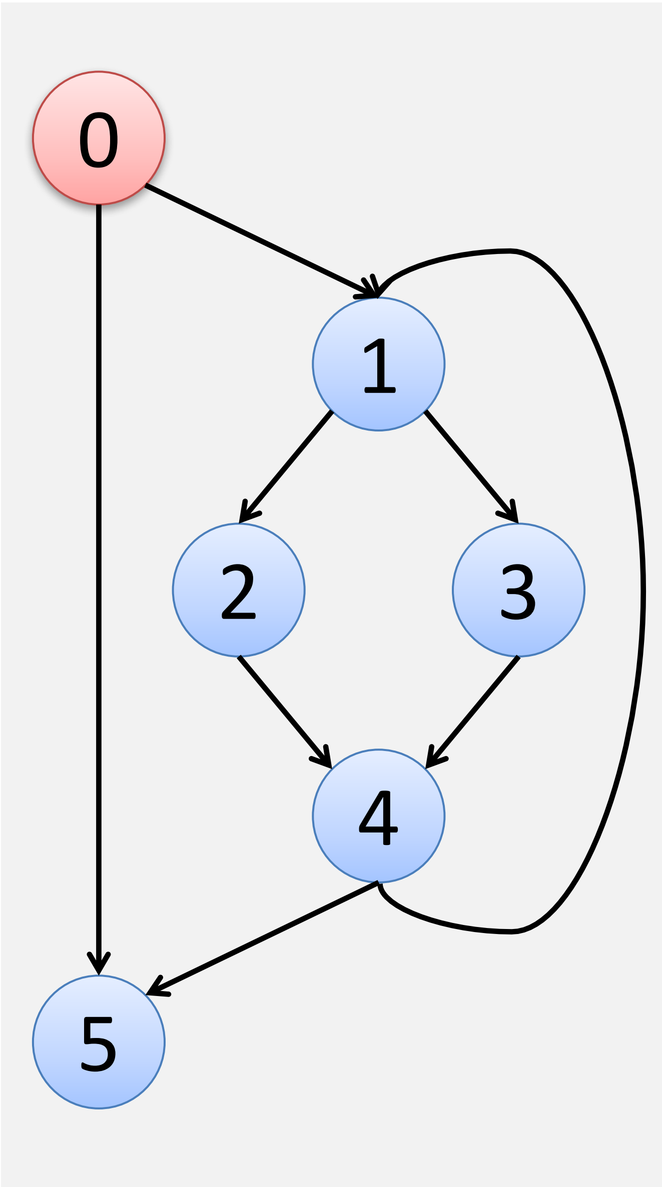


1 **dominates** 4 because you cannot execute 4 unless you have already executed 1



1 **<u>dominates</u>** 4 because you cannot execute 4 unless you have already executed 1

3 **<u>does not dominate</u>** 4 because there is a path (0→1→2→4) that reaches 4 without executing 3.

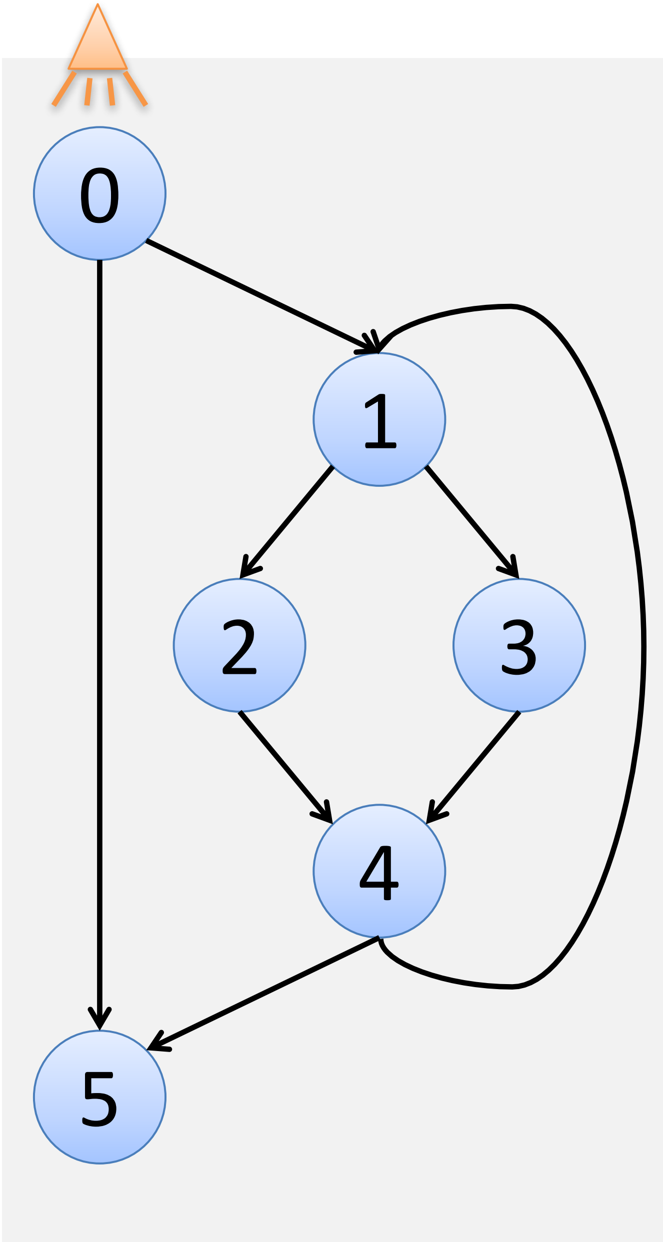


0 dominates all the basic blocks.

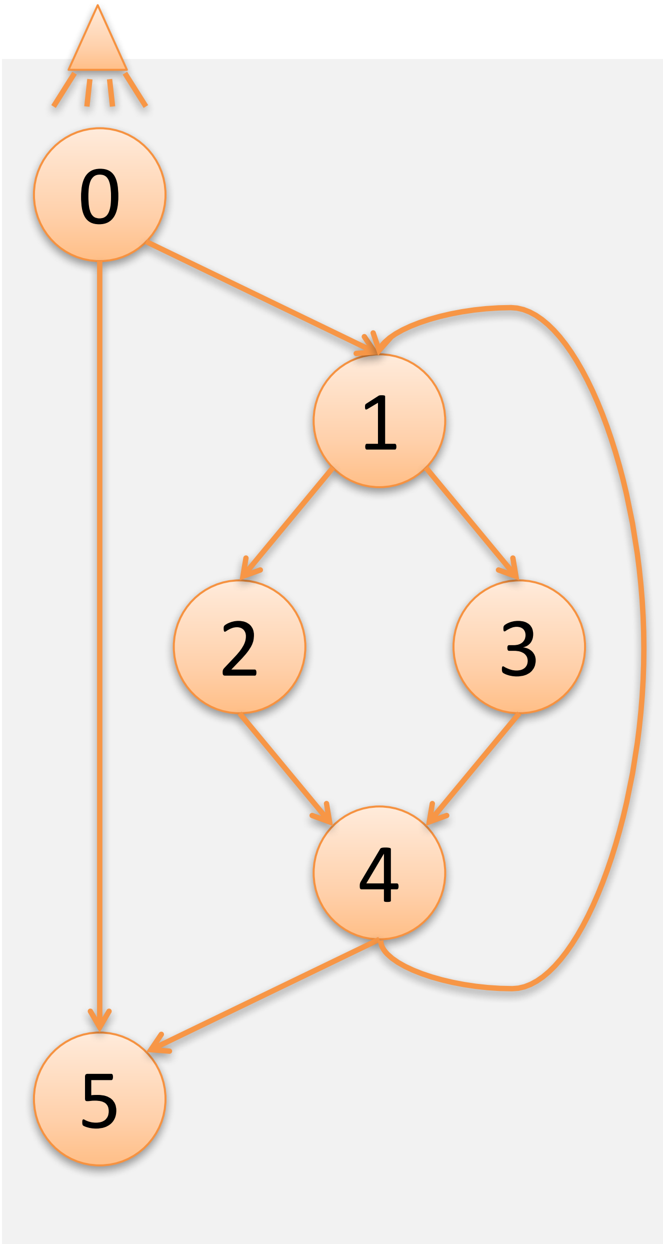
1 **<u>dominates</u>** 4 because you cannot execute 4 unless you have already executed 1

3 **<u>does not dominate</u>** 4 because there is a path (0→1→2→4) that reaches 4 without executing 3.

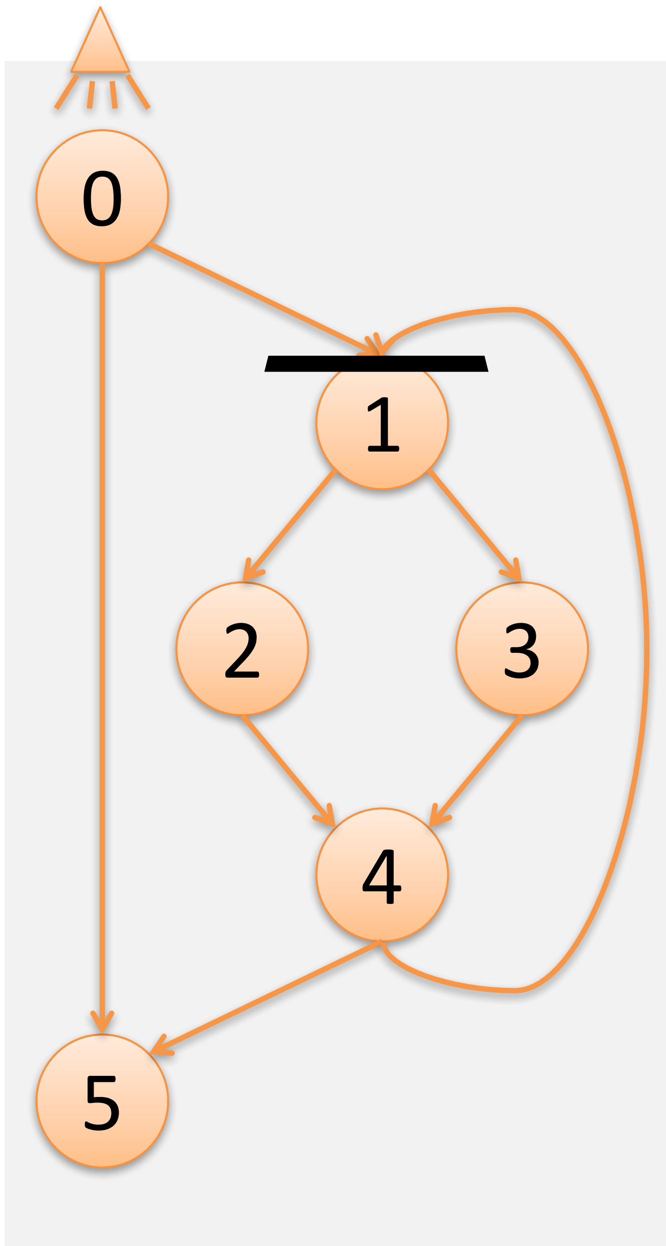
A basic block dominates itself.



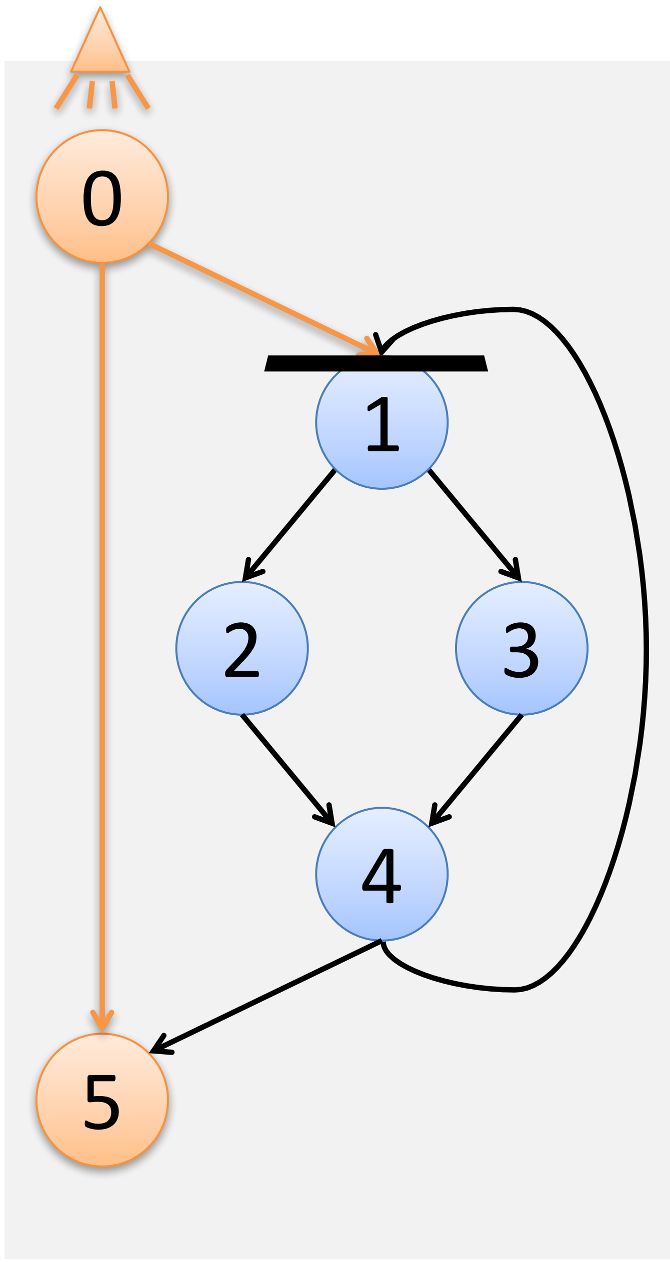
Intuitive Understanding of Dominance



Intuitive Understanding of Dominance

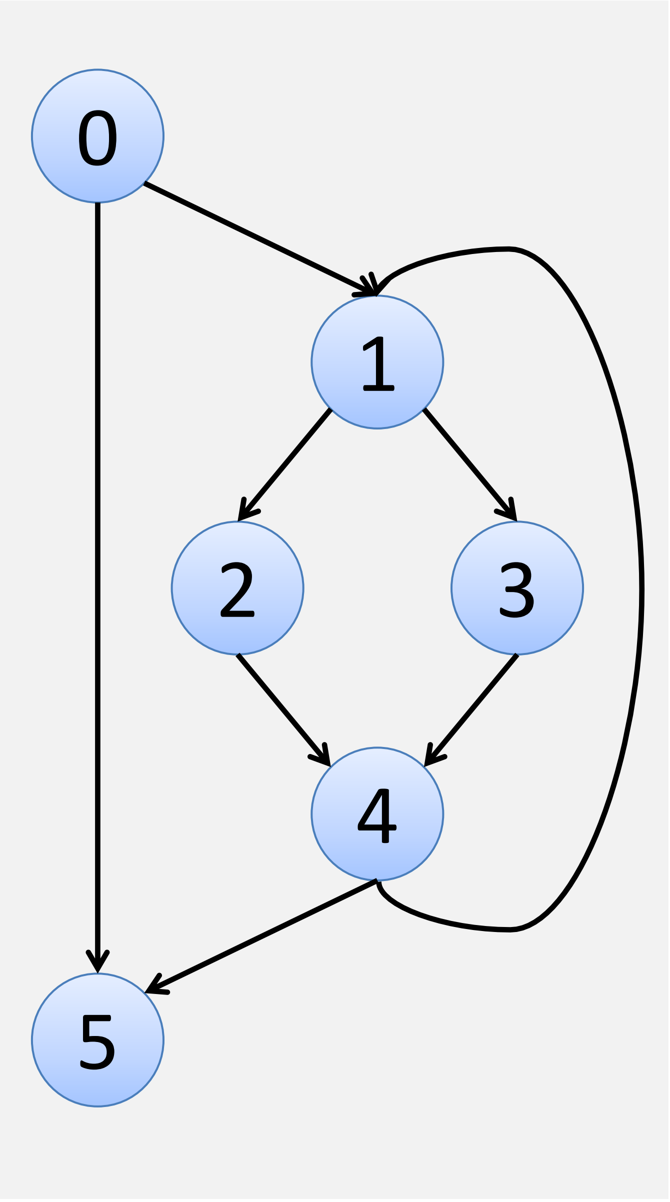


Intuitive Understanding of Dominance

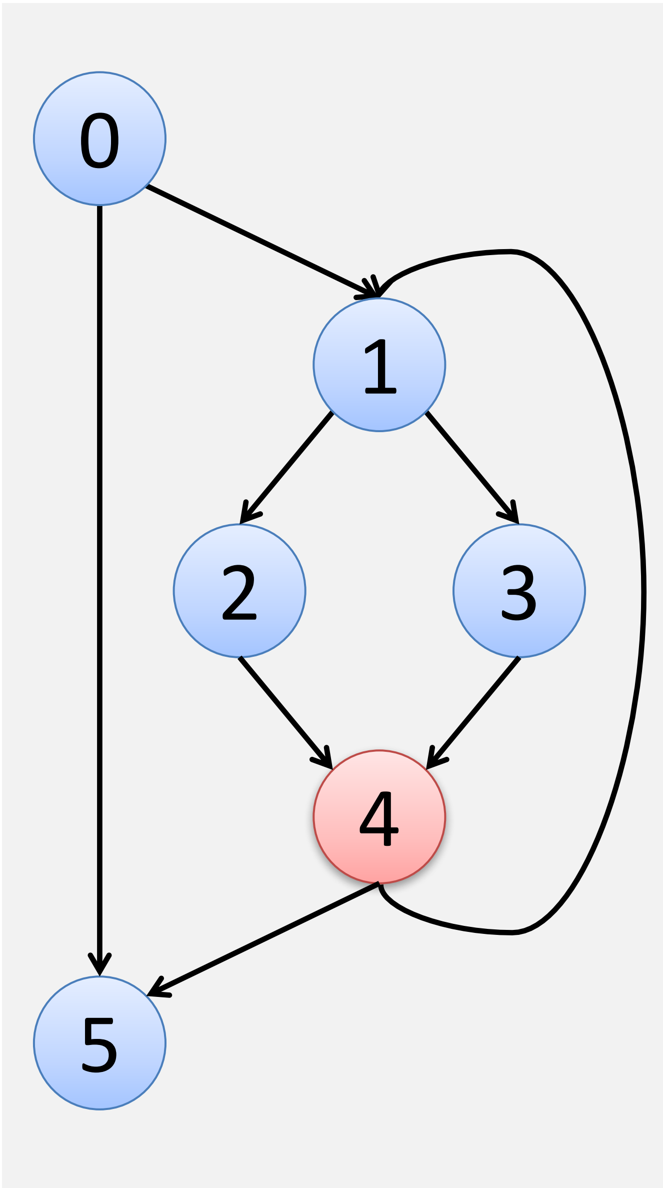


Intuitive Understanding of Dominance

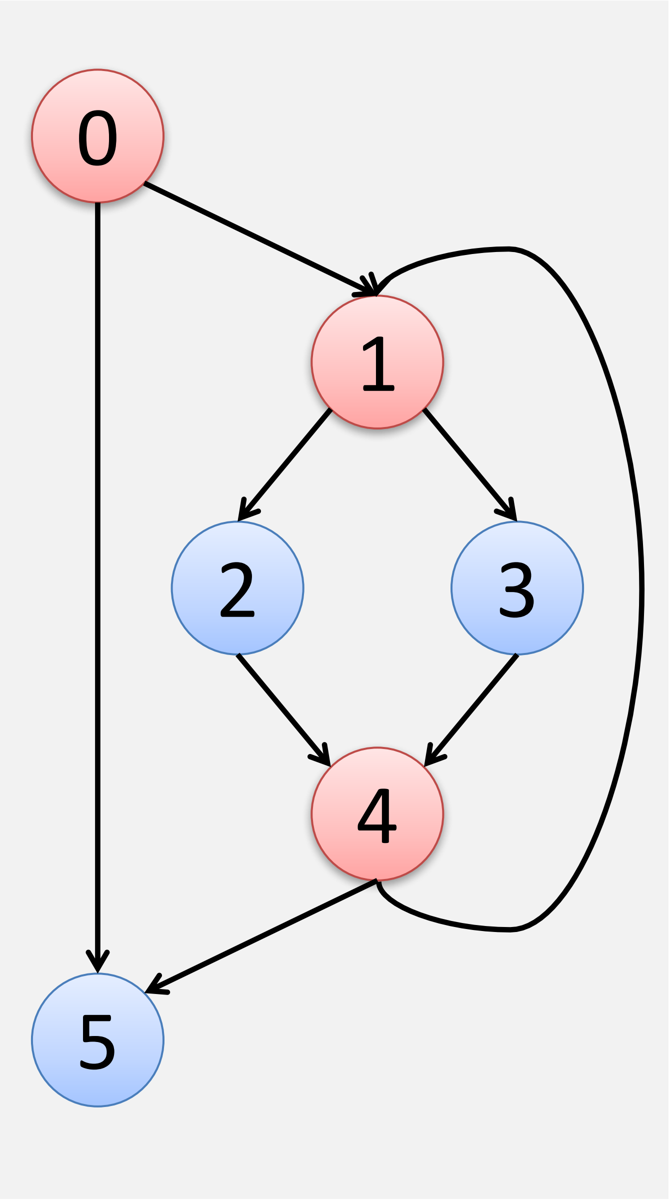
1 dominates nodes 1, 2, 3 and 4.



Which nodes dominate node 4?



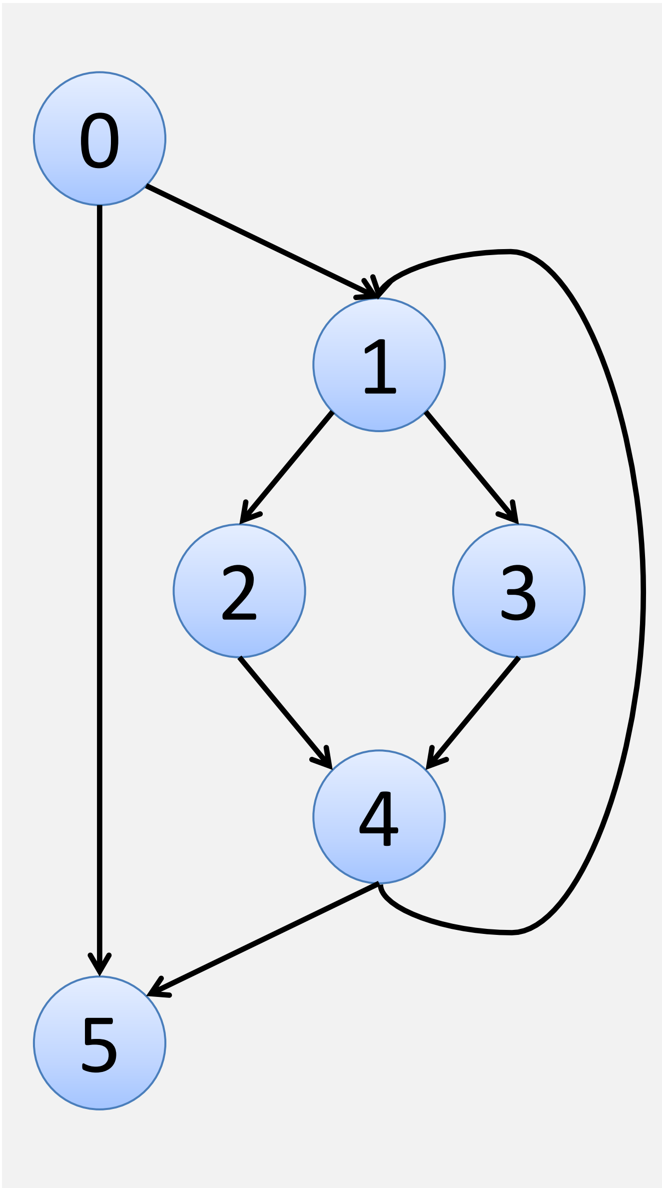
Which nodes dominate node 4?



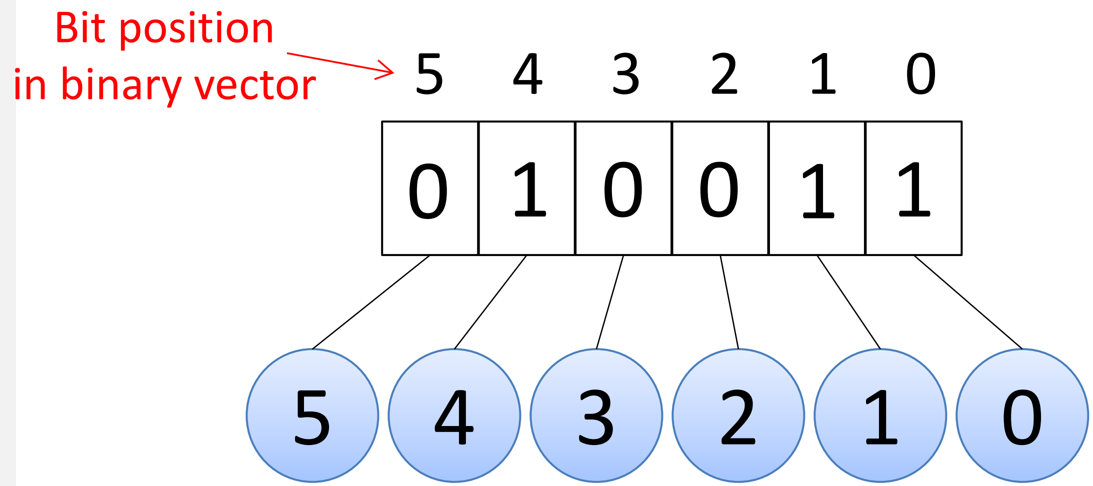
Which nodes dominate node 4?

Dom(4) = {0, 1, 4}

This is called the *Dominator Set* of 4

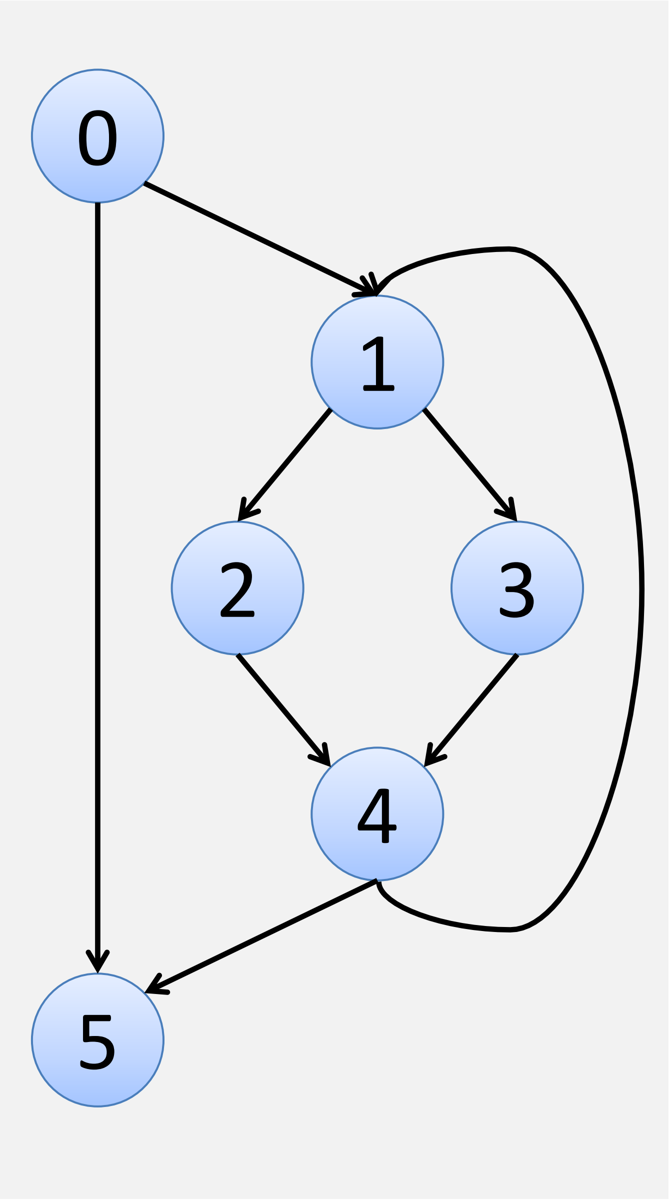


We can use a bit in a binary vector to represent each node in the CFG



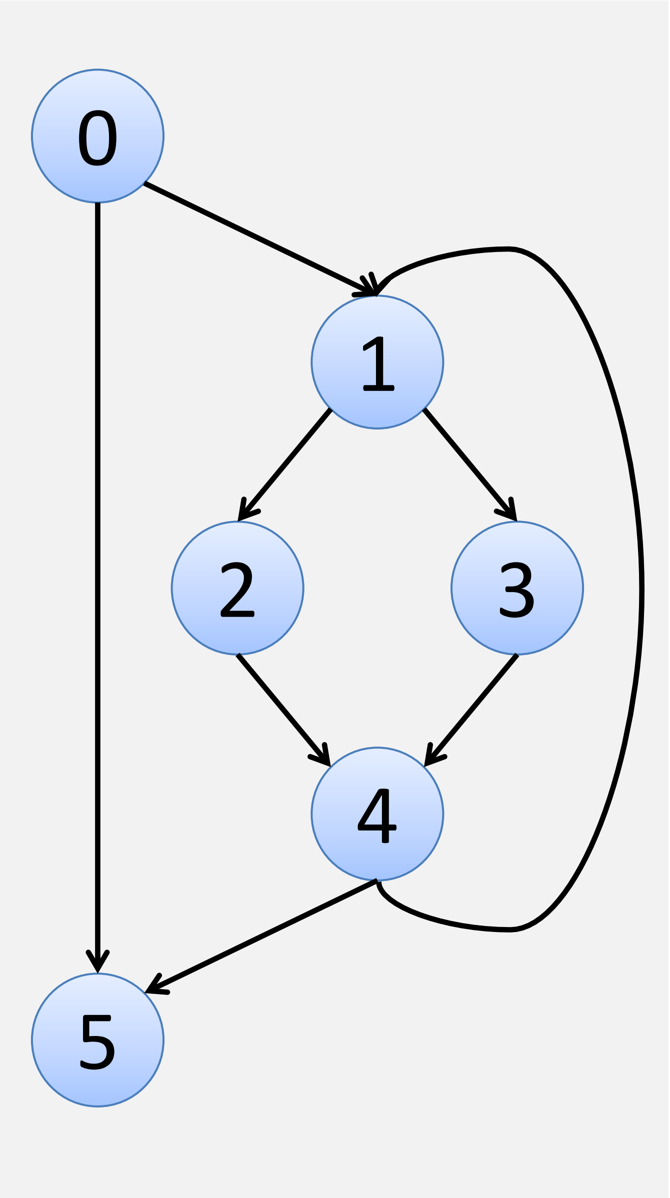
We can now represent the dominator set of 4 as a binary vector

Dom(4) = {0, 1, 4}



Dominator Bit Vectors:
0000 0000 0000 0000 0000 0000 0000 0001
0000 0000 0000 0000 0000 0000 0000 0011
0000 0000 0000 0000 0000 0000 0000 0111
0000 0000 0000 0000 0000 0000 0000 1011
0000 0000 0000 0000 0000 0000 0001 0011
0000 0000 0000 0000 0000 0000 0010 0001

How to Compute Dominator Sets?

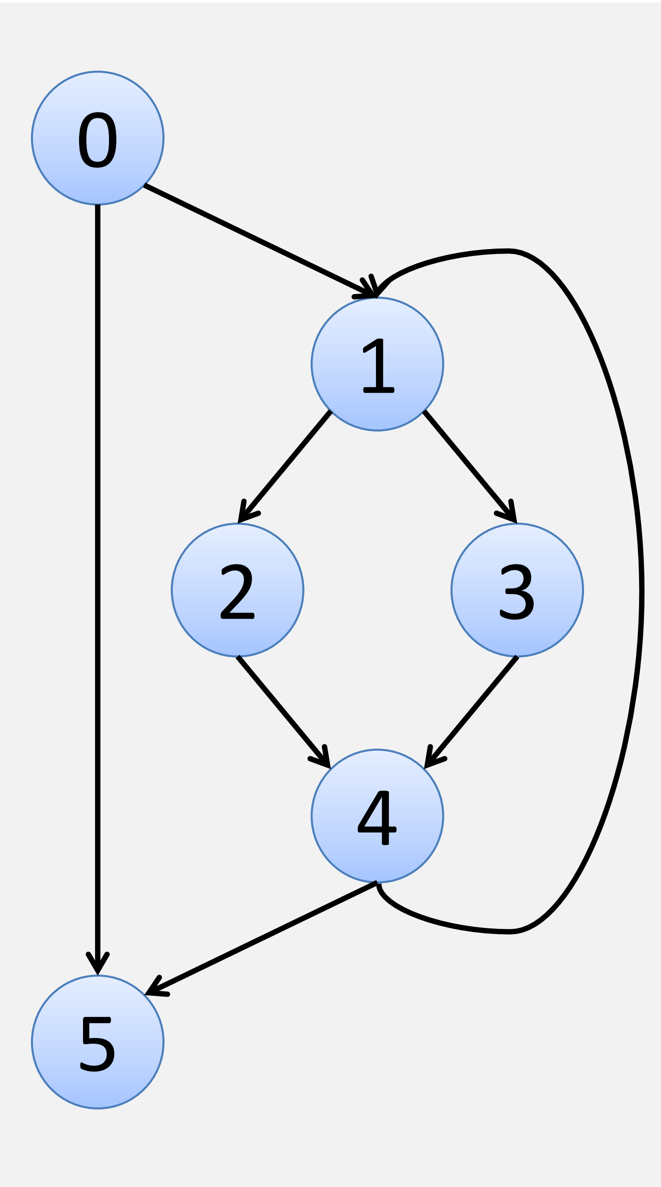


Initialization:

0 is the only dominator of 0

All other nodes are dominated by every node.

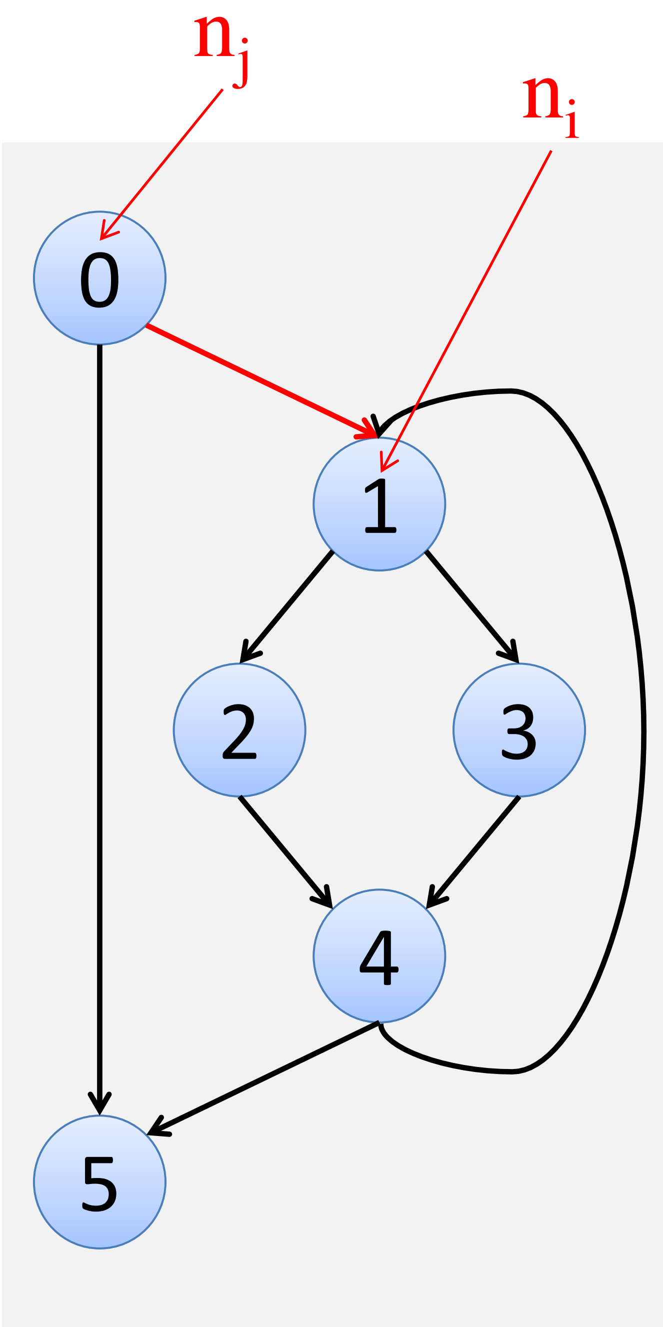
Node	Dominators					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	1	1	1	1	1



For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	1	1	1	1	1



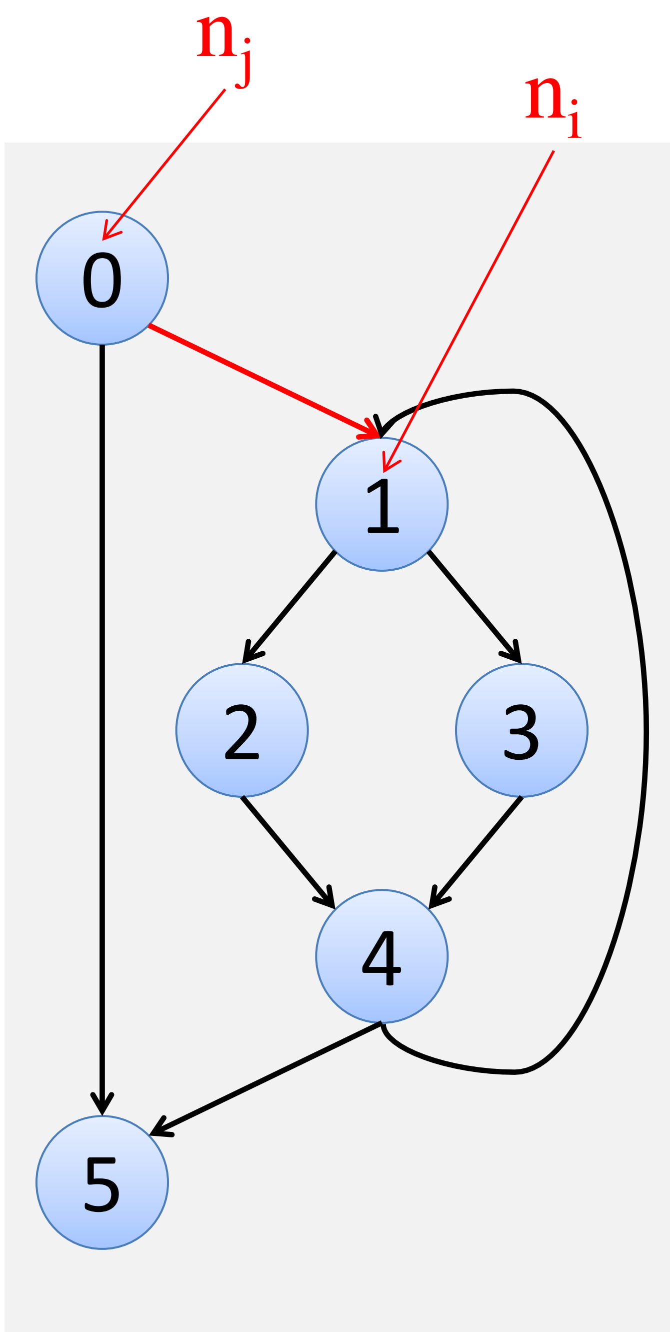
For each edge (n_j, n_i) in CFG:

$$Dom(n_i) = \{n_i\} \cup (Dom(n_i) \cap Dom(n_j))$$

$$Dom(1) = \{1\} \cup (\{0,1,2,3,4,5\} \cap \{0\})$$

$$Dom(1) = \{1\} \cup \{0\} = \{0,1\}$$

Node	Dominators					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	1	1	1	1	1



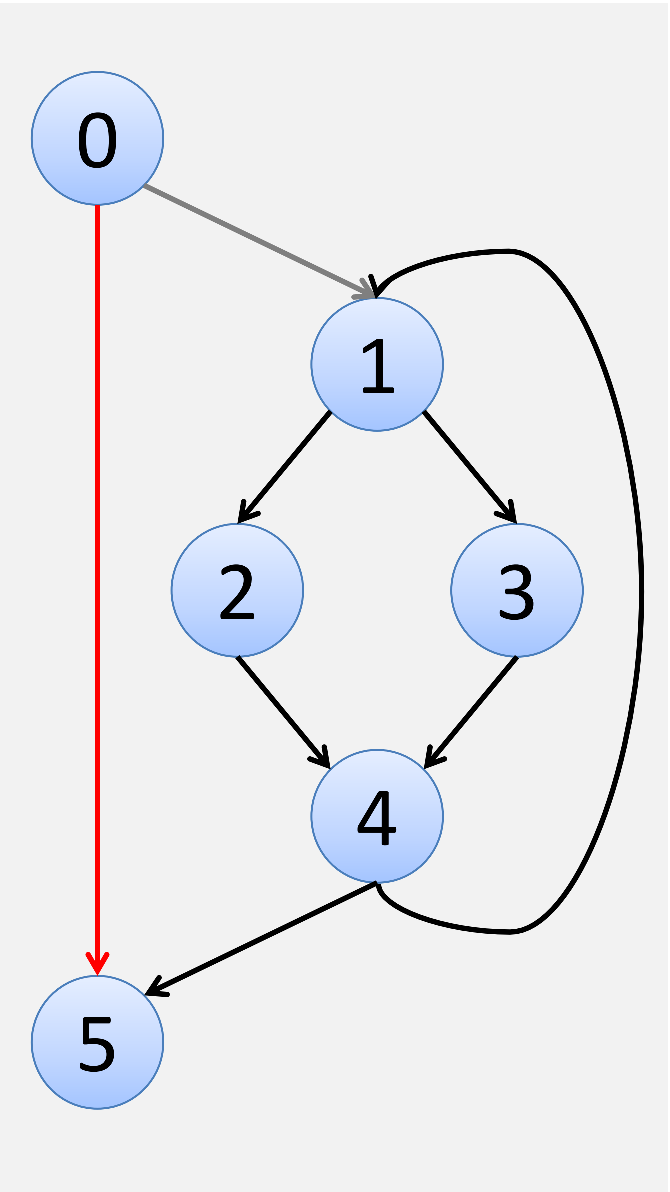
For each edge (n_j, n_i) in CFG:

$$Dom(n_i) = \{n_i\} \cup (Dom(n_i) \cap Dom(n_j))$$

$$Dom(1) = \{1\} \cup (\{0,1,2,3,4,5\} \cap \{0\})$$

$$Dom(1) = \{1\} \cup \{0\} = \{0,1\}$$

Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	1	1	1	1	1



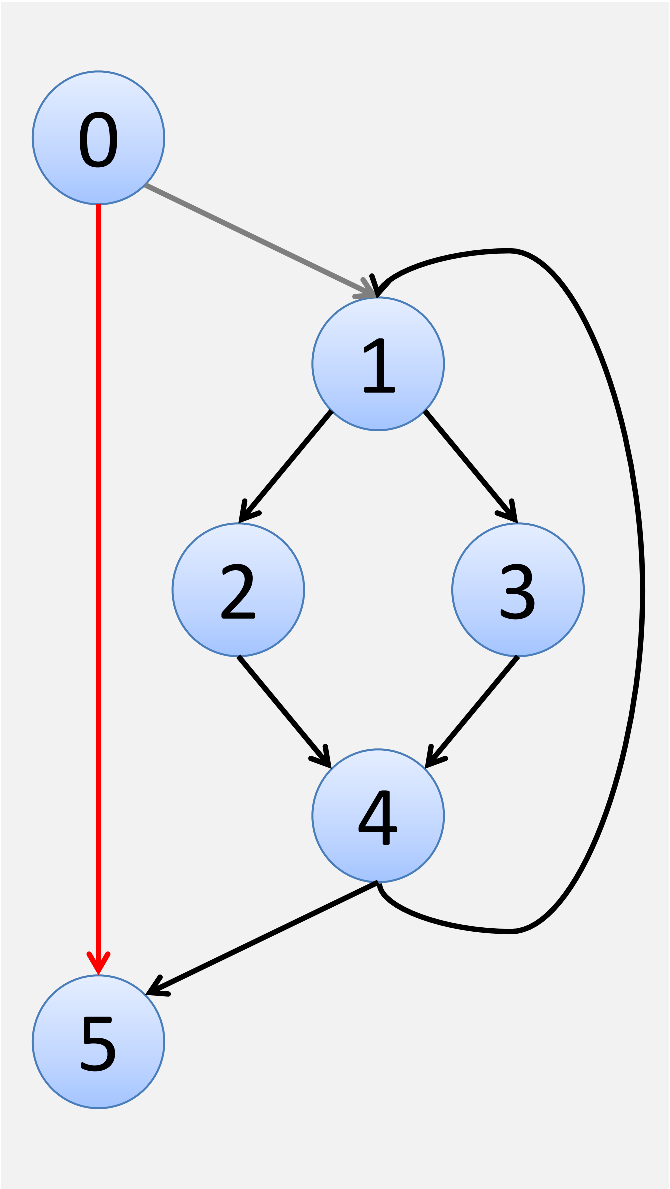
For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

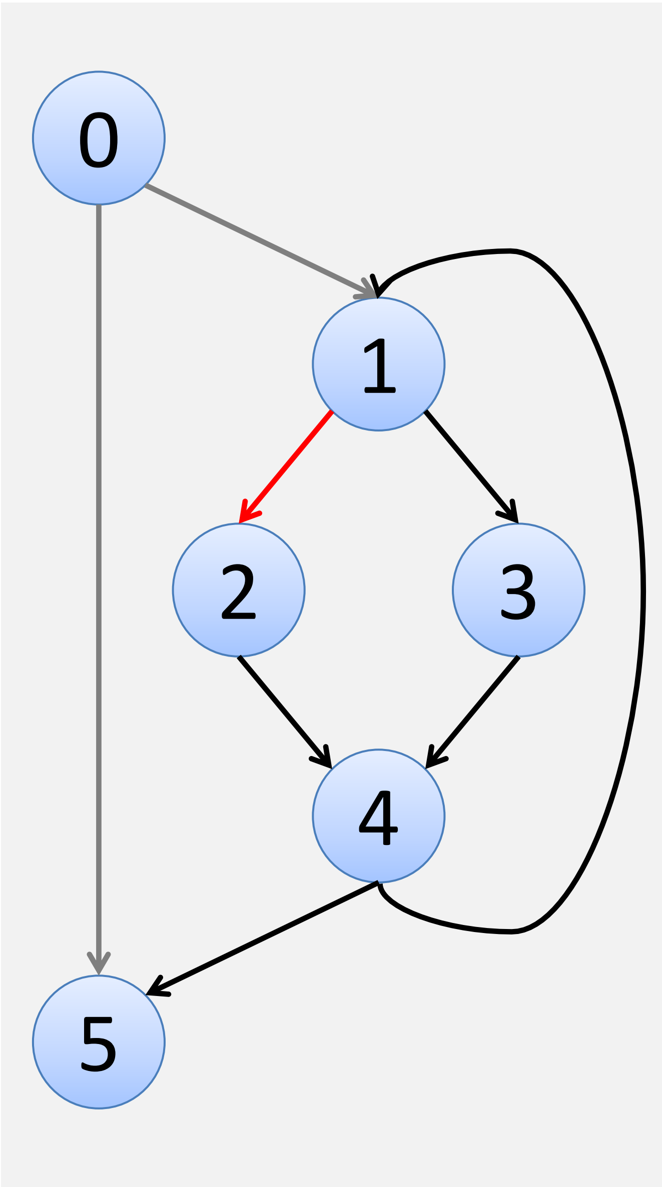
Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	1	1	1	1	1

For each edge (n_j, n_i) in CFG:

$$Dom(n_i) = \{n_i\} \cup (Dom(n_i) \cap Dom(n_j))$$



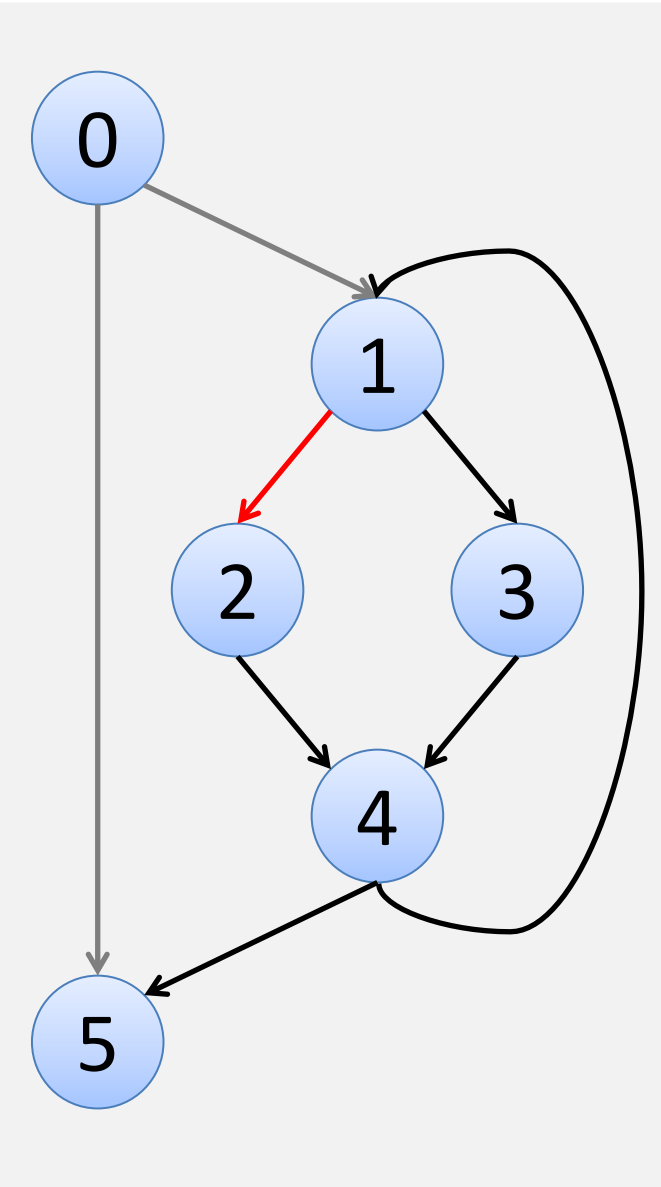
Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	0	0	0	0	1



For each edge (n_j, n_i) in CFG:

$$Dom(n_i) = \{n_i\} \cup (Dom(n_i) \cap Dom(n_j))$$

Node	Dominators					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	0	0	0	0	1



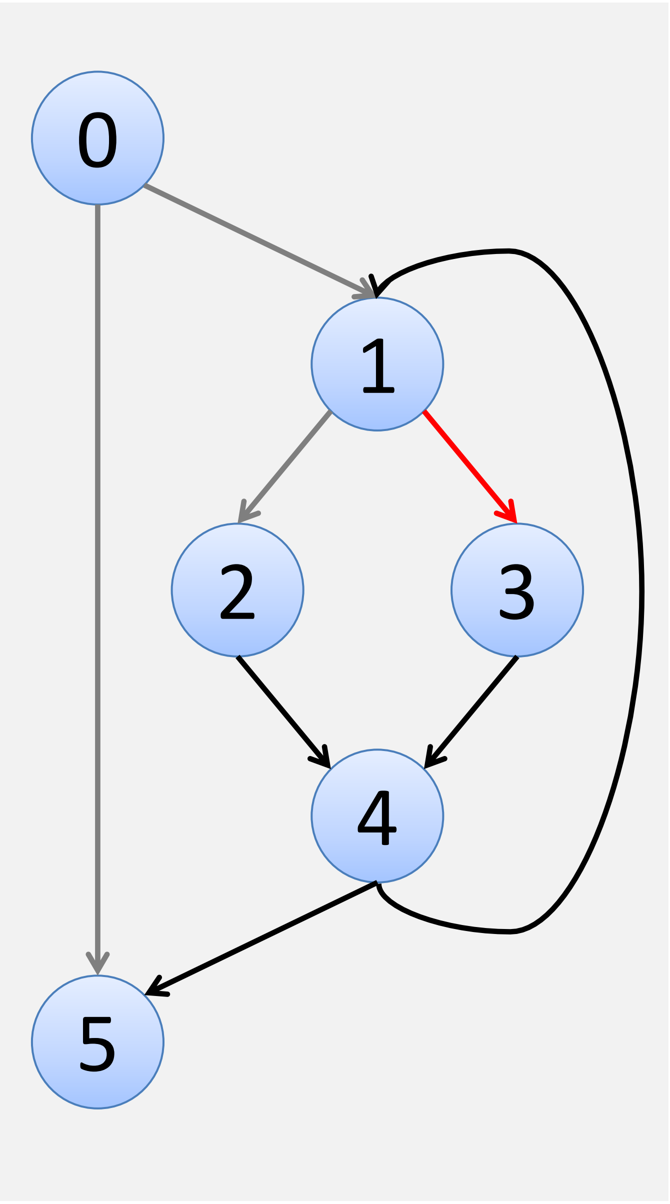
For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

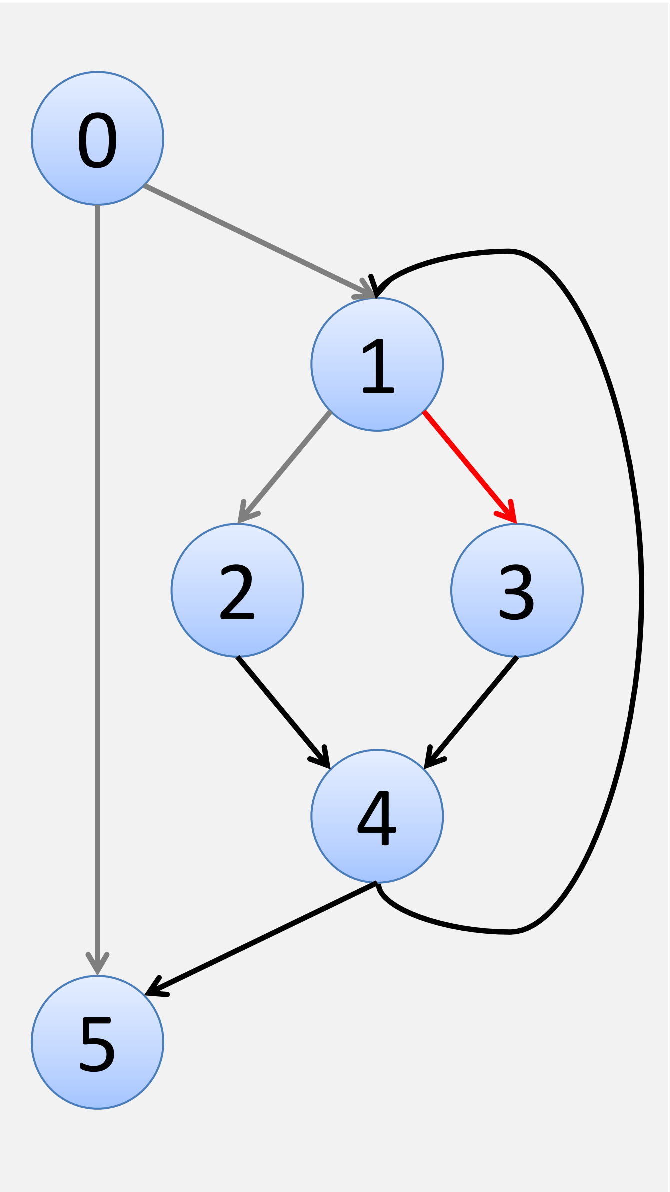
Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	0	0	0	0	1

For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$



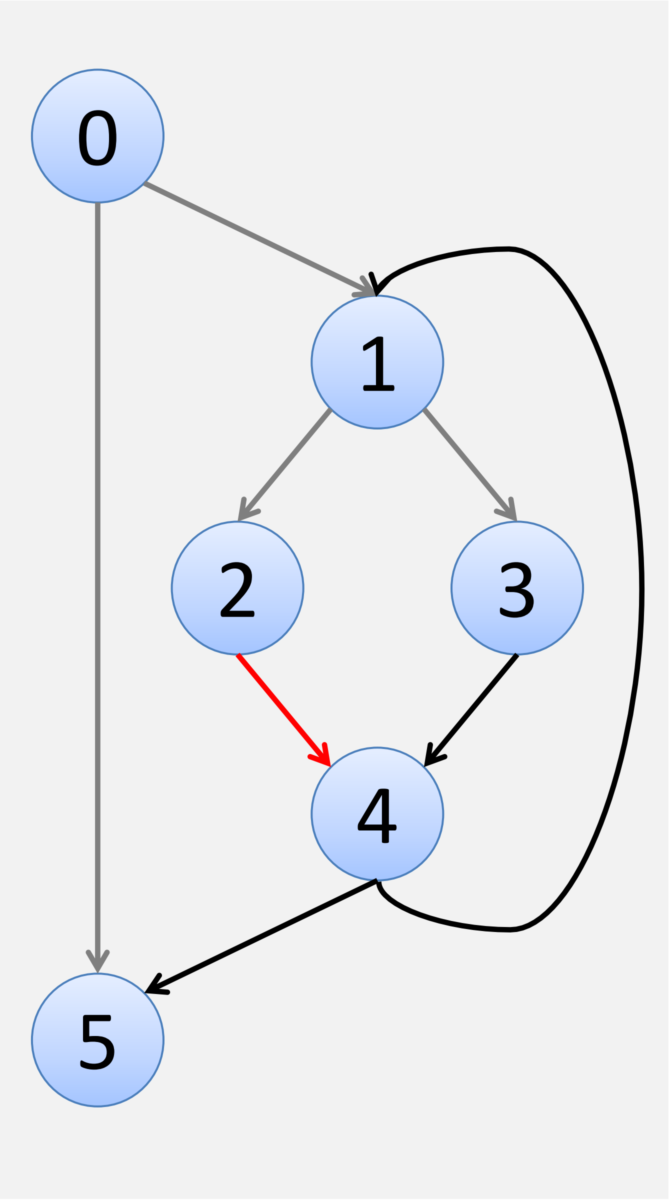
Node	Dominators					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	0	0	0	0	1



For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

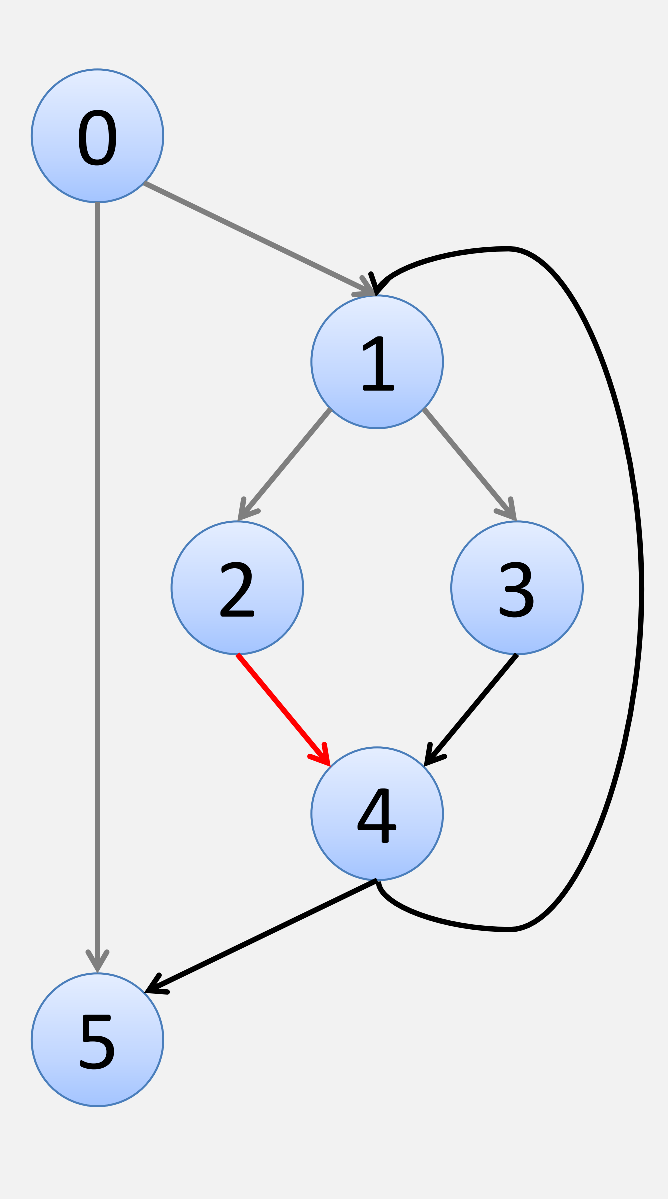
Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	1	1	1	1	1	1
5	1	0	0	0	0	1



For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

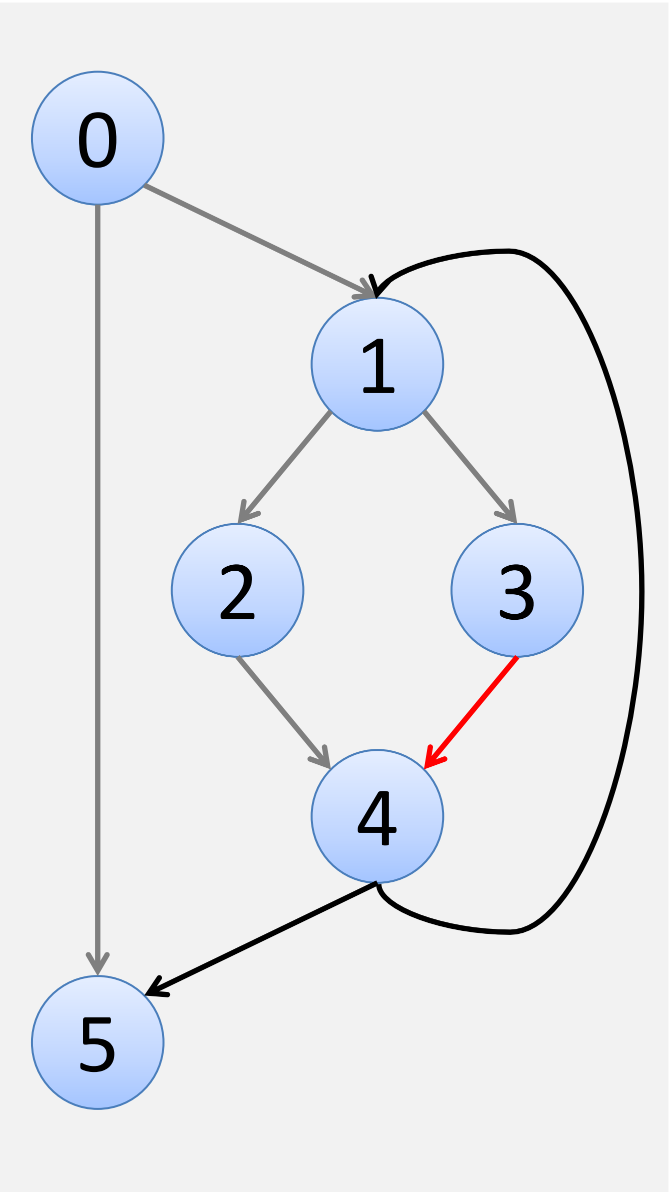
Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	1	1	1	1	1	1
5	1	0	0	0	0	1



For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

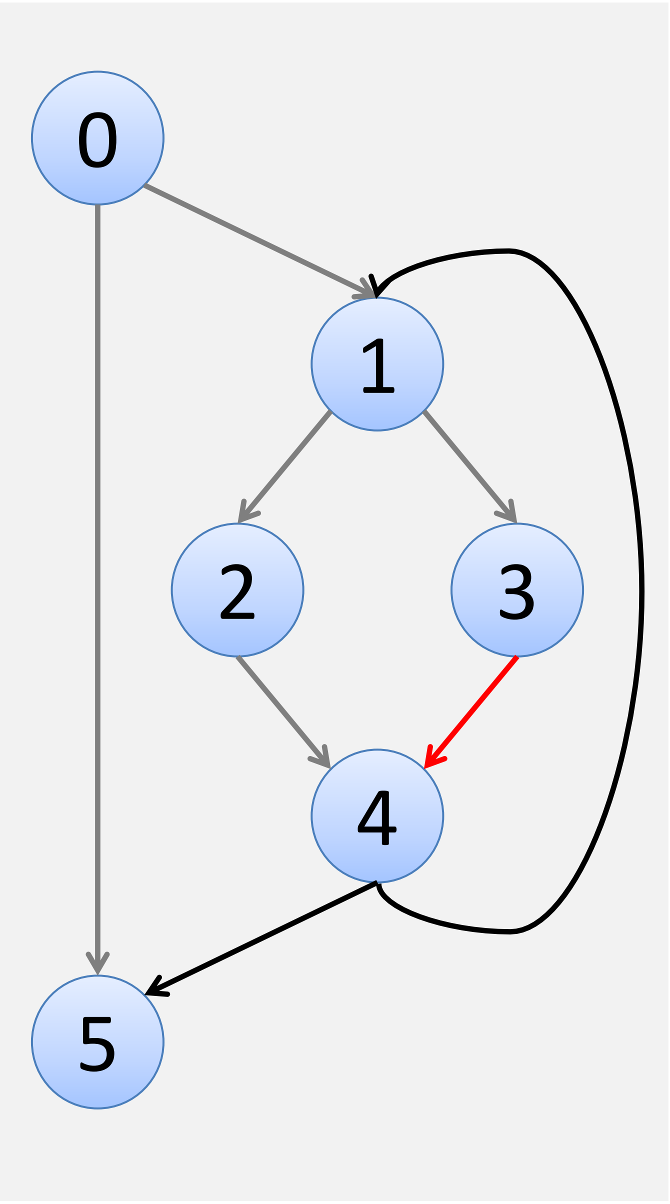
Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	0	1	0	1	1	1
5	1	0	0	0	0	1



For each edge (n_j, n_i) in CFG:

$$Dom(n_i) = \{n_i\} \cup (Dom(n_i) \cap Dom(n_j))$$

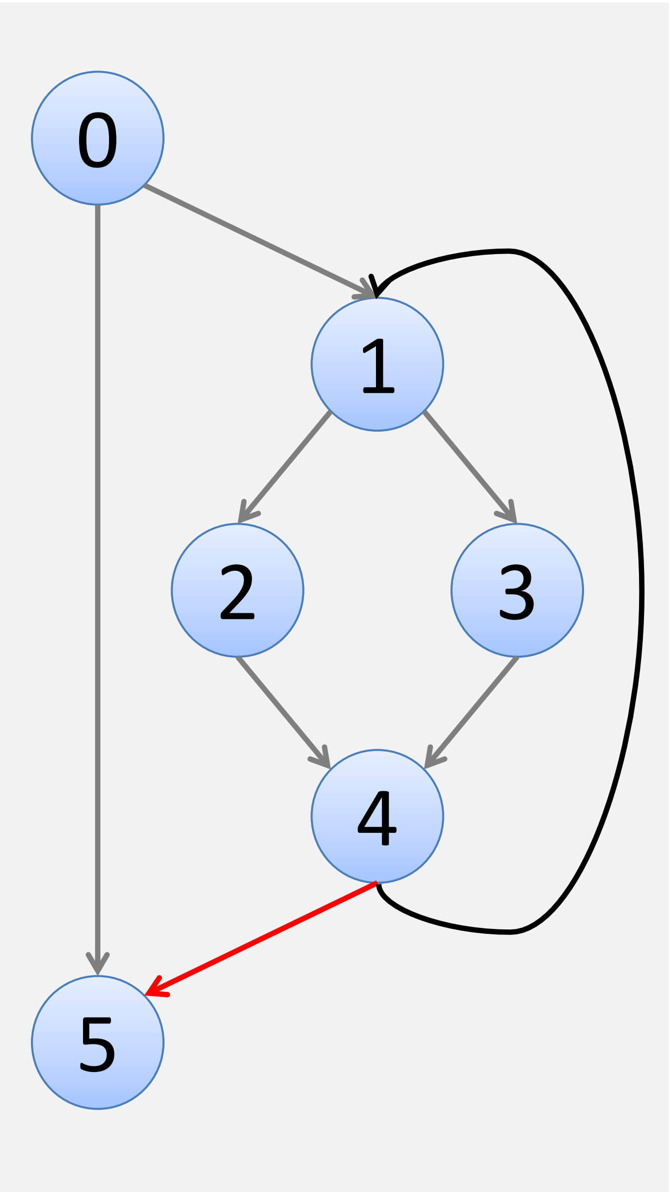
Node	Dominators					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	0	1	0	1	1	1
5	1	0	0	0	0	1



For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

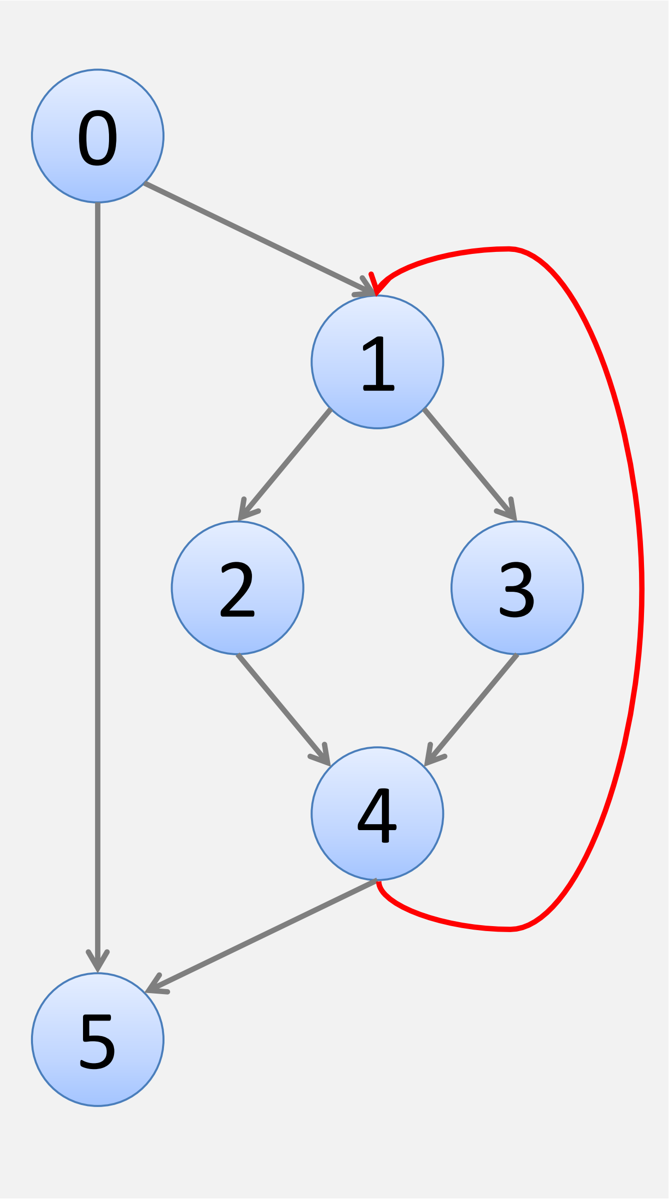
Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	0	1	0	0	1	1
5	1	0	0	0	0	1



For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	0	1	0	0	1	1
5	1	0	0	0	0	1



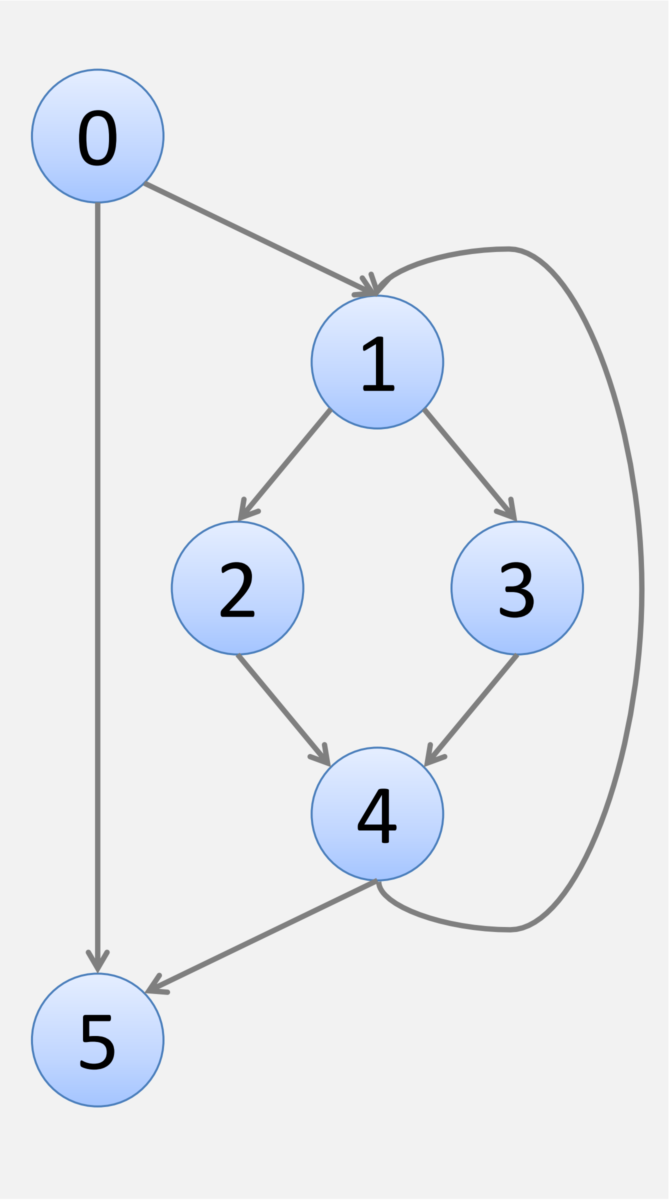
For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$

Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	0	1	0	0	1	1
5	1	0	0	0	0	1

For each edge (n_j, n_i) in CFG:

$$\mathrm{Dom}(n_i) = \{n_i\} \cup (\mathrm{Dom}(n_i) \cap \mathrm{Dom}(n_j))$$



Node	**Dominators**					
	5	**4**	**3**	**2**	**1**	**0**
0	0	0	0	0	0	1
1	0	0	0	0	1	1
2	0	0	0	1	1	1
3	0	0	1	0	1	1
4	0	1	0	0	1	1
5	1	0	0	0	0	1

Bit Vectors

Use as many words as necessary to store the bit vector in memory.

Examples:

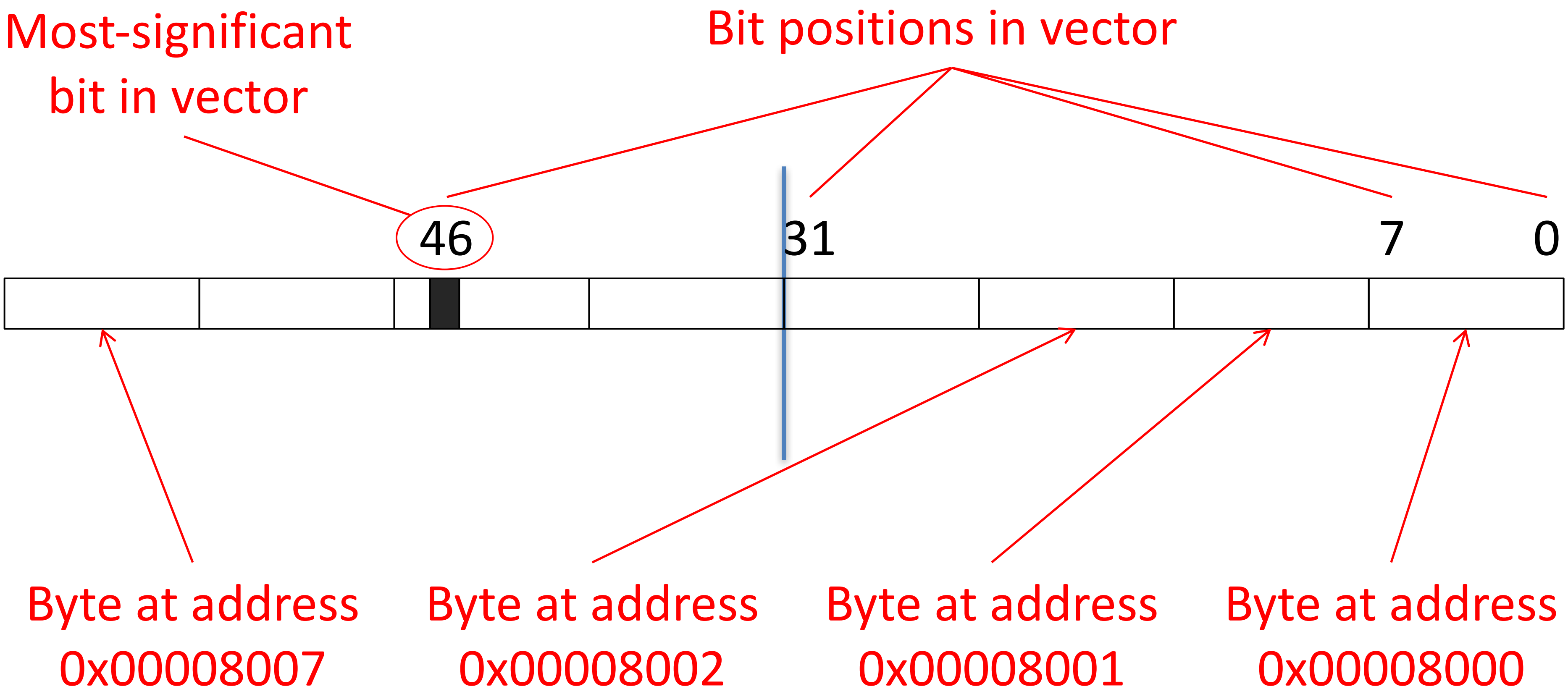
A 17-bit vector occupies one word.

A 42-bit vector occupies two words.

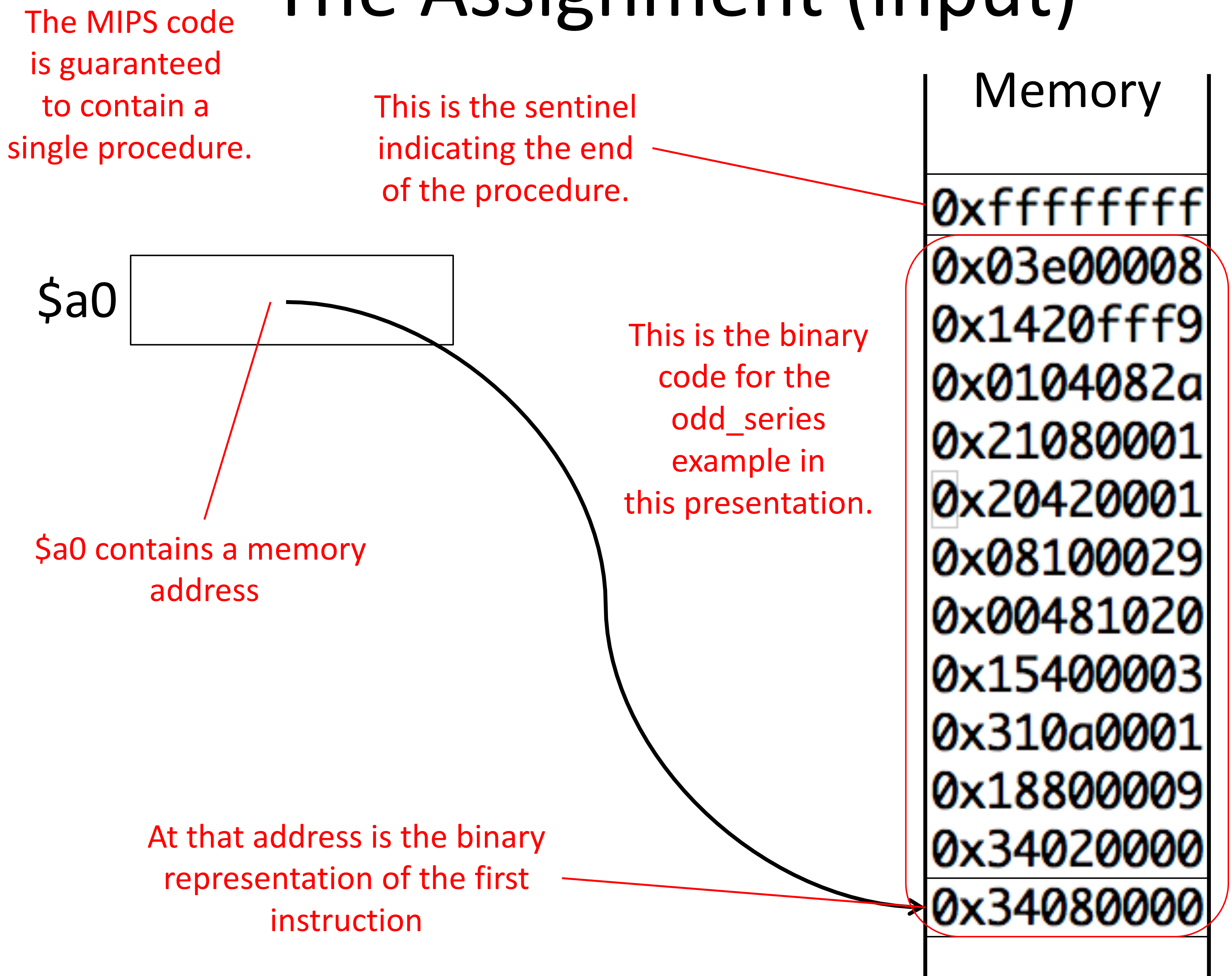
A 65-bit vector occupies three words.

Bit Ordering

Consider a 47-bit vector stored at address 0x00008000.



The Assignment (input)



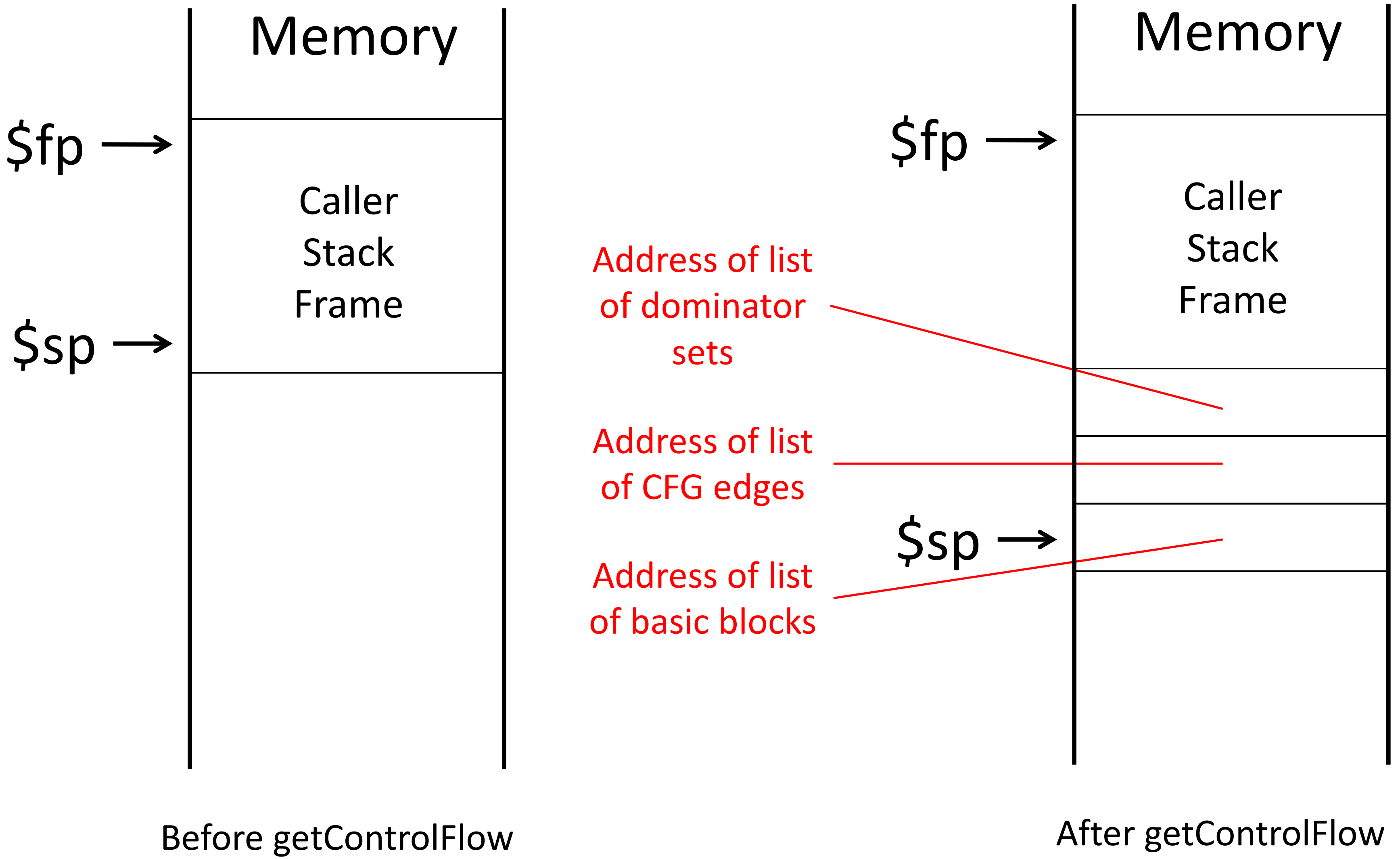
The Assignment (output)

\$v0: number of basic blocks in the procedure.

\$v1: number of edges in the CFG of the procedure.

Three additional memory addresses returned into the stack.

Returning Addresses in Stack



Basic blocks in ascending order of the address of their leaders.

List of Basic Blocks

Basic Block List

0x0000 0001
0x1001 002c
0x0000 0003
0x1001 0020
0x0000 0001
0x1001 001c
0x0000 0002
0x1001 0014
0x0000 0002
0x1001 000c
0x0000 0003
0x1001 0000

higher address ↑

lower address ↓

```
, $0, 0                 ; 52: li $t0, 0 # i
, $0, 0                 ; 53: li $v0, 0 # j
4 36 [DONE-0x10010008]; 54: blez $a0, DONE #
10, $8, 1               ; 56: andi $t2, $t0, 0x1 #
0, $
, $1
0100
2, $
8, $
, $8
, $0
[1001002c] 03e00008  jr $31
```

6 block(s) found.
Block Leader: 0x10010000, Size: 3
Block Leader: 0x1001000C, Size: 2
Block Leader: 0x10010014, Size: 2
Block Leader: 0x1001001C, Size: 1
Block Leader: 0x10010020, Size: 3
Block Leader: 0x1001002C, Size: 1

After getControlFlow address in $sp+0 is the address of this word.

CFG Edge List

Edges in ascending order of the address of the source leader.

# of CFG Edges

higher address ↑

0x1001 002c
0x1001 0020
0x1001 000c
0x1001 0020
0x1001 0020
0x1001 001c
0x1001 0020
0x1001 0014
0x1001 001c
0x1001 000c
0x1001 0014
0x1001 000c
0x1001 002c
0x1001 0000
0x1001 000c
0x1001 0000

lower address ↓

Edges with the same source in ascending order of the address of the target leader.

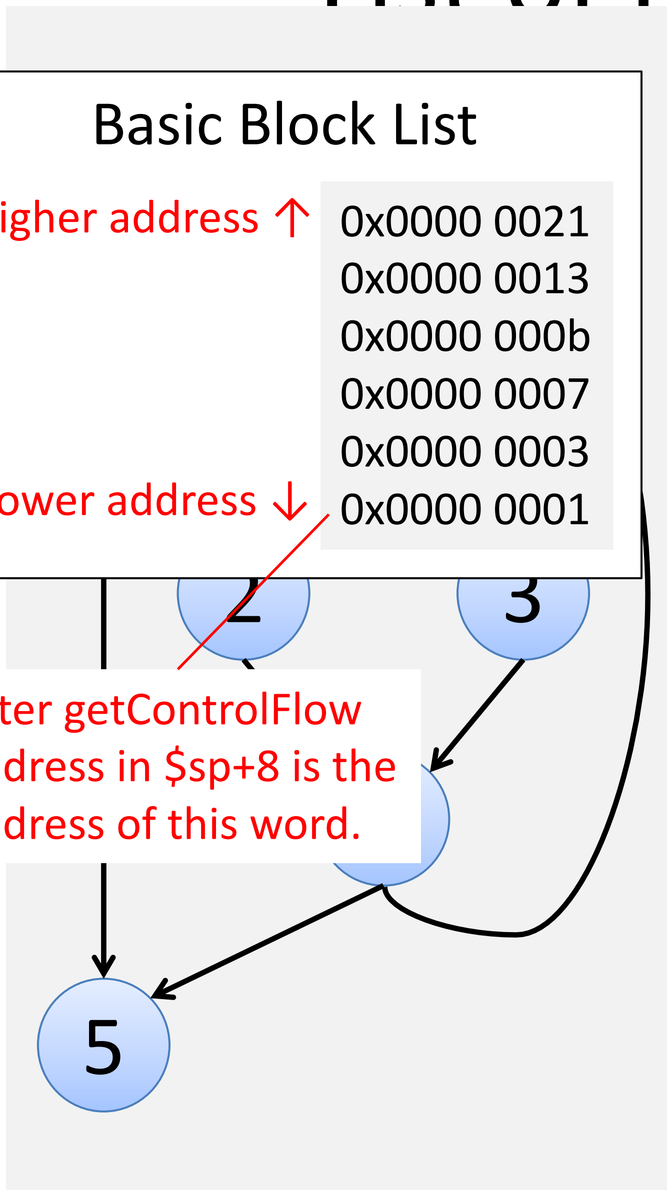
```
, $0, 0                                  # i
, $0, 0                                  # j
4 36 [DONE-0x10010008]; 54: blez $a0, DONE #
10, $8, 1                 ; 56: andi $t2, $t0, 0x1 #
0, $0, 12
, $2, $8
010020 [R
2, $2, 1
8, $8, 1
, $8, $4
, $0, -28
[1001002c] 03e00008   jr $31
```

After getControlFlow address in $sp+4 is the address of this word.

Edges:

0x10010000 --> 0x1001000C
0x10010000 --> 0x1001002C
0x1001000C --> 0x10010014
0x1001000C --> 0x1001001C
0x10010014 --> 0x10010020
0x1001001C --> 0x10010020
0x10010020 --> 0x1001000C
0x10010020 --> 0x1001002C

List of Dominator Sets



Basic Block List

higher address ↑

0x0000 0021
0x0000 0013
0x0000 000b
0x0000 0007
0x0000 0003
0x0000 0001

lower address ↓

After getControlFlow address in $sp+8 is the address of this word.

Dominator Bit Vectors:
0000 0000 0000 0000 0000 0000 0000 0001
0000 0000 0000 0000 0000 0000 0000 0011
0000 0000 0000 0000 0000 0000 0000 0111
0000 0000 0000 0000 0000 0000 0000 1011
0000 0000 0000 0000 0000 0000 0001 0011
0000 0000 0000 0000 0000 0000 0010 0001

If the CFG has more than 32 basic blocks, then each binary vector will occupy more than one word.

Dominator sets in ascending order of the address of the corresponding basic-block's leader.

Testing

- Test Cases
  - A few test cases are provided under Resources
- Student-Generated Test Cases
  - Students will submit test cases
- Printing the Output of your solution
  - MIPS code provided for printing

University of Alberta
Code of Student Behavior

http://www.governance.ualberta.ca/en/CodesofConductandResidenceCommunityStandards/CodeofStudentBehaviour.aspx

30.3.2(2) Cheating
30.3.2(2) a No Student shall in the course of an examination or other similar activity, obtain or attempt to obtain information from another Student or other unauthorized source, give or attempt to give information to another Student, or use, attempt to use or possess for the purposes of use any unauthorized material.