Full Persistent Data-structure

Pointer Machine Model

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Full Persistent Linked List

Operations:

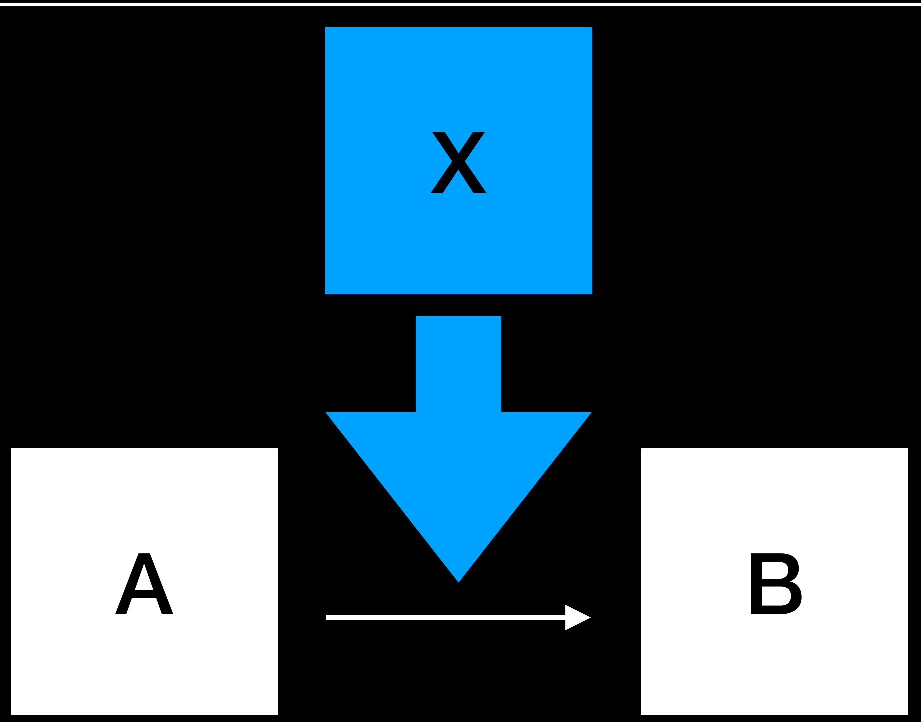
- start = init() : To initiate linked list and “start” pointer holds the starting position in v0
- add(x, y, a, v) : Add new node x after y at version v with f1 = a and f2 = NULL, and update the version in version tree.
- create_node(x, a): Allocate a new node x with value = a, and set its default version = current time
- remove(x,v) : Remove node x and update the version at version v and update the version in version tree.
- iterate_over_LL(v) : Iterate over the whole linked list in version v
- update(x,f_i,val,v) : Update the i-th field in node x to new value ‘val’ at version v and update the version in version tree.

Interesting thing!

add(x,y,v) and remove(x,v) are not Elementary operations

add(X,C,123) consists of

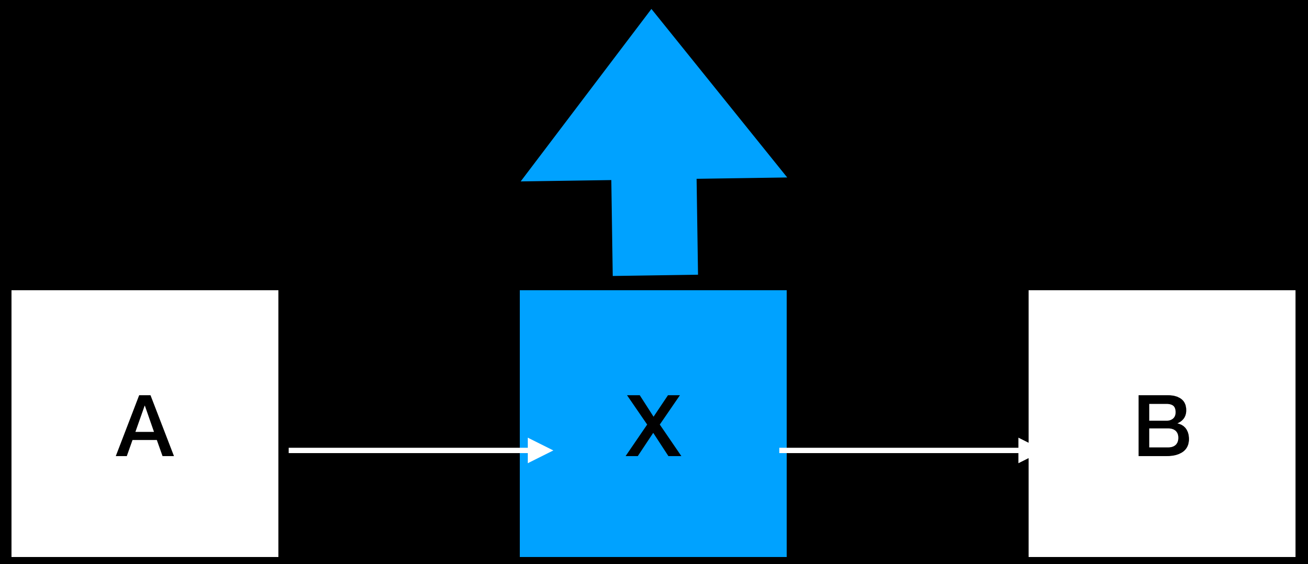
Create node X with value 123
Modify f2 of A to X : update(f2, A, X,v)
Modify f2 of X to C : update(f2, X, C,v)
Modify BP1 of X to A: update(bp1, X, A,v)
Modify BP1 of B to X: update(bp1, B, X,v)
~~Set f1 of X(optional)~~
Add current ver to the respective position in version tree



remove(x) consists of

Modify F2 of Parent C (i.e., X) -> F2 of C (successor of C after version v)

update(f2, A, B,v)
Modify BP1 of B to A: update(bp1, B, A,v)
If all shared reference of X is removed Then free up the memory associated with X



Elementary Operations:

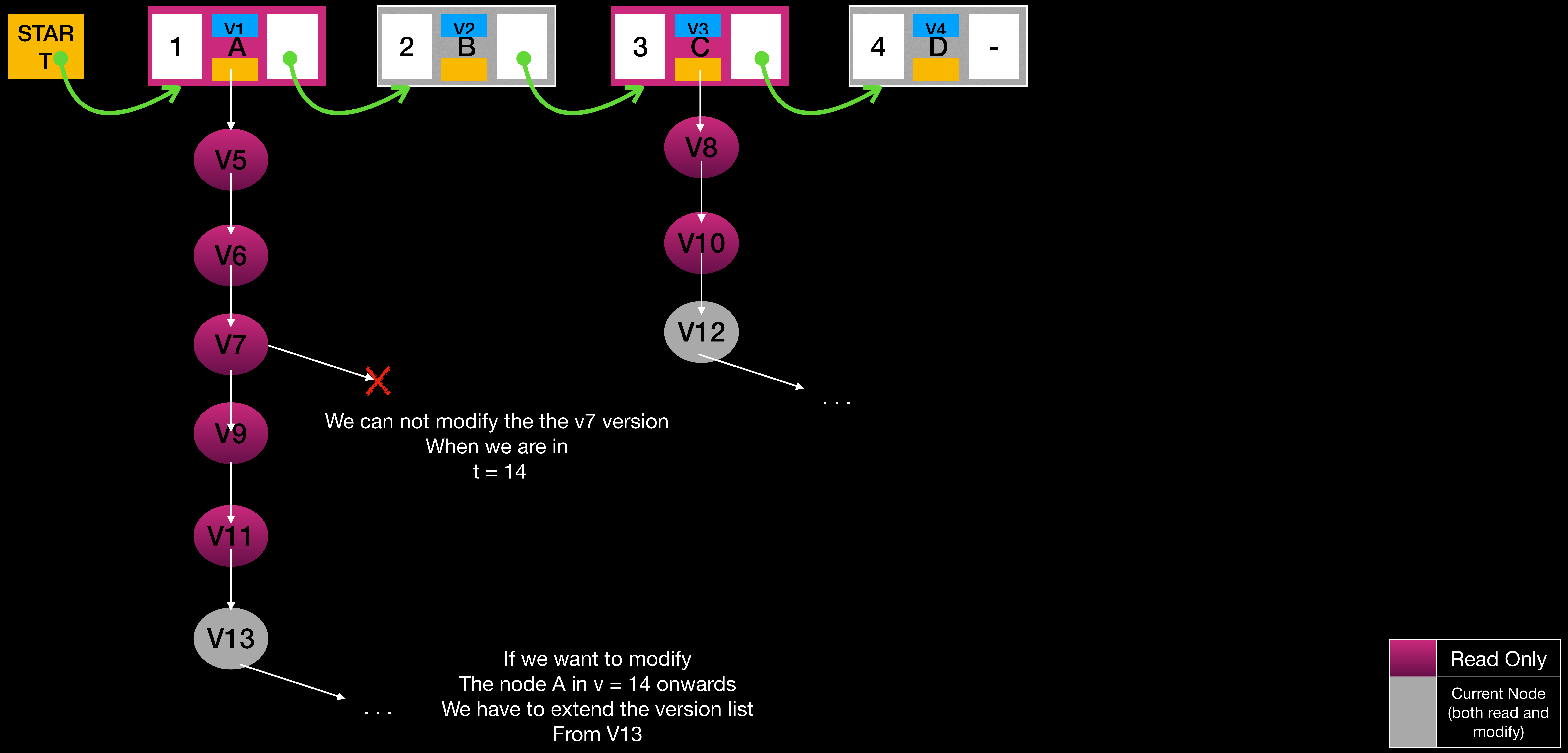
• start = init()
• create_node(x, a)
• iterate_over_LL(v)
• update(x,f_i,val,v)

Why we need Full Persistent Data-structure?

Basic Idea

- Now we can modify any pervious version.
- Branching of versions - is possible
- In Partial Persistent Data Structure we saw Linear Ordering of versions, pervious versions were in read-only state. We could modify the latest version of any node.
- But, in Full Persistent Mode, we can branch the version order using Version Tree (*optimisation can be done using Order Maintenance List*) and modify any node at any version.

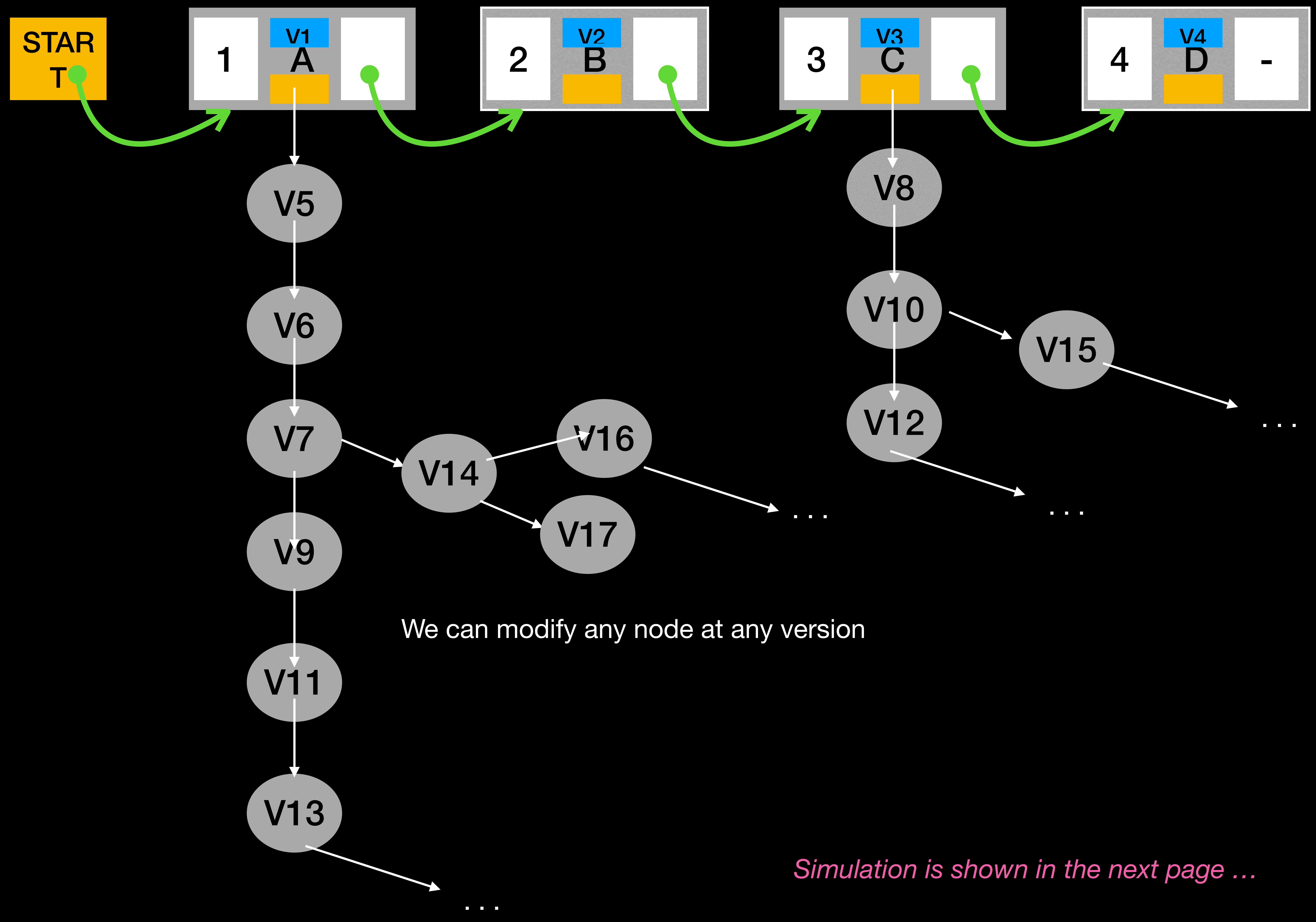
Problem in Partial Persistent Mode



We can not modify the the v7 version
When we are in
t = 14

If we want to modify
The node A in v = 14 onwards
We have to extend the version list
From V13

Remedy in Full Persistent Mode



No concept of Read Only Version

We can modify any node at any version

Simulation is shown in the next page …

	Read Only
	Current Node (both read and modify)

Query: init_LL()

Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

Current time, t = 0

START MODULE

V0

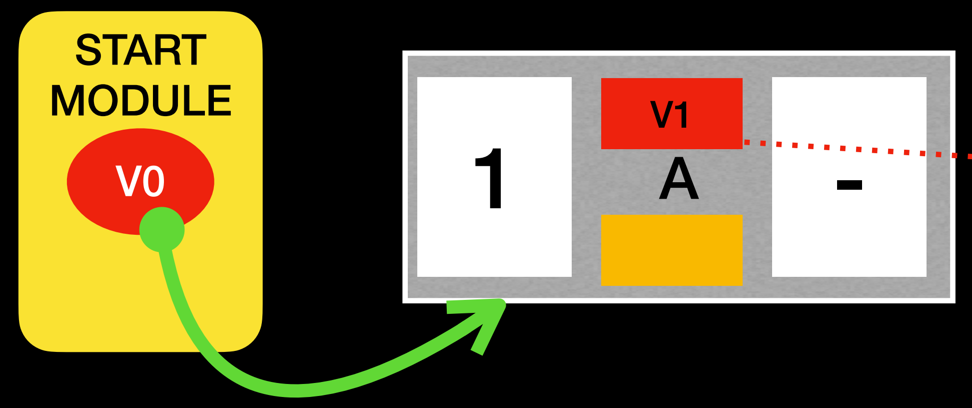
Version tree

V0

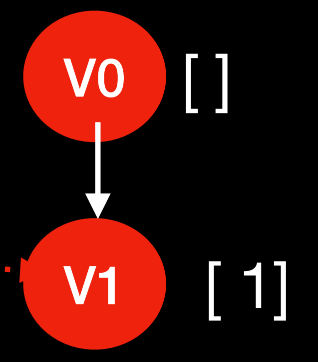
Query: add(A,_,v0,1)

Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

Current time, t = 1



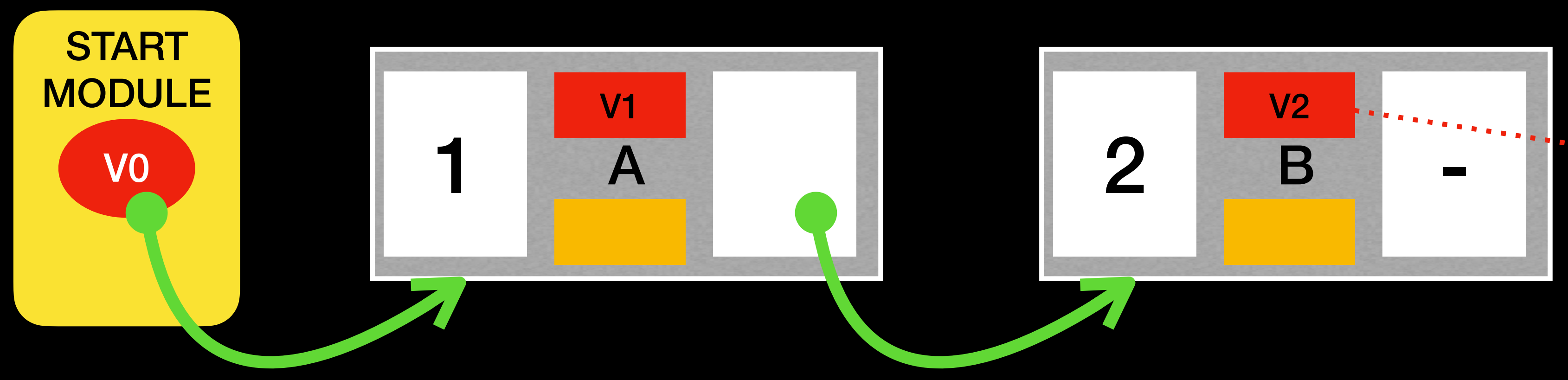
Version tree



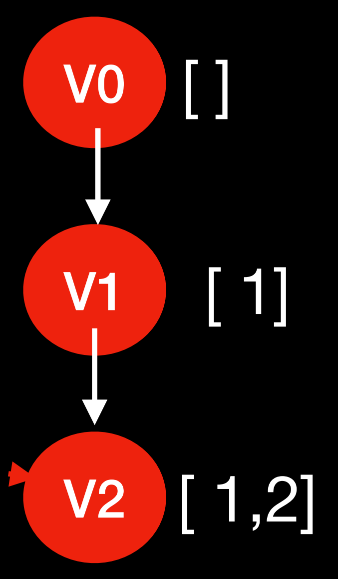
Query: add(B,A,v1,2)

Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

Current time, t = 2



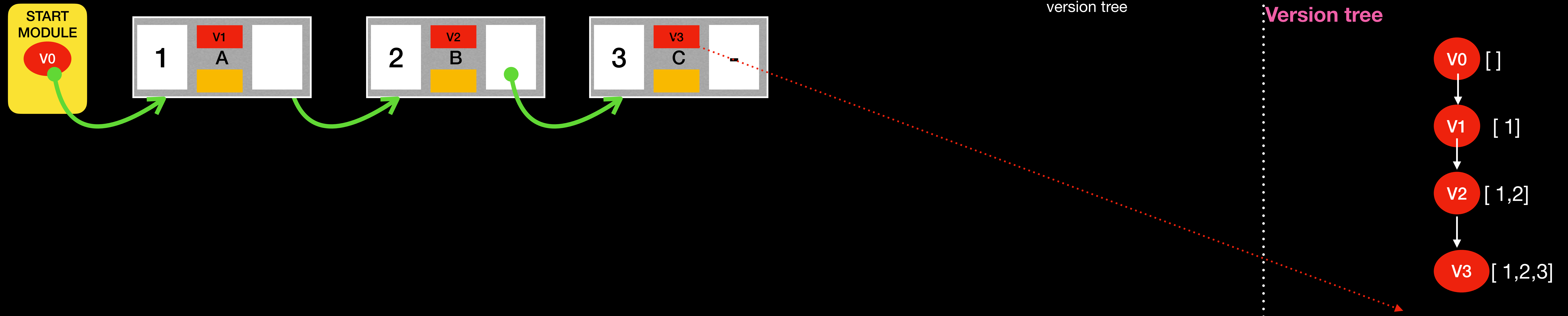
Version tree



Query: add(C,B,v2,3)

Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

Current time, t = 3



Query: add(D,C,v3,4)

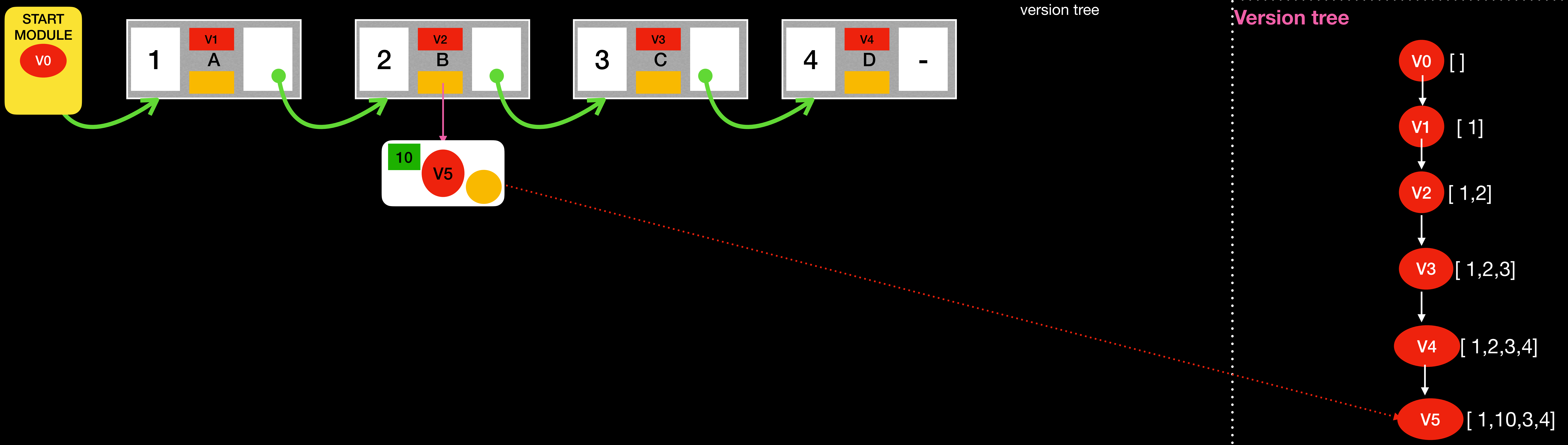
Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

Current time, t = 4

Query: update(B,f1,10,v4)

Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

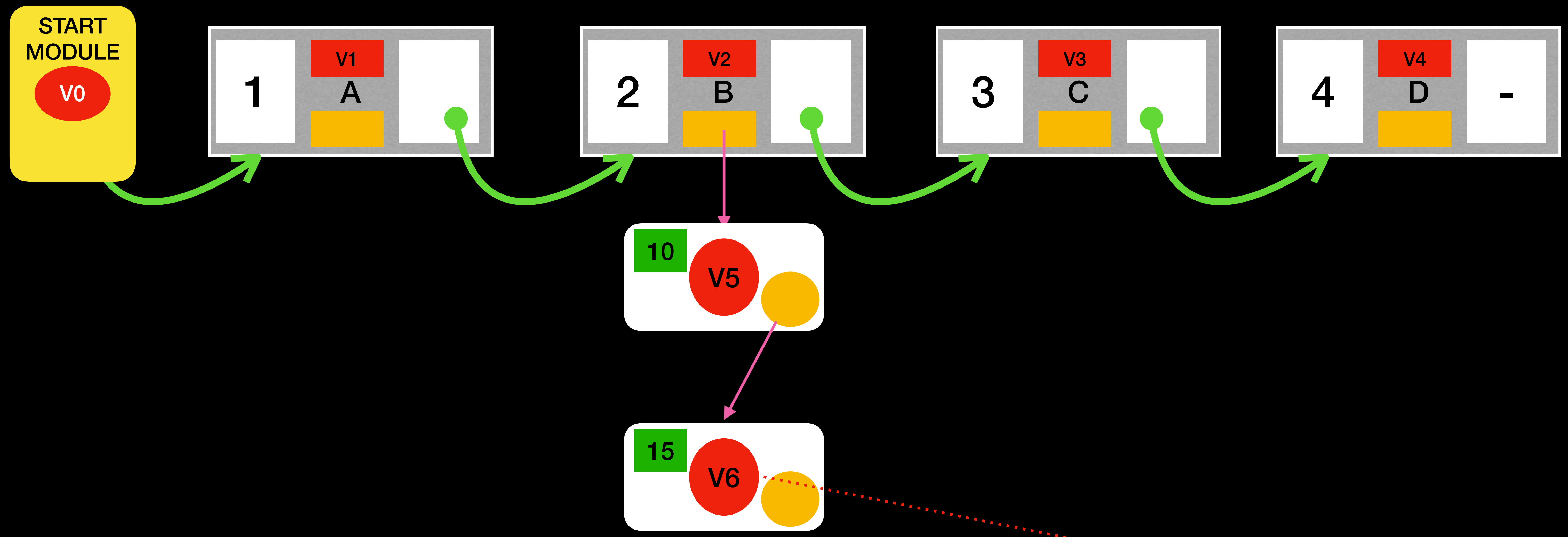
Current time, t = 5



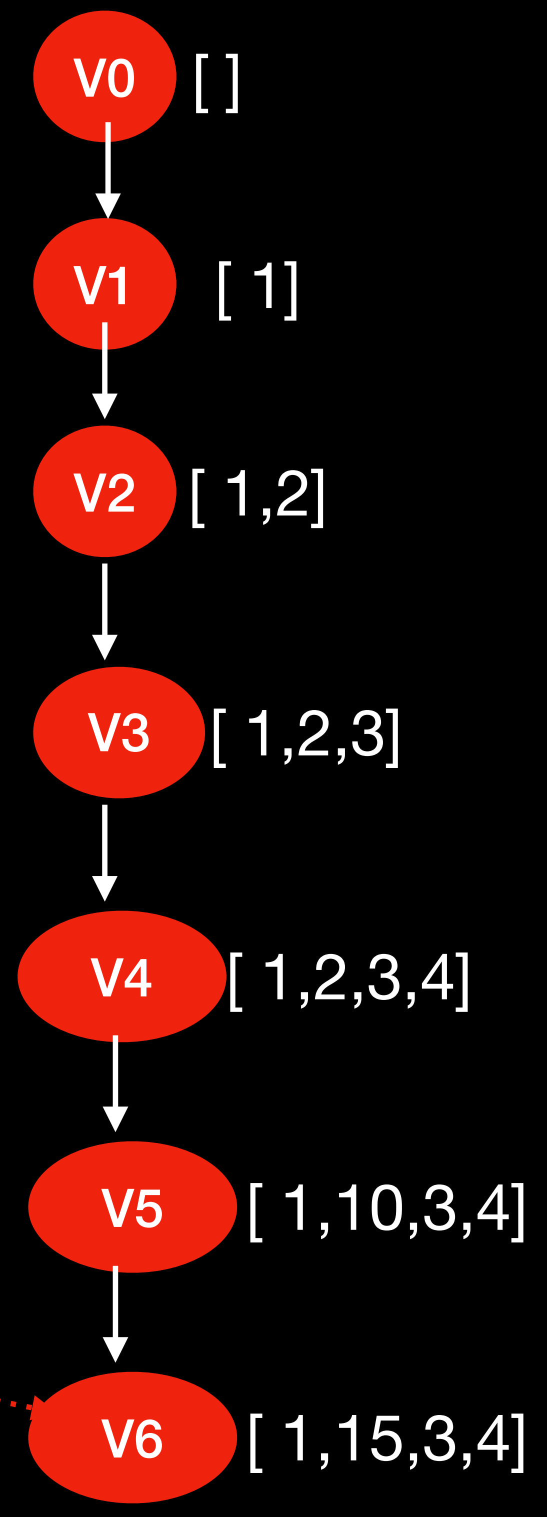
Query: update(B,f1,15,v5)

Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

Current time, t = 6



Version tree



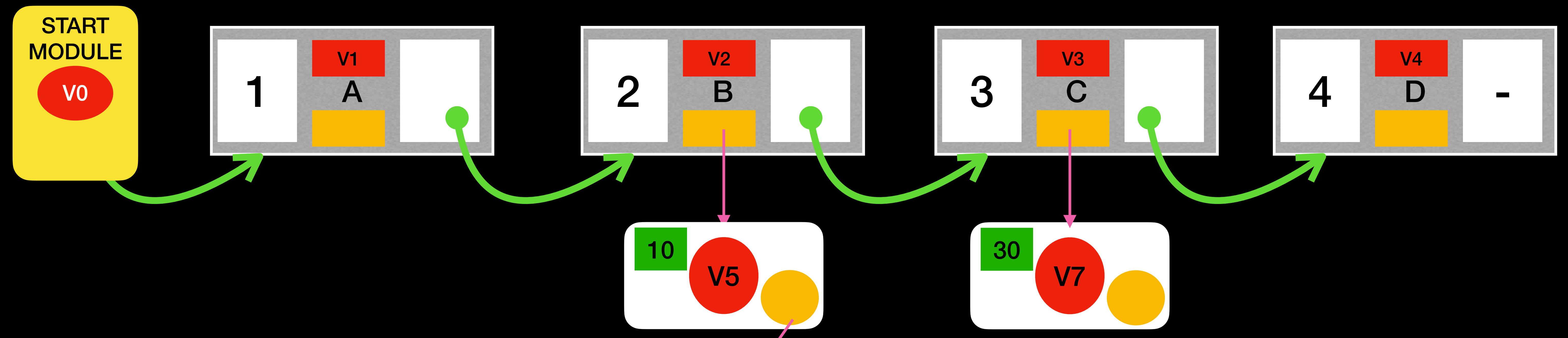
Query: update(C,f1,30,v6)

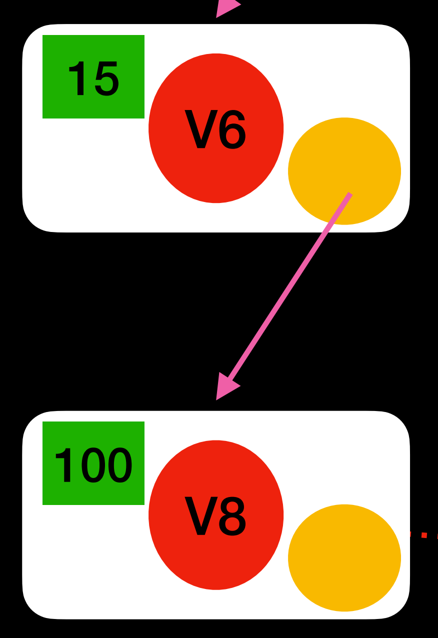
Note: Here **VERSION** at each nodes/modules are not jus numbers, rather they are the **ADDRESS** of corresponding version nodes in version tree

Current time, t = 7

Query: update(B,f1,100,v5)

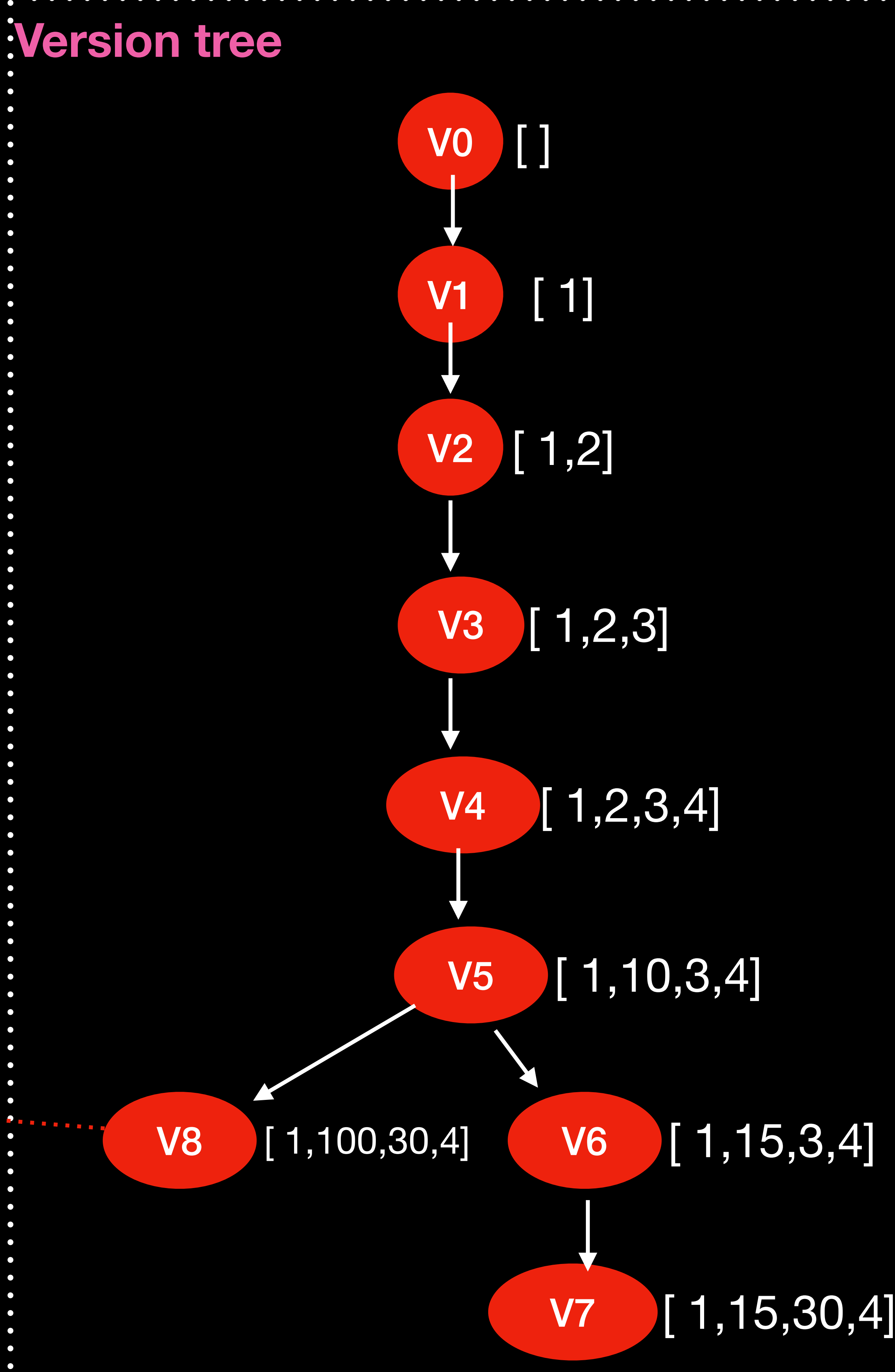
Current time, t = 8





Note: We don’t create
Any tree here
We will keep them
In a Global Version
Tree

As, That should be
Accessible to all nodes



How to do branching ?

1. Create new Update Module with version = v8 and updated fields
2. Just add v8 node to v5 node in v-tree

Query: update(C,f1,35,v8)

Current time, t = 9

Query: update(A,f1,11,v9)

Current time, t = 10

Query: update(C,f1,300,v5)

Current time, t = 11

Query: update(C,f1,333,v9)

Current time, t = 12

Query: update(B,f1,111,v2)

Current time, t = 13

Query: update(D,f1,40,v7)

Current time, t = 14

Query: update(B,f1,121,v11)

Current time, t = 15

INVALID Query: update(C,f1,3000,v13)

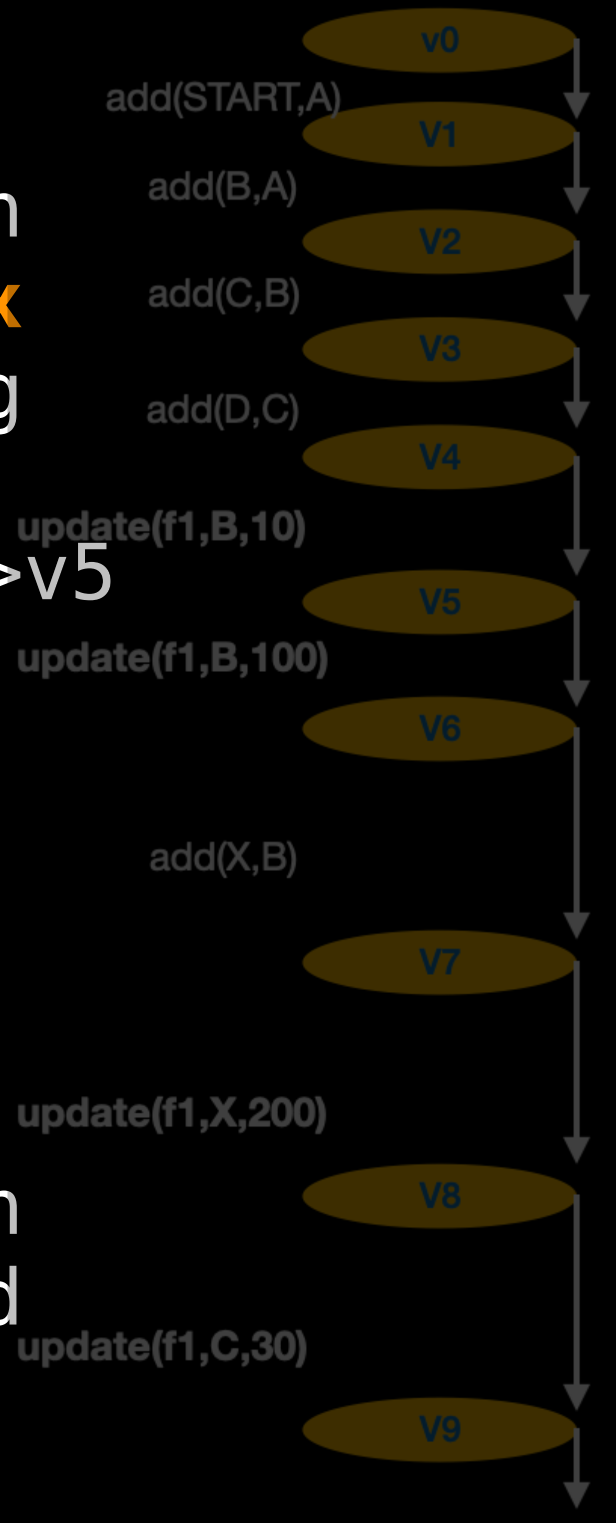
Current time, t = 15

Ok cool !! How to iterate through list in version v

Iteration in Partial Mode vs Full Mode iterate_LL_at_v(vx)

Partial Mode

1. Start from start module



2. Choose those lines whose version **IS JUST LESS THAN OR EQUAL TO v_x** (as, suppose if we are traversing for v5 , either v0,v1,v2,v3, v4 or v5 can be on that path, lines>v5 can't be on that).

3. The word "JUST LESS" is written because if a NODE has two version lines in that, e.g. v2 and v4 and we are searching for v5, then we should prefer v4 line over v2.

Full Mode

1. Start from start module

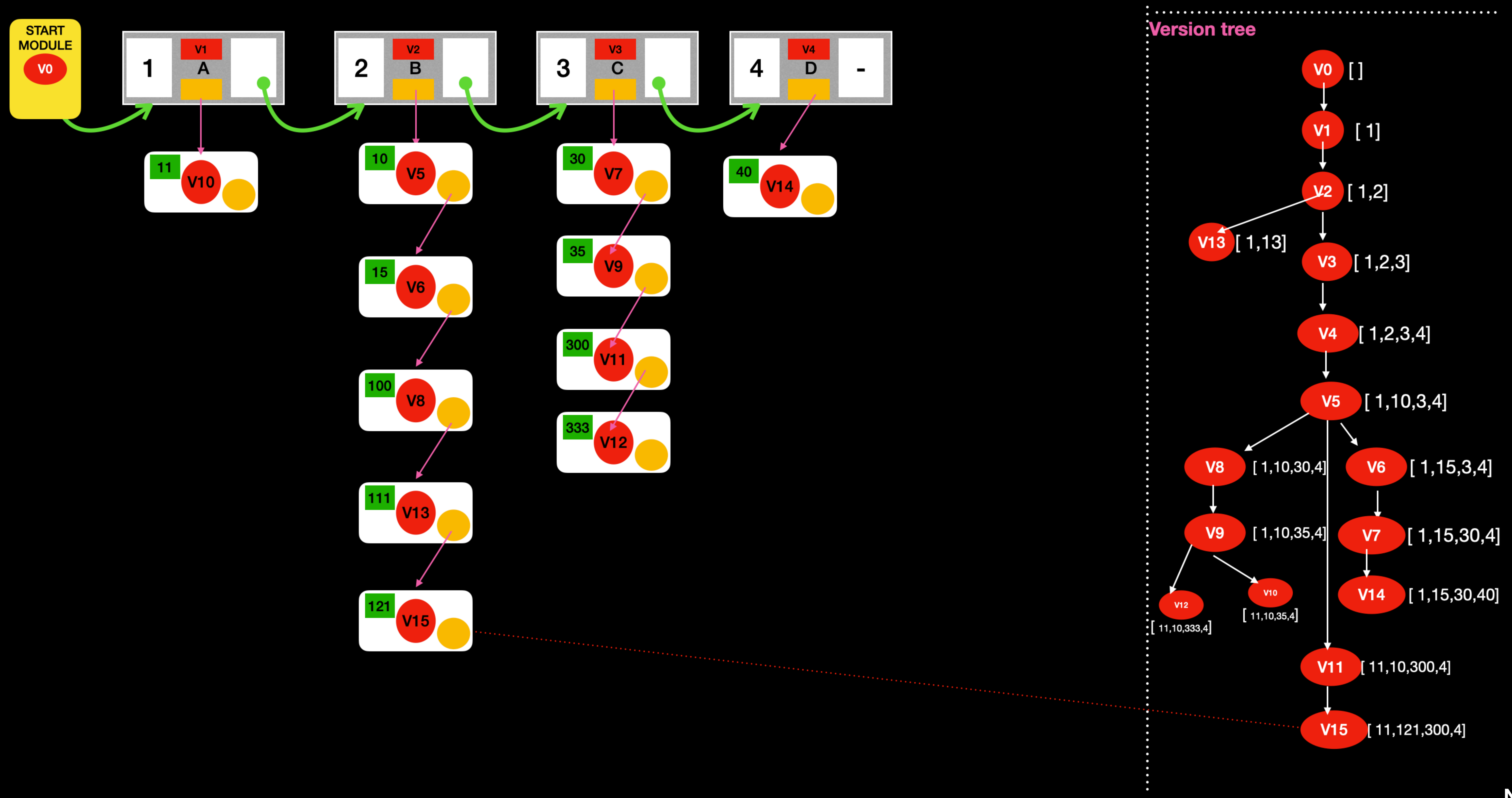
2. Choose those lines whose VERSION IS **IS NEAREST/LOWEST ANCESTOR OR EQUAL TO THAT OF v_x**

3. Here, we are searching for LOWEST ANCESTOR Because, versions are now not just number. The versions are now nodes of a version tree. E.g. suppose we are searching for who is before v14, here v11,v12,v13 .. may be numerically less than 14 but, in the structure v7 is v14's parent.

4. It was not a concern in Partial mode because the versions were linear. In a linear order v13<v14 if and only if v13 is just before v14.

Question!!

How to choose **NEAREST/LOWEST ANCESTOR from all possible ancestors ?**



Suppose, we are searching for v14
Status in node B,.

Note that, v2, v5, v6 are possible ancestors.
But, v6 is Nearest Ancestor of v14

How Do I Find that?

**ALL POSSIBLE ANCESTORS MUST BE IN A LINEAR ORDER.
AND, WE KNOW THAT THE VERSION WITH HIGHEST MAGNITUDE IS THE MOST RECENT IN LINEAR ORDER**

Hence, we can say

Full Persistent Data-structure

is a general form of

Partial Persistent Data-structure

😀

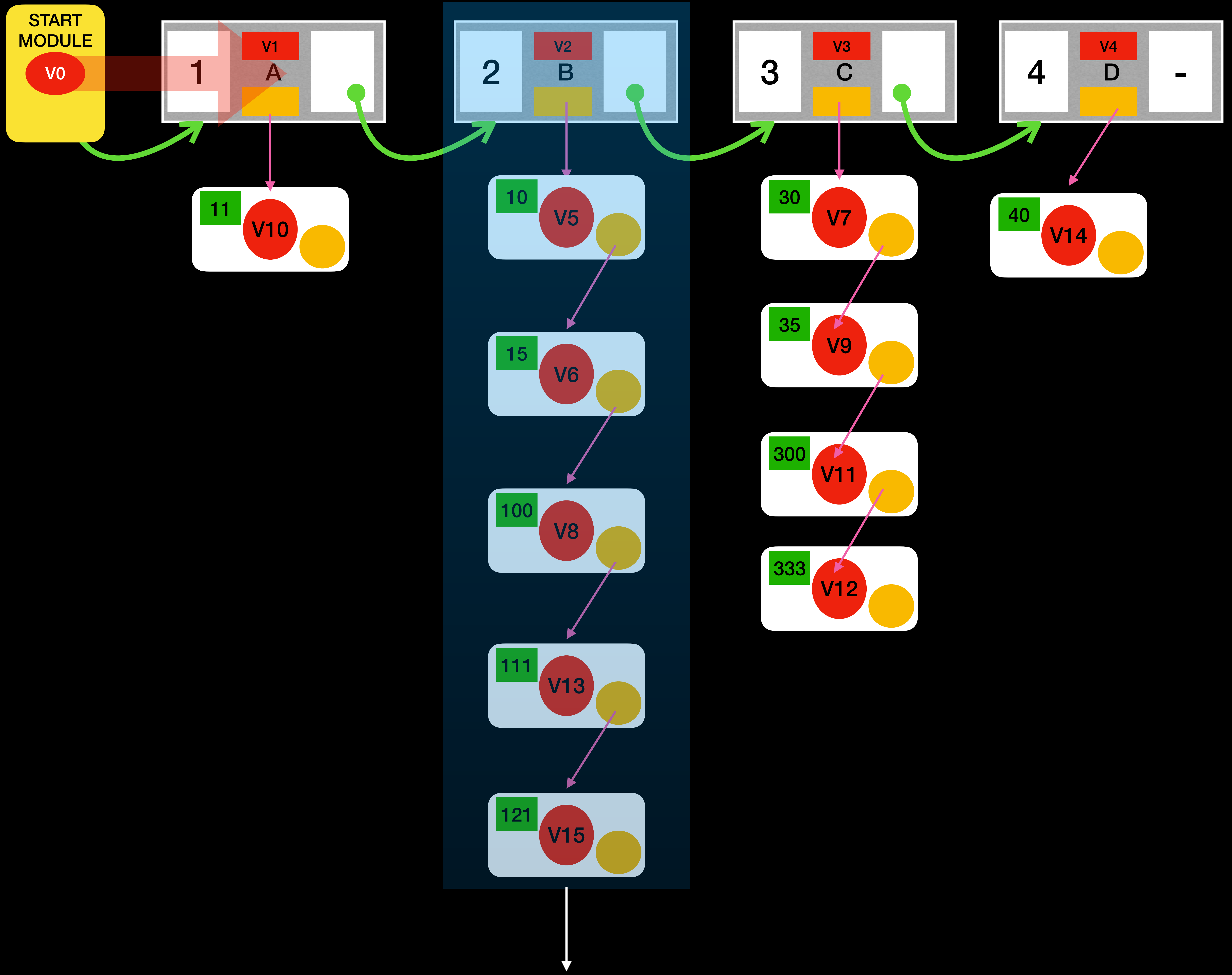
iterate_LL_at_v(v12)

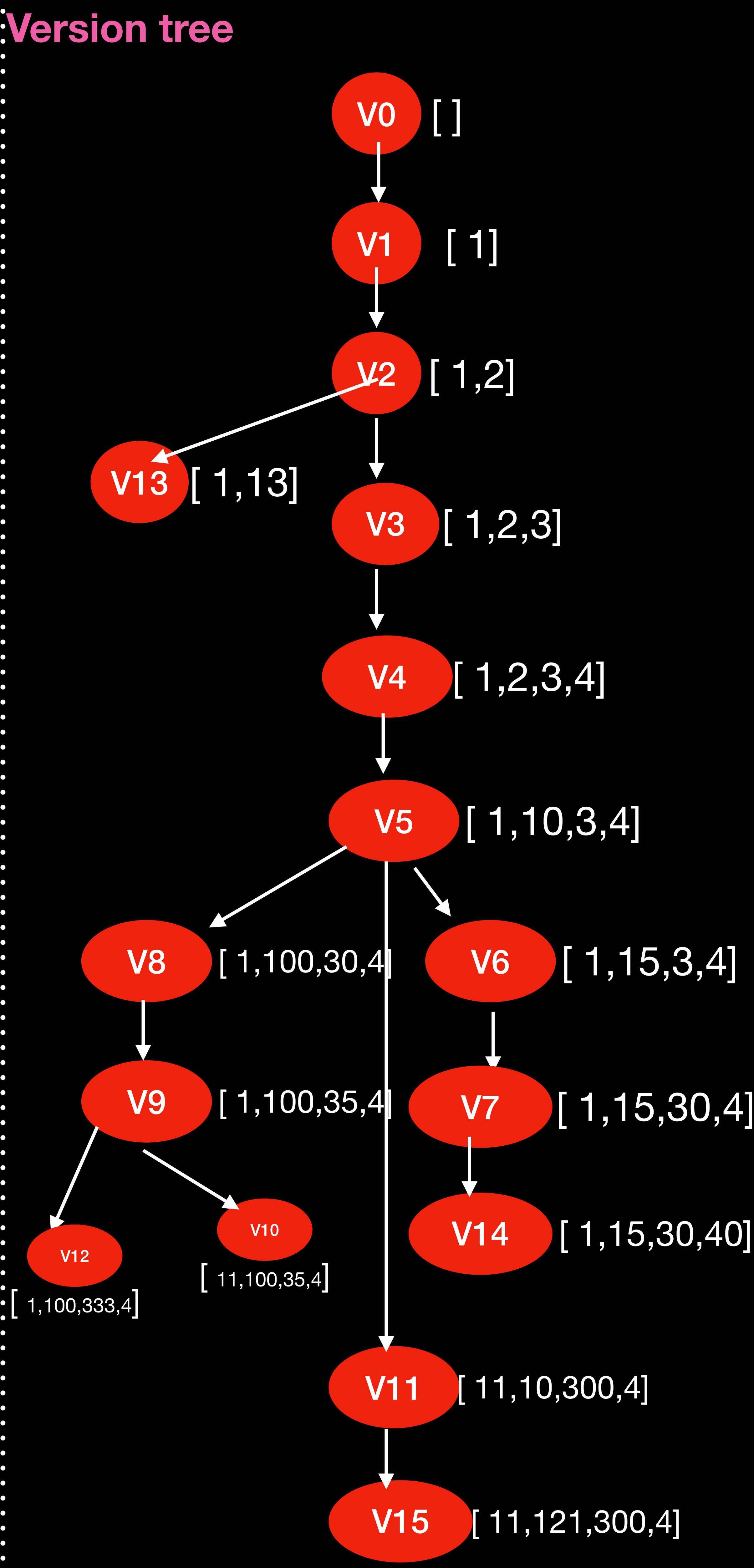
iterate_LL_at_v(v12)

OUPTUT : 1(v1)

iterate_LL_at_v(v12)

Current time, t = 15





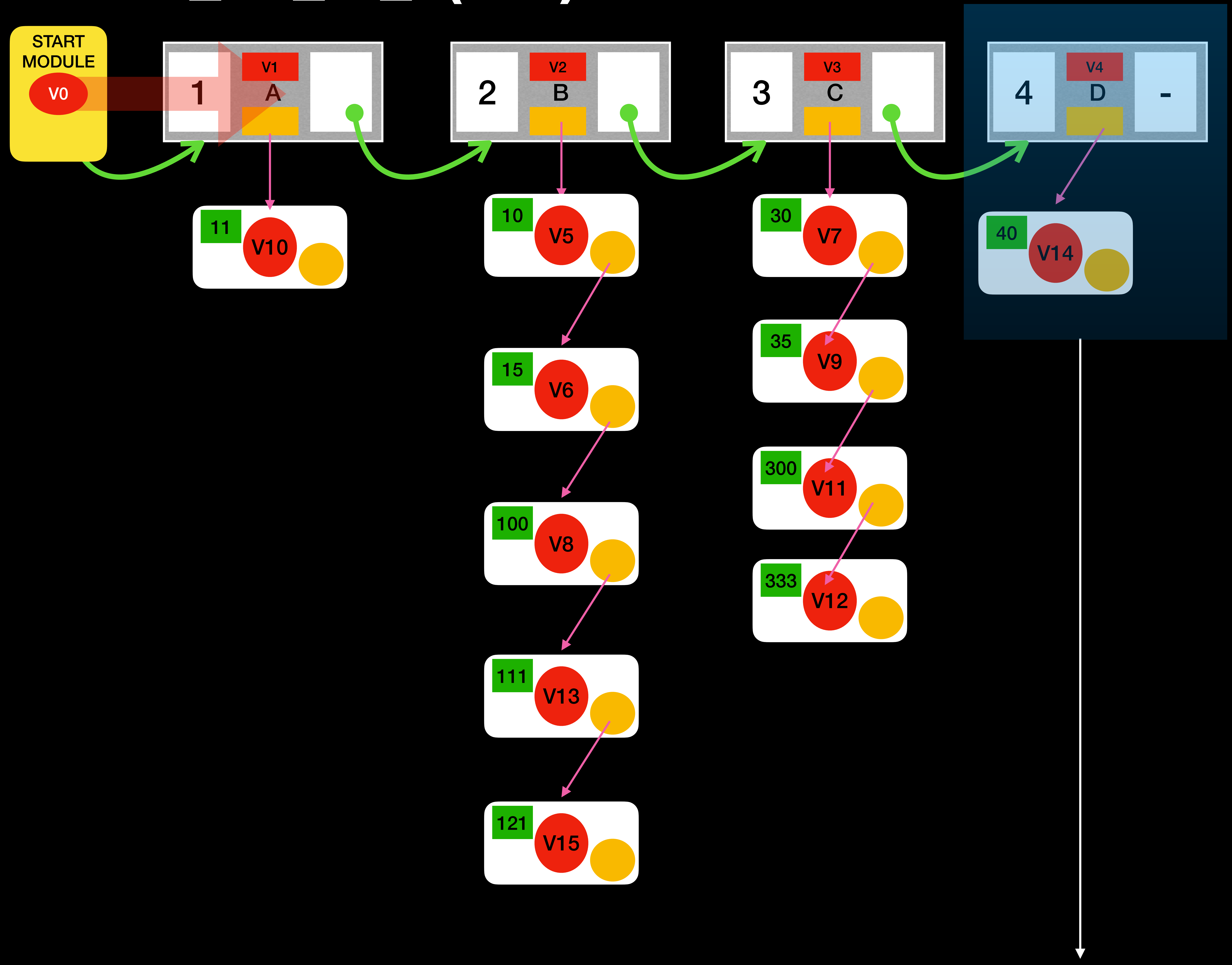
OUPTUT : 1 (v1) 100 (v8)

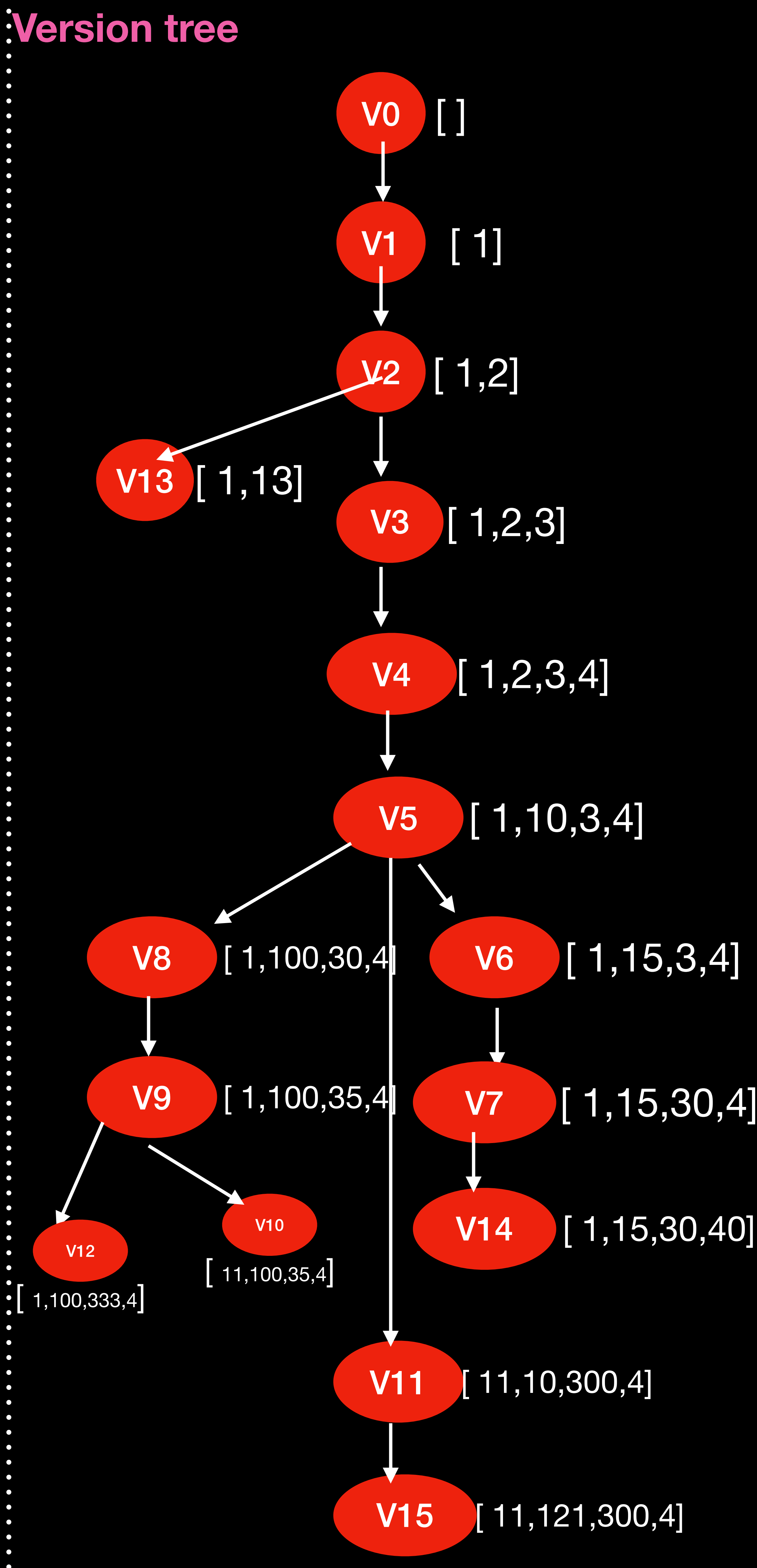
iterate_LL_at_v(v12)

OUPTUT : 1 (v1) 100 (v8) 333(v12)

iterate_LL_at_v(v12)

Current time, t = 15

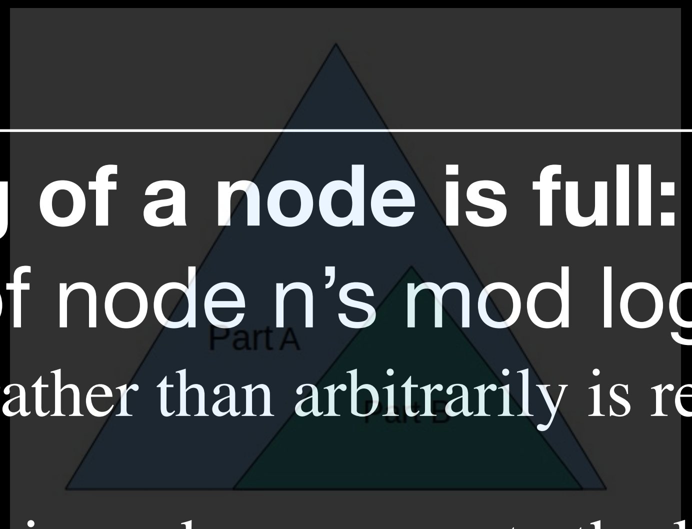




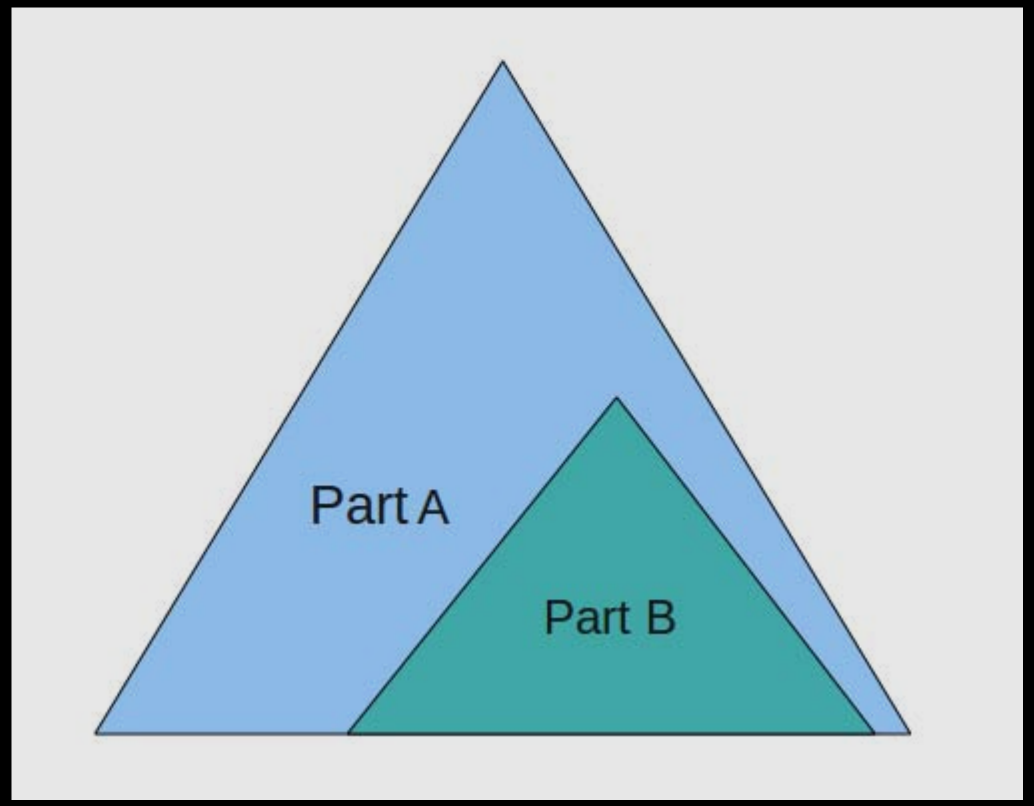
OUPTUT : 1 (v1) 100 (v8) 333(v12) 4 (v4)

Implementation Using Pointer Machine

Basic Difference In Structure in Pointer machine

Partial Persistent PM	Full Persistent PM
Versions are Just Numbers.	Versions are reference to Nodes Of Version Maintenance Data structure (typically, V Tree)
Here we allow upto 2 * p modification in each node	Here we allow upto 2(d + p + 1) modification in each node. Additionally we now also version **back-pointers**.
We create a copy of the the node, when the Mod-log of a node is full, we create a copy of the node -> node’ with the latest values of fields and BPs. And, Don’t copy any thing to Mod_log in node’.	 **When the Mod-log of a node is full:** Split the contents of node n’s mod log into two parts. Partitioning into subtrees rather than arbitrarily is required. From the ‘old’ mod entries in node n, compute the latest values of each field and write them into the data and back pointer section of node m

Major **Difference**



We split the mod-log of older node into 1:1 or 2:1 partition

Transfer the 50% or 33% recent mods to the newly created node

Set the the fields of newly created node, according to the latest values from the previous 50% or 66% Mods left in the older node.

Why?

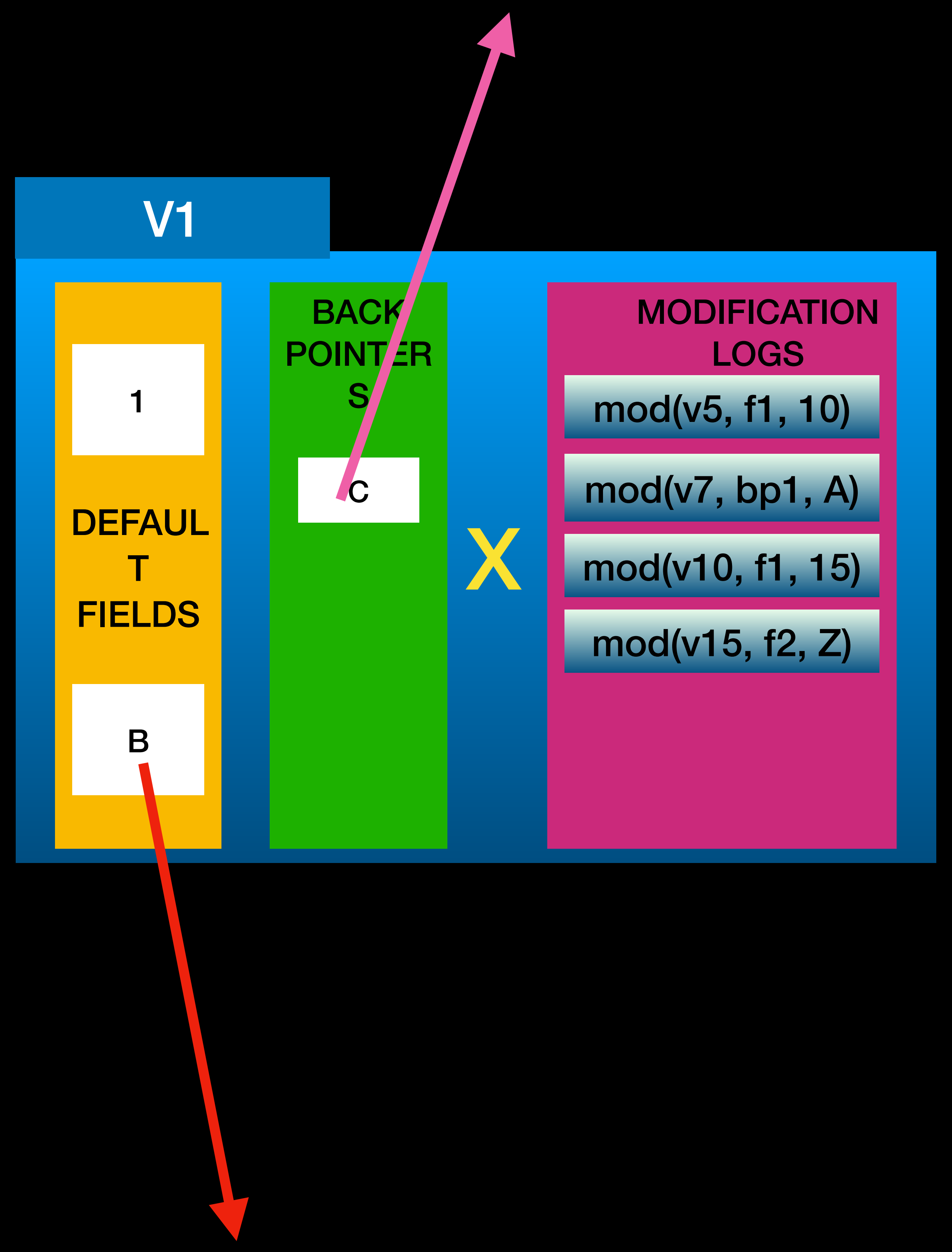
To reduce the pressure on a node of particular version.
As, we can modify a particular node of a specific version multiple number of time in Full Persistent Strategy.

Bad Way (We just create copy with 1:0 split):
A particular node of a specific version with Full Mod-Log
will create a empty-mod copy how many times we tried to modify that specific version.

Good Way (We just create copy with 1:1 / 2:1 split):
That particular node of a specific version with Full Mod-Log is now not Full anymore it has 50% or 33% space in Mod-log free to keep the upcoming modification.

Visualisation is given at next page

Problem with 1:0 Approach (What was in Partial Persistent Mode)

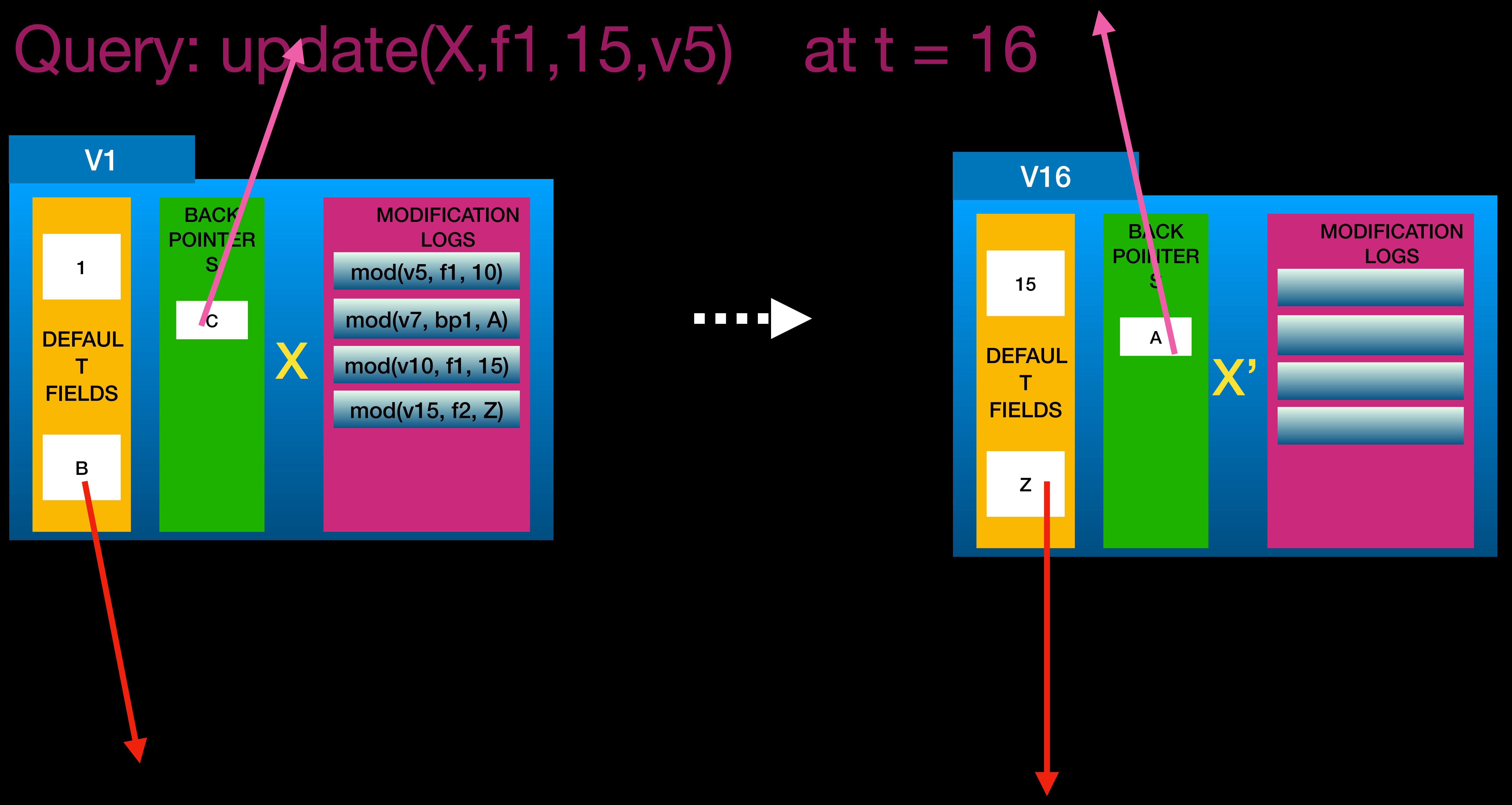


Suppose Node in any version (cur t >=15) looks like this

NOTE: THIS IS NOT DONE IN FULL PERSISTENT STRATEGY

Problem with 1:0 Approach (What was in Partial Persistent Mode)

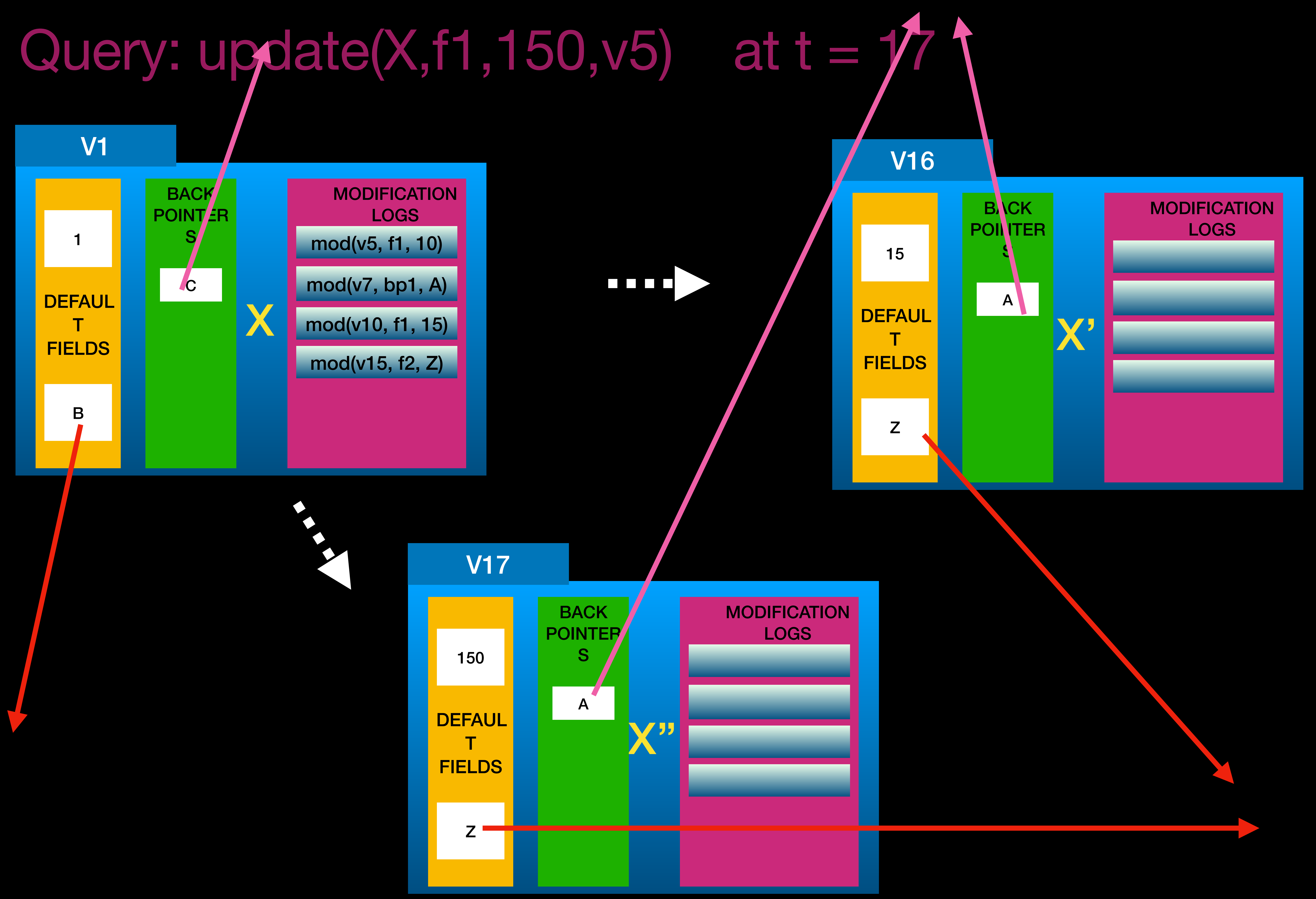
Query: update(X,f1,15,v5)   at t = 16



NOTE: THIS IS NOT DONE IN FULL PERSISTENT STRATEGY

Problem with 1:0 Approach (What was in Partial Persistent Mode)

Query: update(X,f1,150,v5)   at t = 17



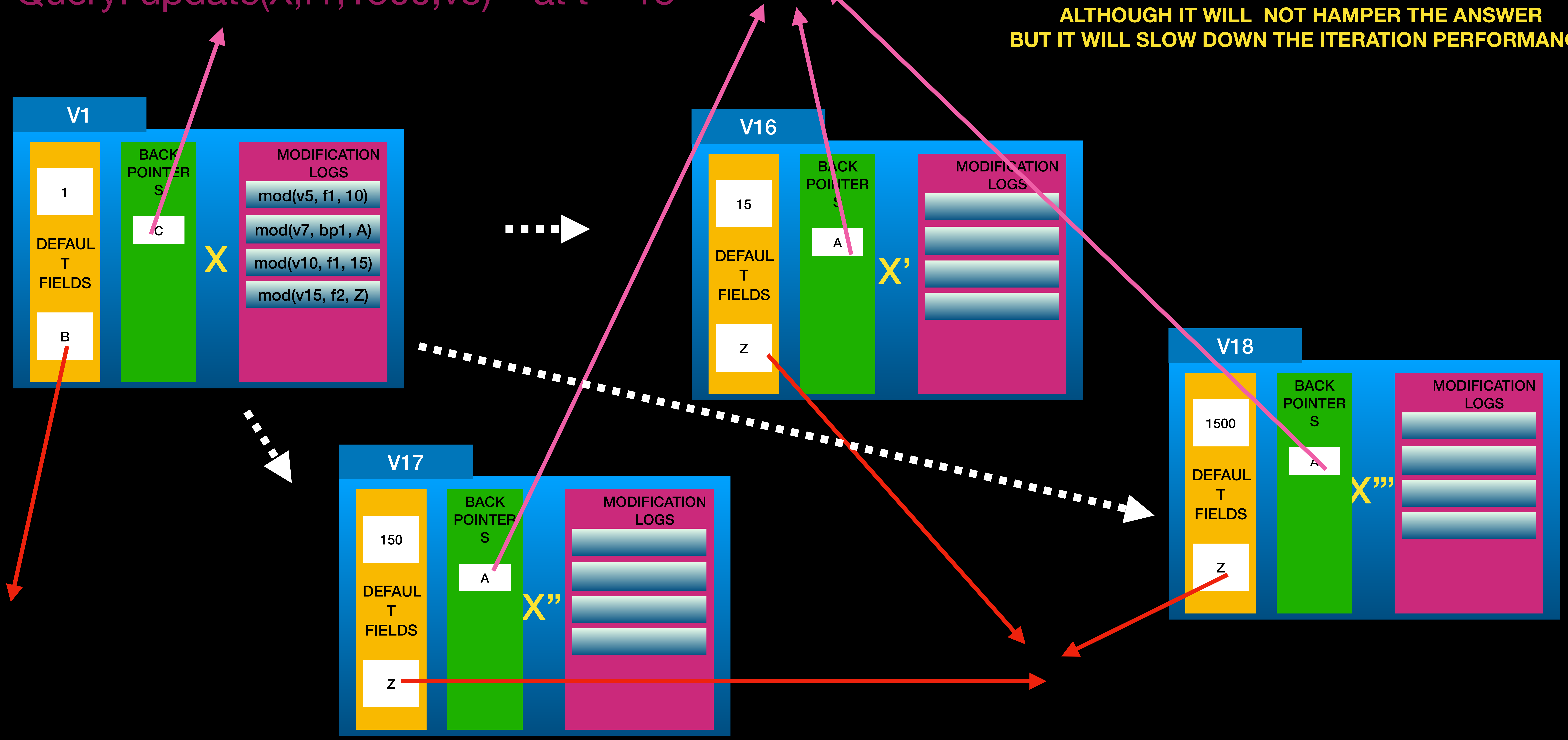
NOTE: THIS IS NOT DONE IN FULL PERSISTENT STRATEGY

Problem with 1:0 Approach (What was in Partial Persistent Mode)

Query: update(X,f1,1500,v5)   at t = 18

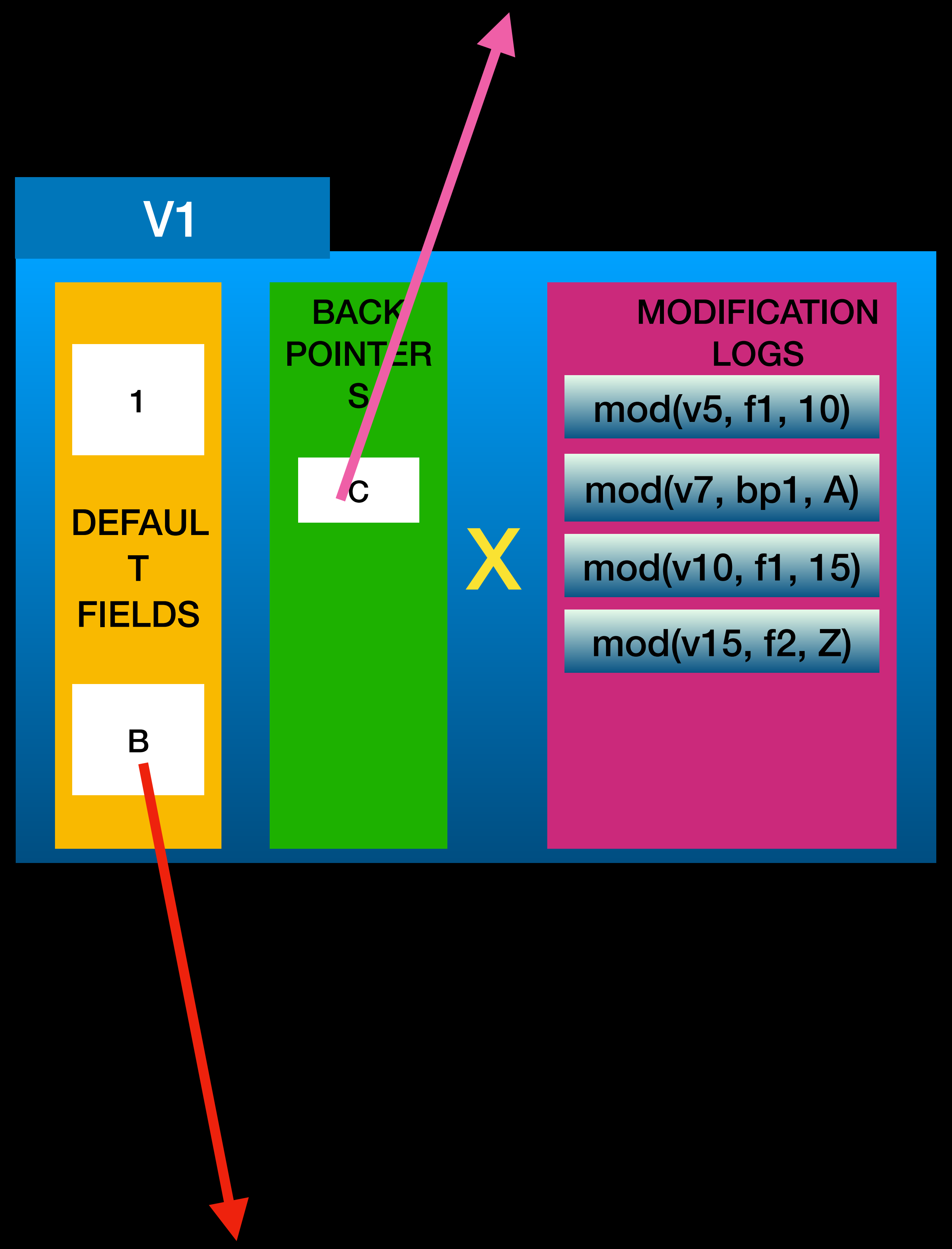
CONCERN:

WE ARE CREATING EMPTY COPIES REPEATEDLY
ALTHOUGH IT WILL NOT HAMPER THE ANSWER
BUT IT WILL SLOW DOWN THE ITERATION PERFORMANCE



NOTE: THIS IS NOT DONE IN FULL PERSISTENT STRATEGY

OPTIMISATION with 1:1 OR 2:1 Approach



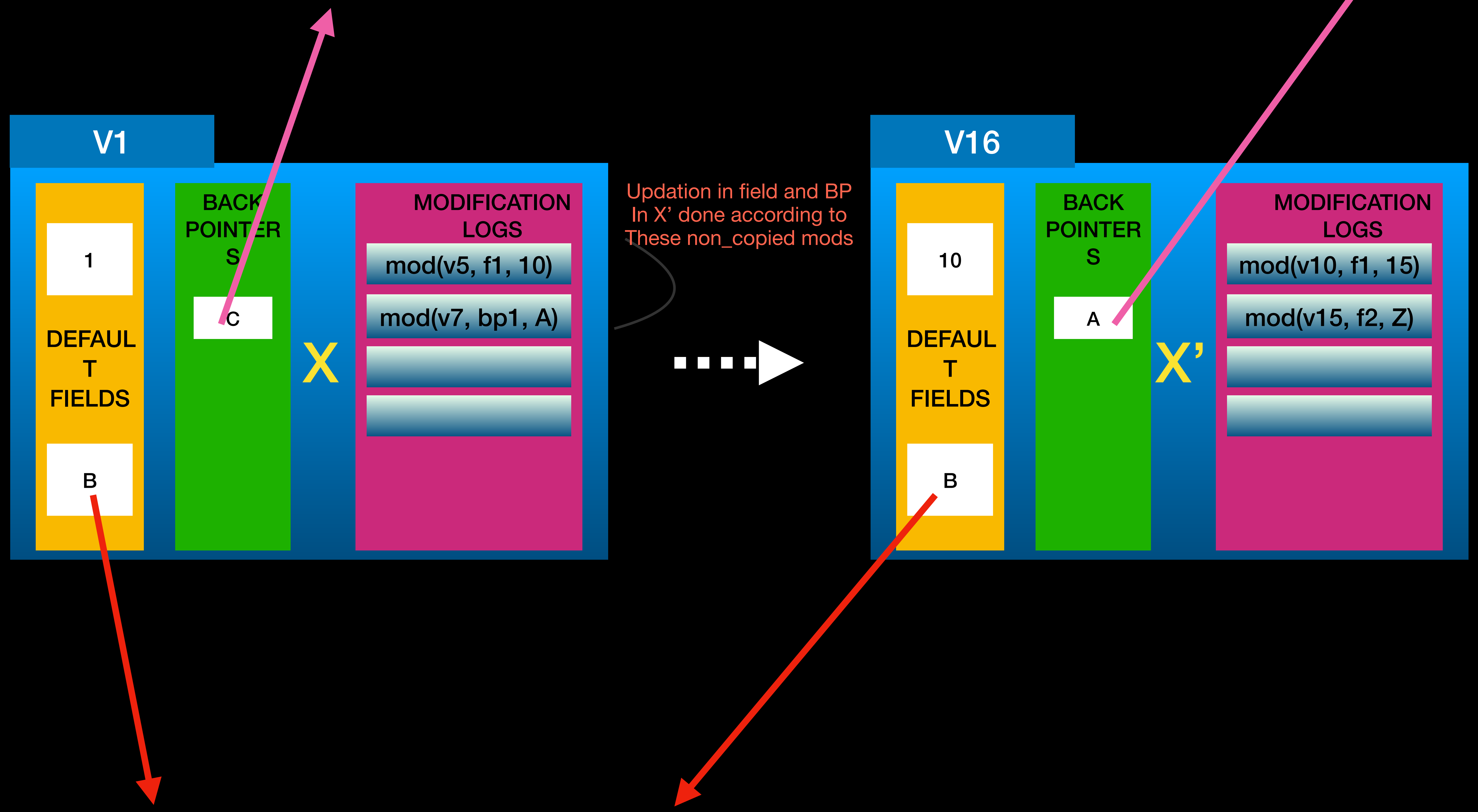
Suppose Node in any version (cur t >=15) looks like this

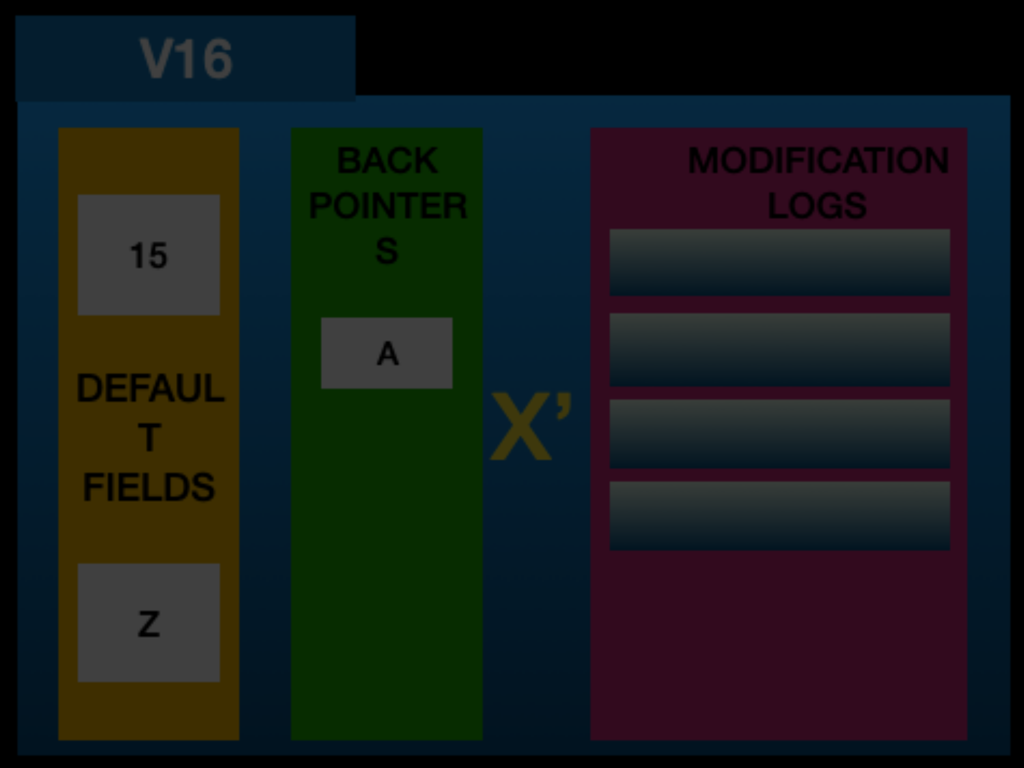
WE ARE GOING TO PRESENT 1:1 SPLIT

NOTE: THIS IS DONE IN FULL PERSISTENT STRATEGY

OPTIMISATION with 1:1 Approach

Query: update(X,f1,15,v5) at t = 16



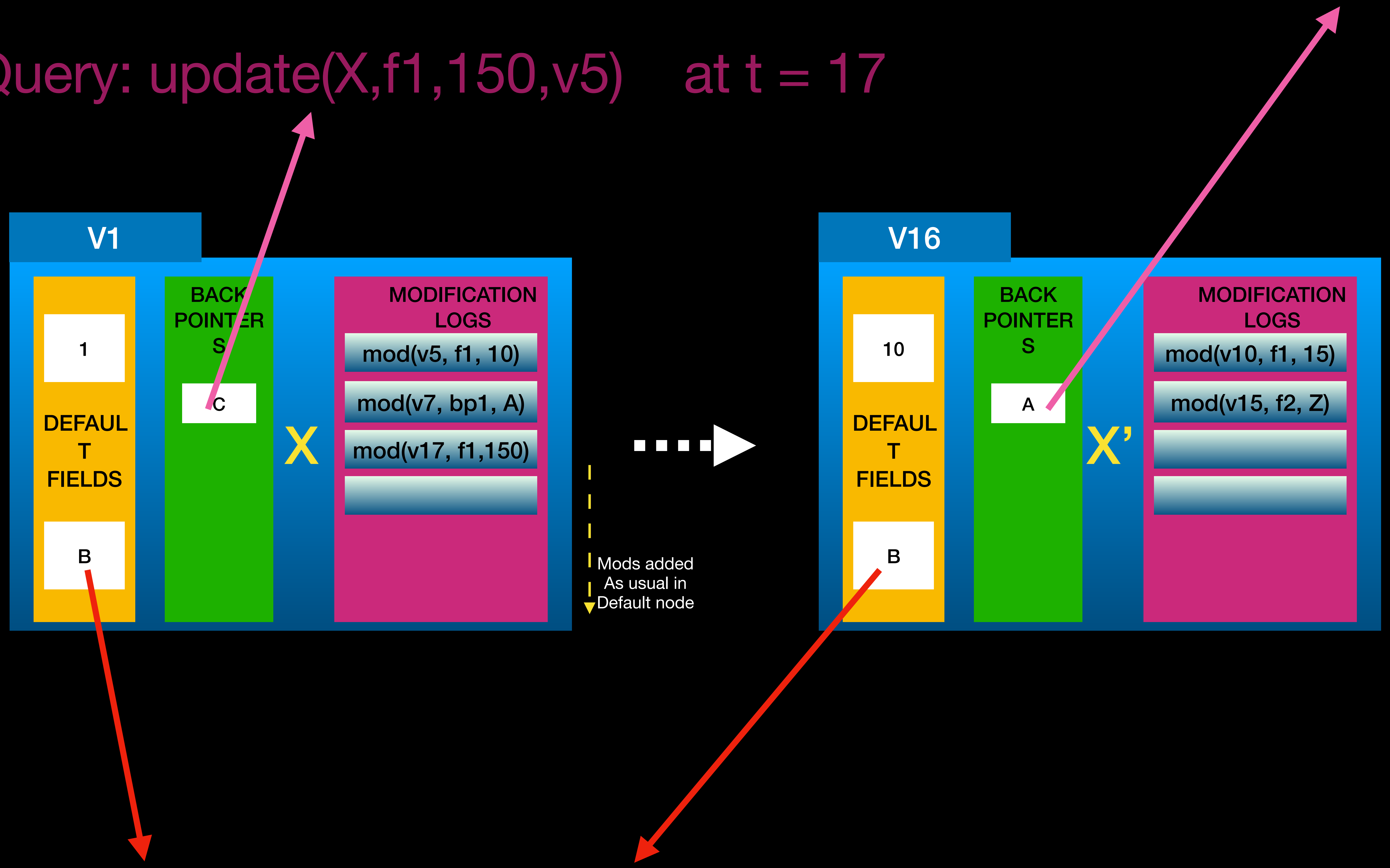


IN 1:0 MODE

NOTE: THIS IS DONE IN FULL PERSISTENT STRATEGY

OPTIMISATION with 1:1 Approach

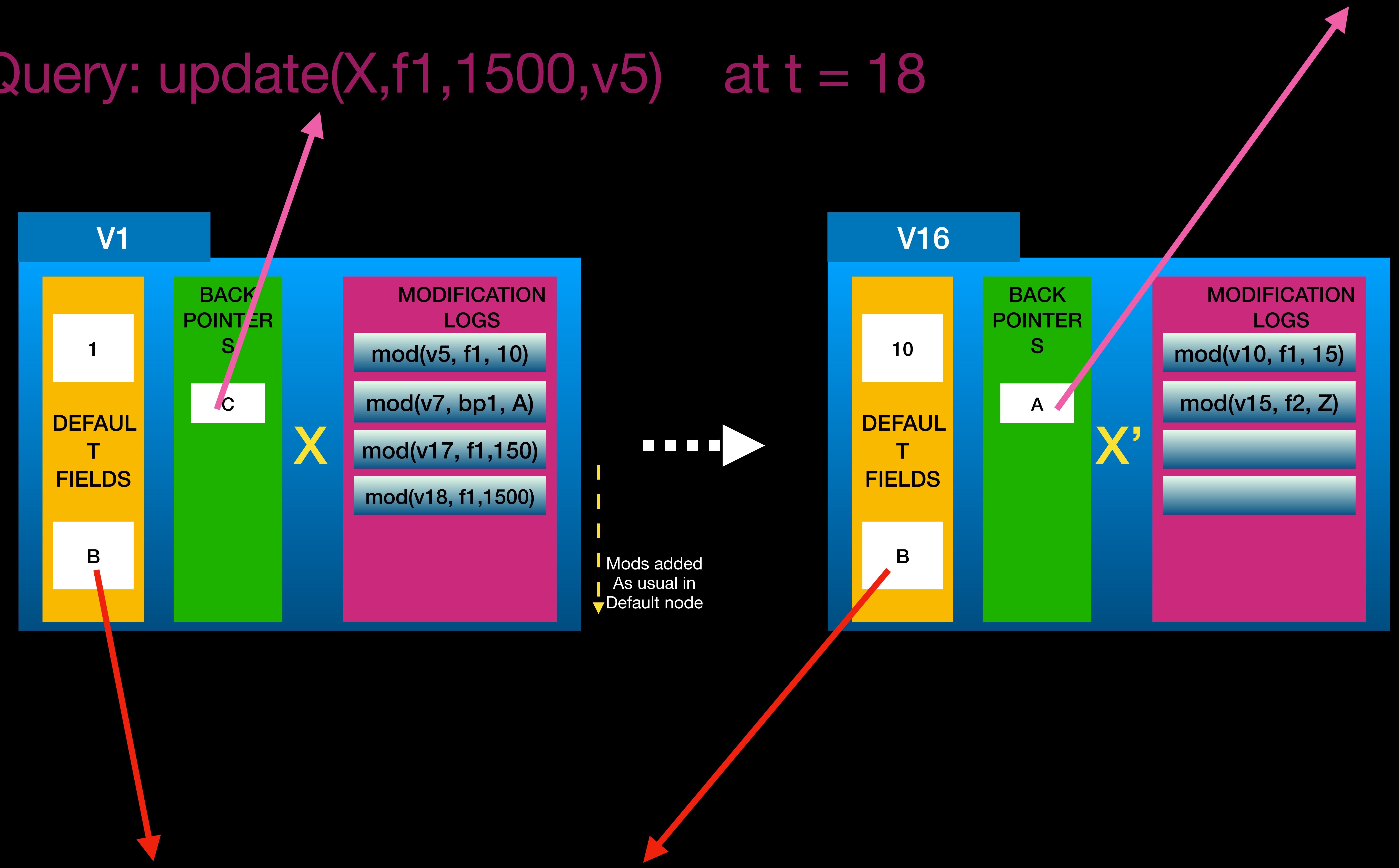
Query: update(X,f1,150,v5)   at t = 17

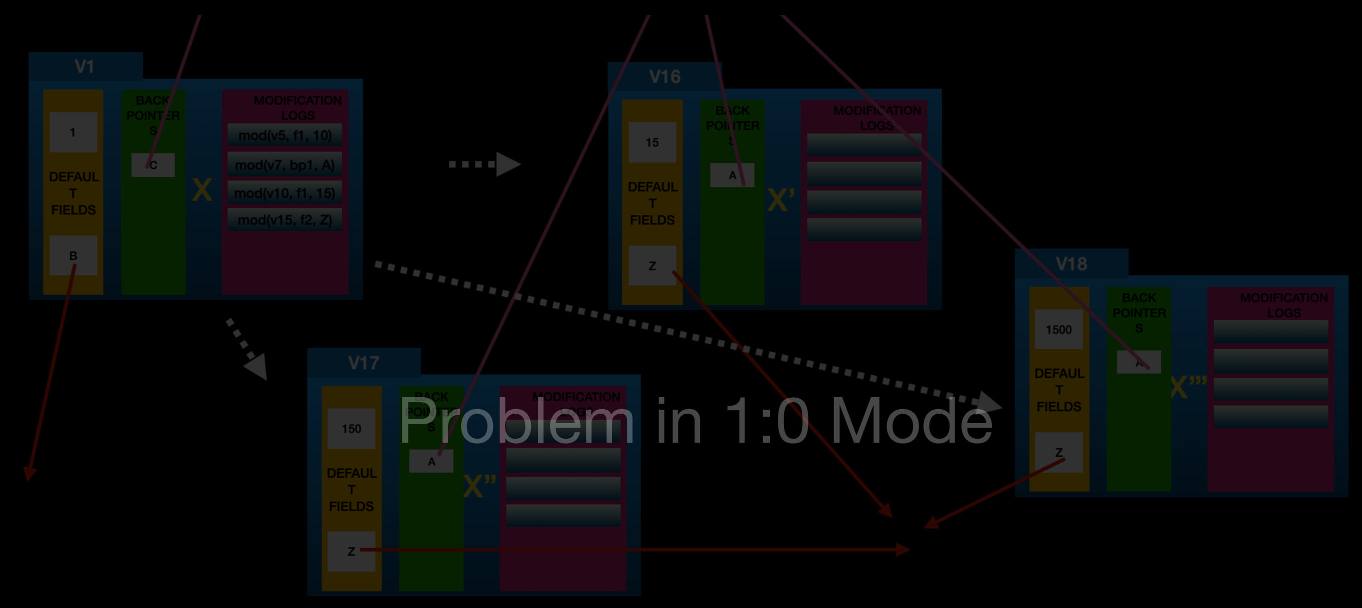


NOTE: THIS IS DONE IN FULL PERSISTENT STRATEGY

OPTIMISATION with 1:1 Approach

Query: update(X,f1,1500,v5) at t = 18





CONCERN:

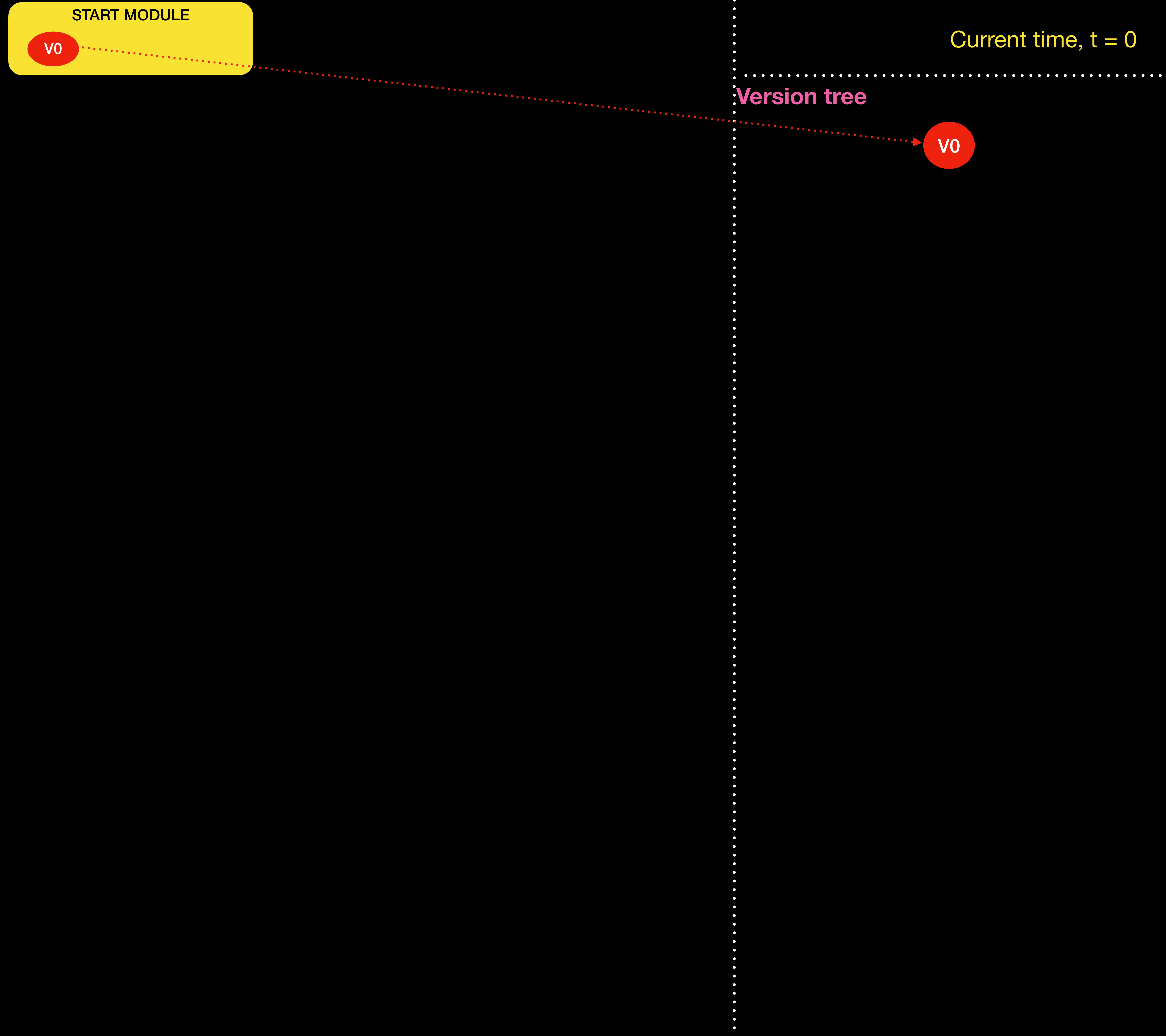
HERE WE ARE NOT CREATING SUCCESSIVE EMPTY_MOD NODE-copies

😀

NOTE: THIS IS DONE IN FULL PERSISTENT STRATEGY

Simulation Using Full Persistent Model

Query: init_LL()



Query: add(A,_,v0,1)

add(X,W,v90,1000)
at time = 95
Includes

Create new node X with f1 = 1000, defaultVersion = v95
update(W,f2,X,v90)
update(X, bp, W, v90) [here, update means set at default level]
Add v95 under v90 in version tree

Query: add(B,A,v1,2)

Query: add(C,B,v2,3)

Query: add(D,C,v3,4)

Query: update(B,f1,10,v4)

Query: update(B,f1,15,v5)

Query: update(C,f1,30,v6)

Query: update(B,f1,100,v5)

Query: update(C,f1,35,v8)

Query: update(C,f1,300,v5)

Query: update(C,f1,333,v9)

Query: update(B,f1,111,v2)

Query: update(D,f1,40,v7)


Query: update(C,f1,321,v11)
START MODULE
V0
Current time, t = 15
Version tree
V0 [ ]
V1 [1]
V2 [1,2]
V13 [111,1 3]
V3 [1,2,3]
V4 [1,2,3,4]
V5 [1,10,3,4]
V8 [1,100,30,4]
V6 [1,15,3,4]
V9 [1,100,35,4]
V7 [1,15,30,4]
V14 [1,15,30,40]
V12 [1,100,333,4]
V10 [11,100,35,4]
V11 [11,10,30
V15 ?
V1
1
DEFAULT FIELDS
B
BACK POINTERS
-
A
MODIFICATION LOGS
mod(f1,11,v10)
V2
2
DEFAULT FIELDS
C
BACK POINTERS
A
B
MODIFICATION LOGS
mod(f1,10,v5)
mod(f1,15,v6)
mod(f1,100,v8)
mod(f1,111,v13)
V3
3
DEFAULT FIELDS
D
BACK POINTERS
B
C
MODIFICATION LOGS
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,300,v11)
mod(f1,333,v12)
V4
4
DEFAULT FIELDS
BACK POINTERS
C
D
MODIFICATION LOGS
mod(f1,40,v14)
V15
DEFAULT FIELDS
BACK POINTERS
C’
MODIFICATION LOGS
STEP 1
CREATE AN EMPTY NODE NAMED C’ WITH DEF. VERSION V15
PTO->

Query: update(C,f1,321,v11)

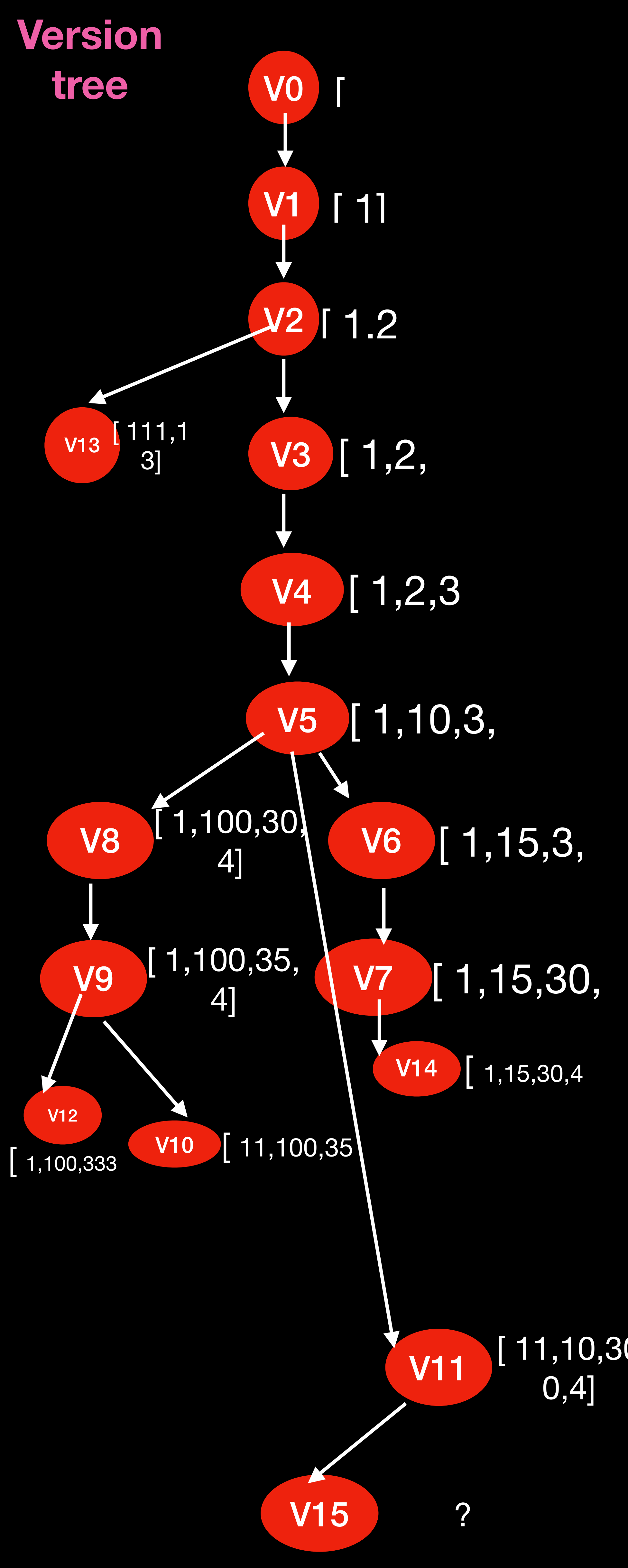
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,300,v11)
mod(f1,333,v12)
V15

Topostort

mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
mod(f1,300,v11)
V15

HOW TO DO THE SPLITTING?
ARBITRARILY OR IN A SPECIFIC ORDER?

TOPOLOGICALLY SORT THESE MODS ACCORDING TO THE VERSION ORDER
(if Vy is SUCCESOR of Vx, then Vy is considered Greater - hence Vy will got to right subtree)
Thus, you create an Ascending Order



Open problem!!
I am still thinking for an optimisation
Here. Any one help!!

Who will go to New Copy??

Choose
A Candidate Mod as pivot

Which has most number of mods who are strictly successors of that pivot
In Topological Order

Then transfer that pivot along with its successors to the new copy.

Option 1

mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
mod(f1,300,v11)
V15

/

Option 2

mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
mod(f1,300,v11)
V15

Suppose
Option 2

mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)

THIS PART WILL REMAIN IN THE OLD NODE

mod(f1,300,v11)
V15

PIVOT
THIS WILL DETERMINE THE DEFAULT VERSION OF NEWLY COPIED NODE

THIS PART WILL GO TO THE NEW COPIED NODE

STEP 2, INTERMEDIATE DISCUSSION

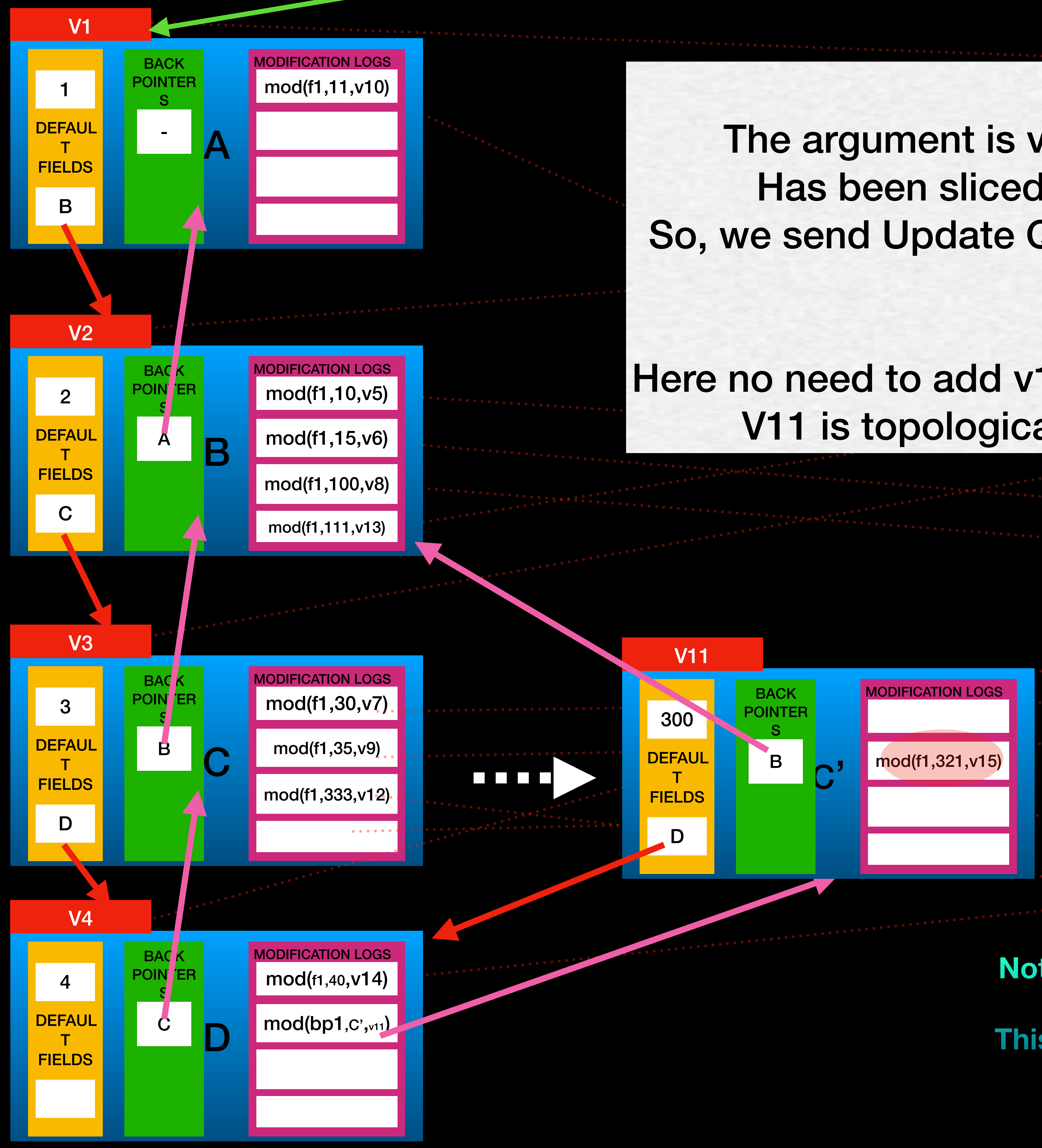
Query: update(C,f1,321,v11)
START MODULE
V0
Current time, t = 15
Version tree
V0 [ ]
V1 [1]
V2 [1,2]
V13 [111,1 3]
V3 [1,2,3]
V4 [1,2,3,4]
V5 [1,10,3,4]
V8 [1,100,30,4]
V6 [1,15,3,4]
V9 [1,100,35,4]
V7 [1,15,30,4]
V14 [1,15,30,40]
V12 [1,100,333,4]
V10 [11,100,35,4]
V11 [11,10,30
V15 ?
V1
1
DEFAUL T FIELDS
B
BACK POINTER S
-
A
MODIFICATION LOGS
mod(f1,11,v10)
V2
2
DEFAUL T FIELDS
C
BACK POINTER S
A
B
MODIFICATION LOGS
mod(f1,10,v5)
mod(f1,15,v6)
mod(f1,100,v8)
mod(f1,111,v13)
V3
3
DEFAUL T FIELDS
D
BACK POINTER S
B
C
MODIFICATION LOGS
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
V4
4
DEFAUL T FIELDS
BACK POINTER S
C
D
MODIFICATION LOGS
mod(f1,40,v14)
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
THIS PART WILL REMAIN IN THE OLD NODE
mod(f1,300,v11)
V15
PIVOT
THIS WILL DETERMINE THE DEFAULT VERSION OF NEWLY COPIED NODE
THIS PART WILL GO TO THE NEW COPIED NODE
NOTE: IT IS NOT V15
V11
300
DEFAUL T FIELDS
D
BACK POINTER S
B
C'
MODIFICATION LOGS
mod(V15 ??)
STEP 2, INTERMEDIATE DISCUSSION
TRANSFER AROUND 50% MODS TO C' FROM C
PTO->

Query: update(C,f1,321,v11)
START MODULE
V0
Current time, t = 15
Version tree
V1
1
DEFAULT FIELDS
B
BACK POINTERS
-
A
MODIFICATION LOGS
mod(f1,11,v10)
V2
2
DEFAULT FIELDS
C
BACK POINTERS
A
B
MODIFICATION LOGS
mod(f1,10,v5)
mod(f1,15,v6)
mod(f1,100,v8)
mod(f1,111,v13)
V3
3
DEFAULT FIELDS
D
BACK POINTERS
B
C
MODIFICATION LOGS
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
V4
4
DEFAULT FIELDS
BACK POINTERS
C
D
MODIFICATION LOGS
mod(f1,40,v14)
V11
300
DEFAULT FIELDS
D
BACK POINTERS
B
C'
MODIFICATION LOGS
mod(f1,321,v15)
V15 Mod is defined as user input
F1 -> 321
STEP 2 - ended
TRANSFER AROUND 50% MODS TO C'
FROM C
PTO->
V0 [ ]
V1 [1]
V2 [1,2]
V13 [111,13]
V3 [1,2,3]
V4 [1,2,3,4]
V5 [1,10,3,4]
V8 [1,100,30,4]
V6 [1,15,3,4]
V9 [1,100,35,4]
V7 [1,15,30,4]
V14 [1,15,30,40]
V12 [1,100,333,4]
V10 [11,100,35,4]
V11 [11,10,30
V15 [11,30,321,4]

Query: update(C,f1,321,v11)

START MODULE
V0

Current time, t = 15



Note:
The argument is v11, because a NEW NODE
Has been sliced off with def. Version v11
So, we send Update Query to B to add a fwd pointer
To a v11.

Here no need to add v11 under v2 as we already know
V11 is topologically at lower poison wrt v2

STEP 3

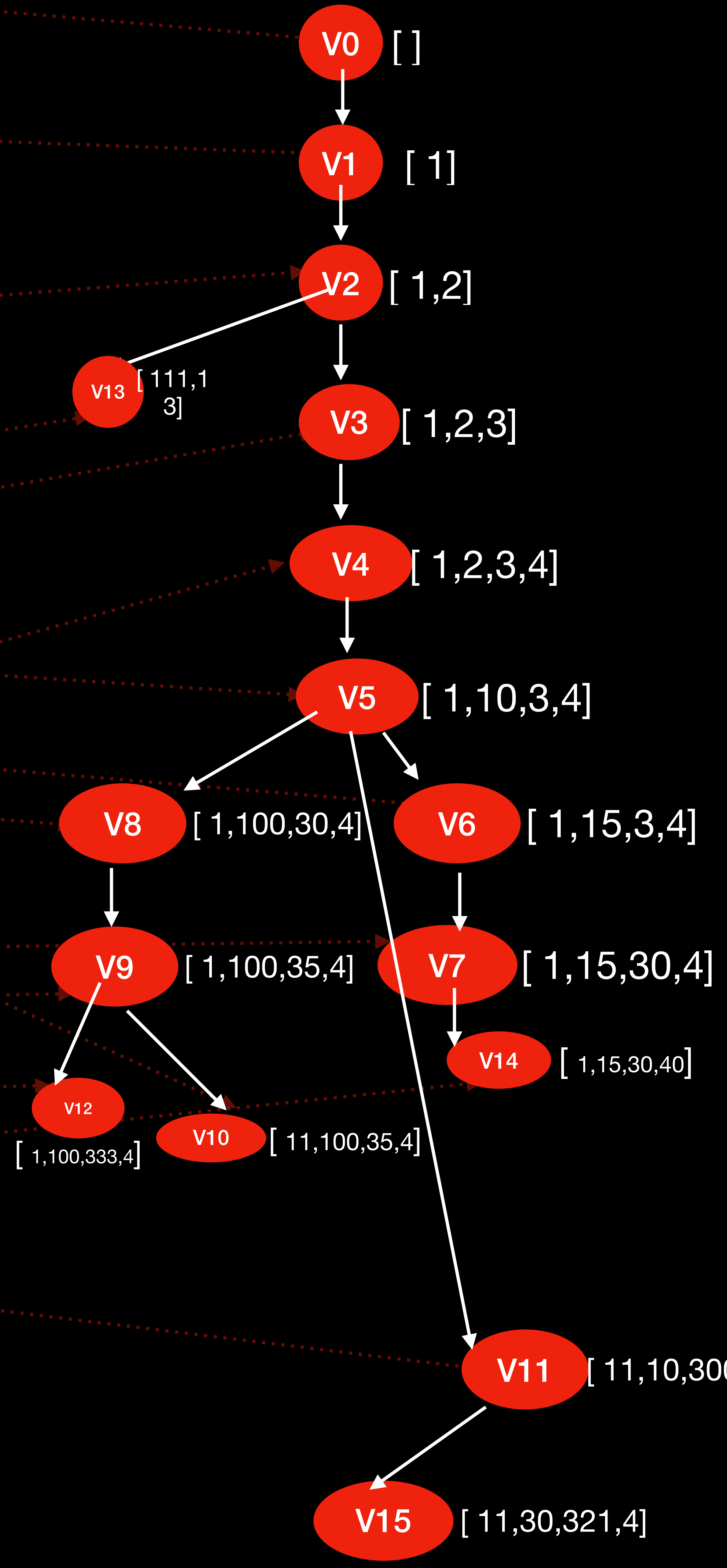
RECURSIVELY
MODIFY THE BACK POINTERS
OF SUCCESSOR

update(D,bp1,C',v11)

Note: Here We Are Not Replacing The Back-pointers
Rather adding mods for bp too (unlike Partial)
This is why, we are strong more number of MODS per
Node

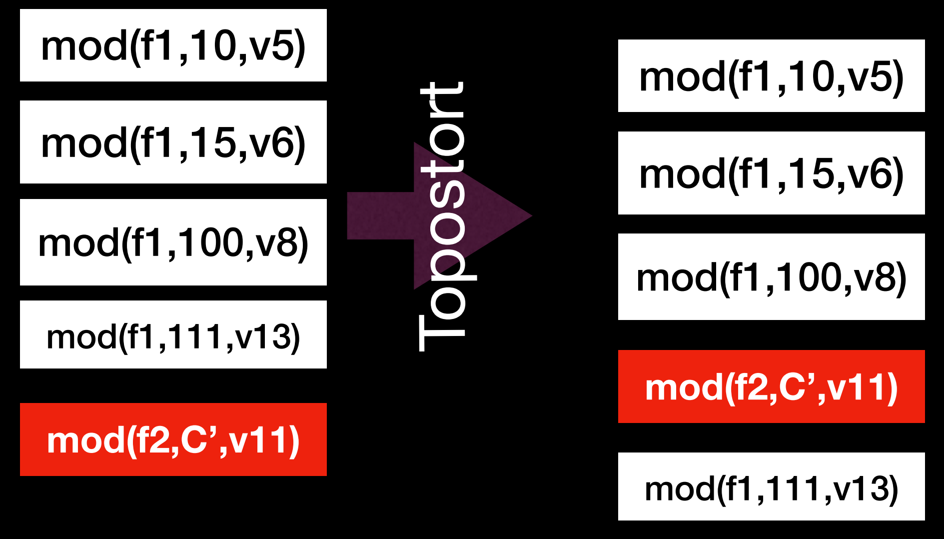
PTO->

Version tree




Query: update(C,f1,321,v11)
START MODULE
V0
Current time, t = 15
Version tree
V1
1
DEFAULT FIELDS
B
BACK POINTERS
-
A
MODIFICATION LOGS
mod(f1,11,v10)
V2
2
DEFAULT FIELDS
C
BACK POINTERS
A
B
MODIFICATION LOGS
mod(f1,10,v5)
mod(f1,15,v6)
mod(f1,100,v8)
mod(f1,111,v13)
V3
3
DEFAULT FIELDS
D
BACK POINTERS
B
C
MODIFICATION LOGS
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
V4
4
DEFAULT FIELDS
BACK POINTERS
C
D
MODIFICATION LOGS
mod(f1,40,v14)
mod(bp1,C',v15)
V11
300
DEFAULT FIELDS
D
BACK POINTERS
B
C'
MODIFICATION LOGS
mod(f1,321,v15)
Note:
The argument is v11, because a NEW NODE
Has been sliced off with def. Version v11
So, we send Update Query to B to add a fwd pointer
To a v11.
Here no need to add v11 under v2 as we already know
V11 is topologically at lower position wrt v2
STEP 4
RECURSIVELY
MODIFY THE FORWARD POINTERS
OF ANCESTORS
update(B,f2,C',v11)
PTO->
V0 [ ]
V1 [1]
V2 [1,2]
V13 [111,1 3]
V3 [1,2,3]
V4 [1,2,3,4]
V5 [1,10,3,4]
V8 [1,100,30,4]
V6 [1,15,3,4]
V9 [1,100,35,4]
V7 [1,15,30,4]
V14 [1,15,30,40]
V12 [1,100,333,4]
V10 [11,100,35,4]
V11 [11,10,30
V15 [11,30,321,4]

Query: update(C,f1,321,v11)
START MODULE
V0
Current time, t = 15
Version tree
STEP 4
RECURSIVELY
MODIFY THE FORWARD POINTERS
OF ANCESTORS
update(B,f2,C',v11)
Mod Logs of B is full!
So create a copy of B at v15 and so on …
V1
1
DEFAULT FIELDS
B
BACK POINTERS
-
A
MODIFICATION LOGS
mod(f1,11,v10)
V2
2
DEFAULT FIELDS
C
BACK POINTERS
A
B
MODIFICATION LOGS
mod(f1,10,v5)
mod(f1,15,v6)
mod(f1,100,v8)
mod(f1,111,v13)
DEFAULT FIELDS
BACK POINTERS
B'
MODIFICATION LOGS
V3
3
DEFAULT FIELDS
D
BACK POINTERS
B
C
MODIFICATION LOGS
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
V11
300
DEFAULT FIELDS
D
BACK POINTERS
B
C'
MODIFICATION LOGS
mod(f1,321,v15)
V4
4
DEFAULT FIELDS
BACK POINTERS
C
D
MODIFICATION LOGS
mod(f1,40,v14)
mod(bp1,C',v15)
V0 [ ]
V1 [1]
V2 [1,2]
V13 [111,13]
V3 [1,2,3]
V4 [1,2,3,4]
V5 [1,10,3,4]
V8 [1,100,30,4]
V6 [1,15,3,4]
V9 [1,100,35,4]
V7 [1,15,30,4]
V14 [1,15,30,40]
V12 [1,100,333,4]
V10 [11,100,35,4]
V11 [11,10,30
V15 [11,30,321,4]
PTO->



HOW TO DO THE SPLITTING? ARBITRARILY OR IN A SPECIFIC ORDER?

TOPOLOGICALLY SORT THESE MODS ACCORDING TO THE VERSION ORDER
(if Vy is SUCCESOR of Vx, then Vy is considered Greater - hence Vy will got to right subtree)
Thus, you create an Ascending Order

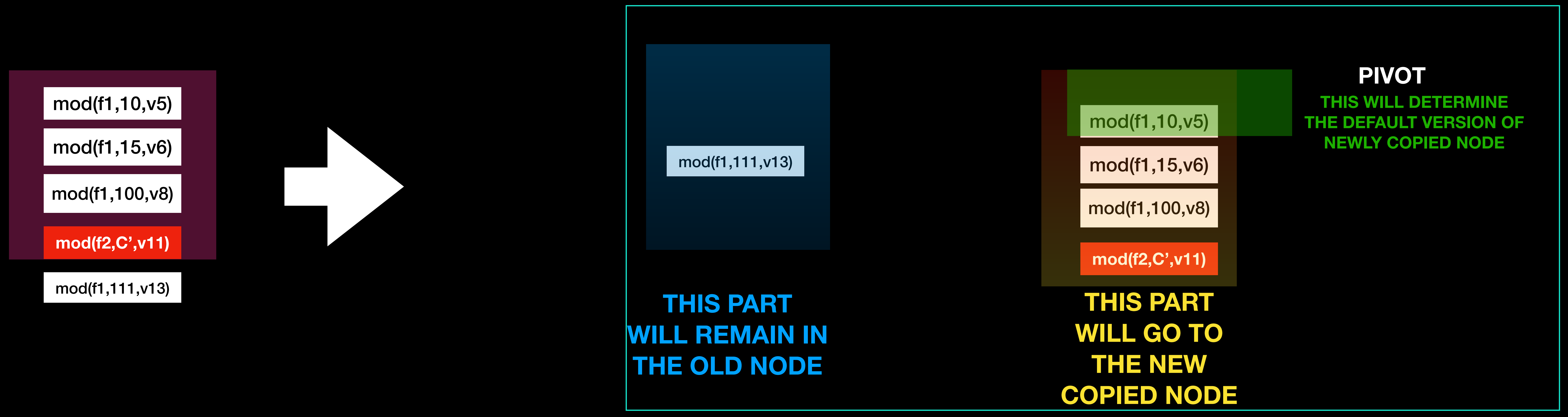
Open problem!!
I am still thinking for an optimisation
Here. Any one help!!

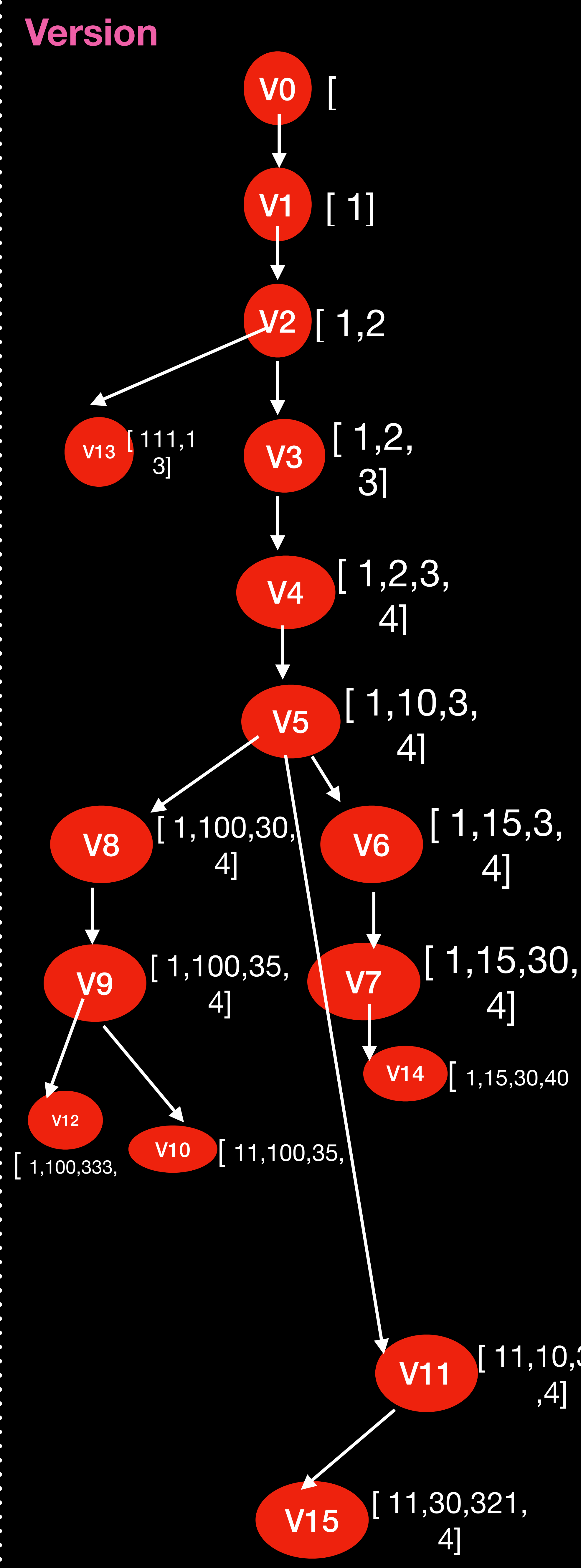
Who will go to New Copy??

Choose
A Candidate Mod as pivot

Which has most number of mods who are strictly successors of that pivot
In Topological Order

Then transfer that pivot along with its successors to the new copy.





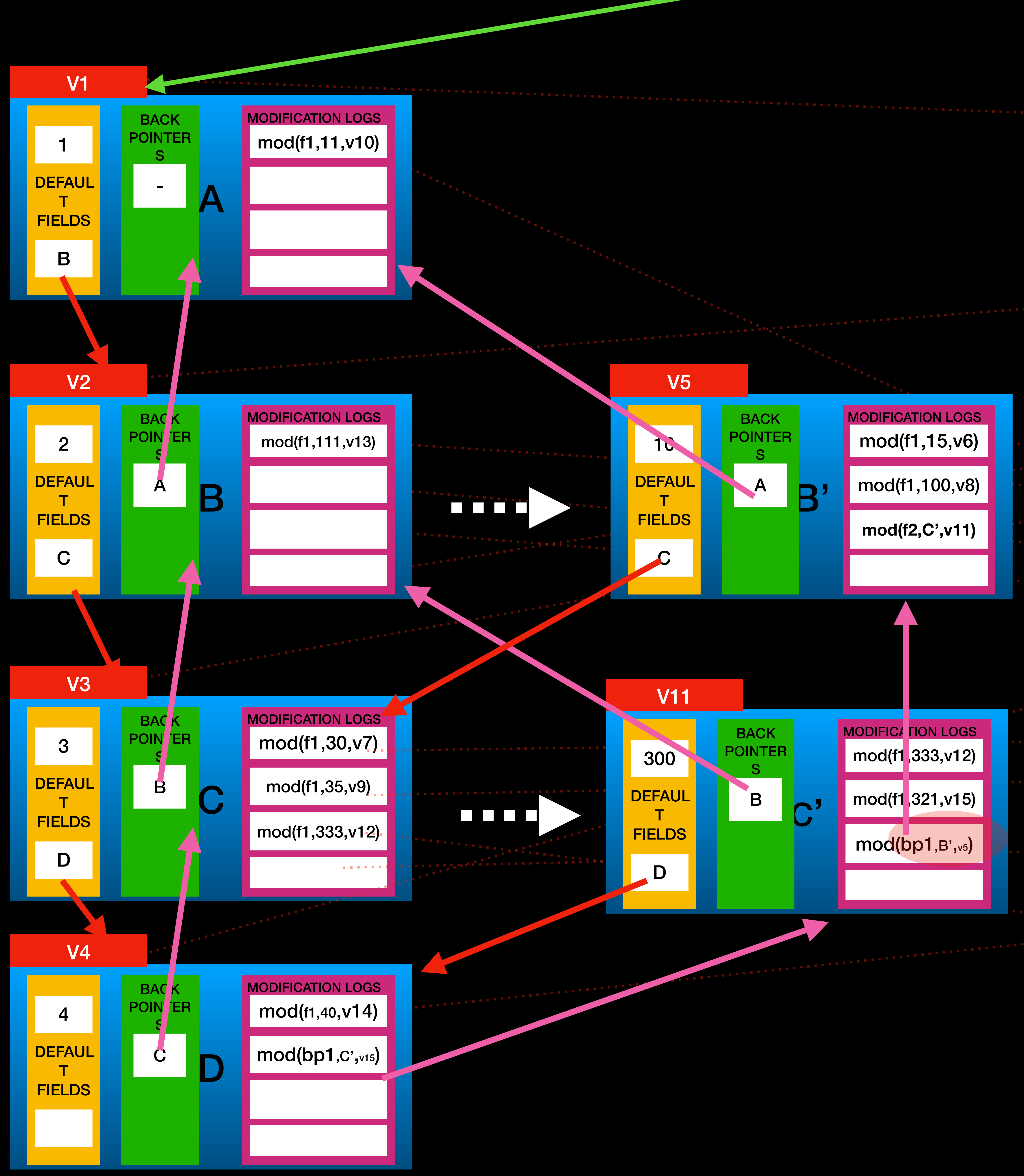
Query: update(C,f1,321,v11)
START MODULE
V0
Current time, t = 15
Version tree
V0 [ ]
V1 [1]
V2 [1,2]
V13 [111,1 3]
V3 [1,2,3]
V4 [1,2,3,4]
V5 [1,10,3,4]
V8 [1,100,30,4]
V6 [1,15,3,4]
V9 [1,100,35,4]
V7 [1,15,30,4]
V14 [1,15,30,40]
V12 [1,100,333,4]
V10 [11,100,35,4]
V11 [11,10,30
V15 [11,30,321,4]
STEP 4
RECURSIVELY
MODIFY THE FORWARD POINTERS
OF ANCESTORS
update(B,f2,C',v11)
ModLogs of B is full!
So create a copy of B at v15 and so on …
PIVOT
V1
1
DEFAUL T FIELDS
B
BACK POINTER S
-
A
MODIFICATION LOGS
mod(f1,11,v10)
V2
2
DEFAUL T FIELDS
C
BACK POINTER S
A
B
MODIFICATION LOGS
mod(f1,111,v13)
V3
3
DEFAUL T FIELDS
D
BACK POINTER S
B
C
MODIFICATION LOGS
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
V4
4
DEFAUL T FIELDS
BACK POINTER S
C
D
MODIFICATION LOGS
mod(f1,40,v14)
mod(bp1,C',v15)
V5
10
DEFAUL T FIELDS
C
BACK POINTER S
A
B'
MODIFICATION LOGS
mod(f1,15,v6)
mod(f1,100,v8)
mod(f2,C',v11)
V11
300
DEFAUL T FIELDS
D
BACK POINTER S
B
C'
MODIFICATION LOGS
mod(f1,333,v12)
mod(f1,321,v15)
PTO->

Query: update(C,f1,321,v11)

START MODULE

V0

Current time, t = 15



STEP 4

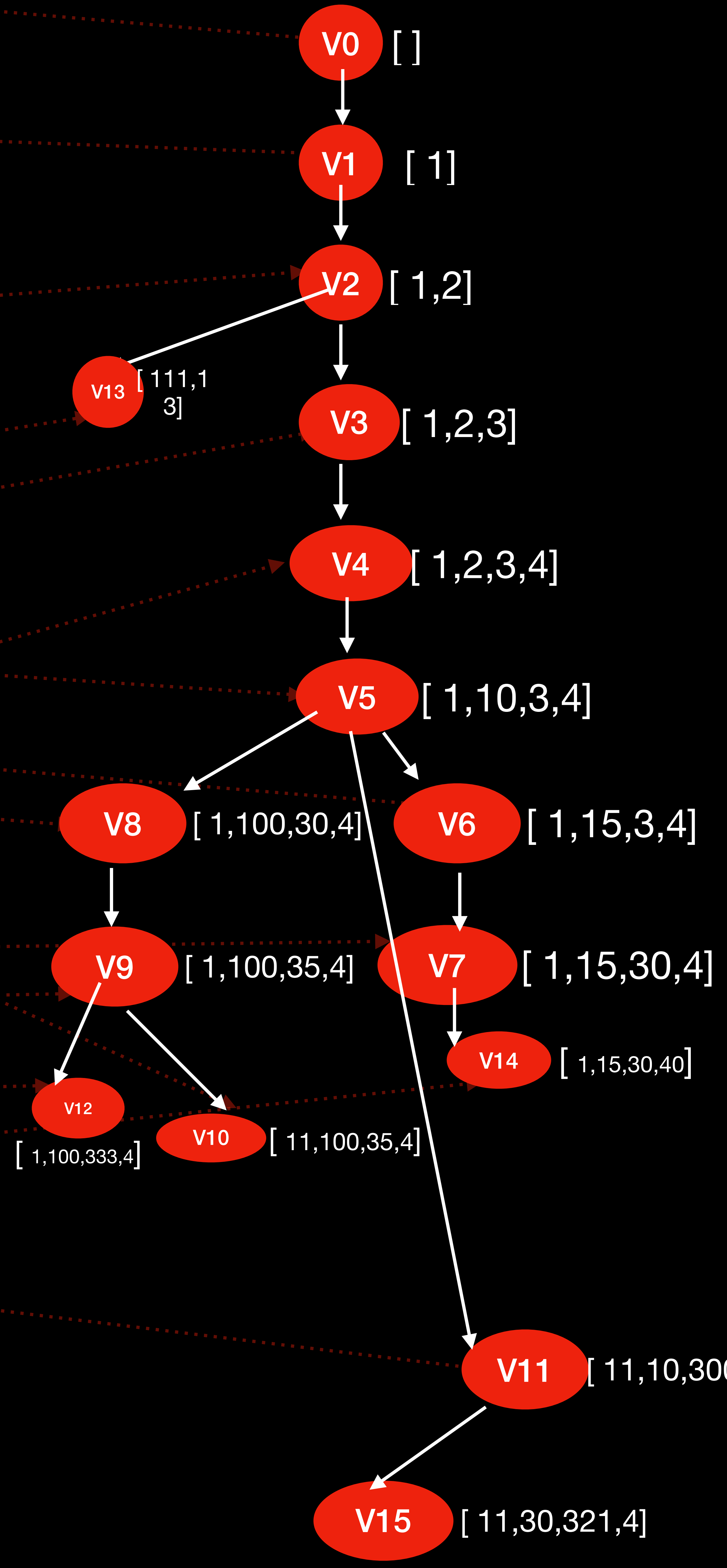
RECURSIVELY
MODIFY THE FORWARD POINTERS
OF ANCESTORS

update(B,f2,C',v11)

RECURSIVELY
MODIFY THE BACK POINTERS
OF LATEST SUCCESSOR

update(C', bp1,B',v5)

Version tree



PTO->


Query: update(C,f1,321,v11)
START MODULE
V0
V1
1
DEFAULT FIELDS
B
BACK POINTERS
-
A
MODIFICATION LOGS
mod(f1,11,v10)
mod(f2,B',v5)
V2
2
DEFAULT FIELDS
C
BACK POINTERS
A
B
MODIFICATION LOGS
mod(f1,111,v13)
V3
3
DEFAULT FIELDS
D
BACK POINTERS
B
C
MODIFICATION LOGS
mod(f1,30,v7)
mod(f1,35,v9)
mod(f1,333,v12)
V4
4
DEFAULT FIELDS
BACK POINTERS
C
D
MODIFICATION LOGS
mod(f1,40,v14)
mod(bp1,C',v15)
V5
10
DEFAULT FIELDS
C
BACK POINTERS
A
B'
MODIFICATION LOGS
mod(f1,15,v6)
mod(f1,100,v8)
mod(f2,C',v11)
V11
300
DEFAULT FIELDS
D
BACK POINTERS
B
C'
MODIFICATION LOGS
mod(f1,333,v12)
mod(f1,321,v15)
mod(bp1,B',v5)
STEP 4
RECURSIVELY
MODIFY THE FORWARD POINTERS
OF ANCESTORS
update(B,f2,C',v11)
RECURSIVELY
MODIFY THE FORWARD POINTERS
OF ANCESTORS
update(A,f2,B',v5)
Here, we face no problem
As A has sufficient mod logs
Left
PTO->
Current time, t = 15
Version tree
V0 [ ]
V1 [1]
V2 [1,2]
V13 [111,13]
V3 [1,2,3]
V4 [1,2,3,4]
V5 [1,10,3,4]
V8 [1,100,30,4]
V6 [1,15,3,4]
V9 [1,100,35,4]
V7 [1,15,30,4]
V14 [1,15,30,40]
V12 [1,100,333,4]
V10 [11,100,35,4]
V11 [11,10,30
V15 [11,30,321,4]

Query: update(C,f1,321,v11)

Query: update(C,f1,321,v11)

INVALID Query: update(C,f1,3000,v13)

C Node was absent
In
Version 13

We have to check it in implementation

Same Way we can show

-> Deletion of Node remove(x,v)
-> Insertion of Node add(x, y, v)

Shown in partial persistent mode

iterate_LL_at_v(v12)

iterate_LL_at_v(v12)

Choose those lines whose VERSION IS
IS NEAREST/LOWEST ANCESTOR
OR EQUAL TO THAT OF v_x = 12

Here, it is v1 for f1 and v5 for f2

iterate_LL_at_v(v12)

START MODULE
V0

Current time, t = 15

iterate_LL_at_v(v12)

iterate_LL_at_v(v12)