

cat | printf "%d\n" 79

lv 4

Min

79

cat | printf "Max"

Max

cat | printf "%d\n" 49

lv 3

Min

49

79

cat | printf "Max"

Max

cat | printf "%d\n" 12

lv 2

Min

12

23

49

79

cat | printf "Max"

Max

cat | printf "%d\n" 12

lv 1

Min

12

23

49

79

98

cat | printf "Max"

Max

cat | printf "%d\n" 11

lv 0

Min

11

12

23

45

49

71

79

98

cat | printf "Max"

Max

Skip list (5 levels)

Find(26)

Remove(82)

trougnouf@tp:~/pres

[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot

1 2 3

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (079% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.18 | 2016-03-16 11:08:45

cat | printf "%d\n" 4

lv4

cat | printf "Min"

Min

cat | printf "Max"

Max

cat | printf "%d\n" 3

lv3

cat | printf "Min"

Min

cat | printf "Max"

Max

cat | printf "%d\n" 2

lv2

cat | printf "Min"

Min

23

23

cat | printf "Max"

Max

cat | printf "%d\n" 1

lv1

cat | printf "Min"

Min

23

98

cat | printf "Max"

Max

cat | printf "%d\n" 0

lv0

cat | printf "Min"

Min

1123457198

Max

Skip list (5 levels)

Insert(71)

flipCoin(): 0

Insert(11)

flipCoin(): 0

trougnouf@tp:~/pres

[19] 5242  
[trougnouf@tp pres]\$ scrot  
[19]+ Done  
[trougnouf@tp pres]\$ xpad &  
[19] 5252  
[trougnouf@tp pres]\$ scrot

123

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (077% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.22 | 2016-03-16 10:52:25

cat | printf "%d\n" 4

lv4

cat | printf "Min"

Min

cat | printf "Max"

Max

cat | printf "%d\n" 3

lv3

cat | printf "Min"

Min

49

cat | printf "Max"

Max

cat | printf "%d\n" 2

lv2

cat | printf "Min"

Min

23

49

cat | printf "Max"

Max

cat | printf "%d\n" 1

lv1

cat | printf "Min"

Min

23

49

98

cat | printf "Max"

Max

cat | printf "%d\n" 0

lv0

cat | printf "Min"

Min

11

23

45

49

71

98

cat | printf "Max"

Max

Skip list (5 levels)

Insert(11)

flipCoin(): 0

Insert(49)

flipCoin(): 1,1,1,0

trougnouf@tp:~/pres

[21] 5262

[20] Done

[trougnouf@tp pres]\$ xpad &

[22] 5265

[21] Done

[trougnouf@tp pres]\$ scrot

1

2

3

no IPv6

132.5 GiB

DHCP: yes

VPN: no

W: (077% at OnNetworks11)

192.168.1.4

E: down

FULL 102.23%

0.18

2016-03-16 10:53:45

cat | printf "%d\n" 4

lv4

cat | printf "Min"

Min

cat | printf "Max"

Max

cat | printf "%d\n" 3

lv3

cat | printf "Min"

Min

49

cat | printf "Max"

Max

cat | printf "%d\n" 2

lv2

cat | printf "Min"

Min

23

49

cat | printf "Max"

Max

cat | printf "%d\n" 1

lv1

cat | printf "Min"

Min

23

49

82

98

cat | printf "Max"

Max

cat | printf "%d\n" 0

lv0

cat | printf "Min"

Min

11

23

45

49

71

82

98

cat | printf "Max"

Max

Skip list (5 levels)

Insert(49)

flipCoin(): 1,1,1,0

Insert(82)

flipCoin(): 1,0

trougnouf@tp:~/pres

[trougnouf@tp pres]\$ xpad &

[19] 5270

[trougnouf@tp pres]\$ xpad &

[20] 5273

[19] Done

[trougnouf@tp pres]\$ scrot

1

2

3

no IPv6

132.5 GiB

DHCP: yes

VPN: no

W: (076% at OnNetworks11)

192.168.1.4

E: down

FULL 102.23%

0.30

2016-03-16 10:54:40

cat | printf "%d\n" 4

lv4

cat | printf "Min"

Min

cat | printf "Max"

Max

cat | printf "%d\n" 3

lv3

cat | printf "Min"

Min

49

cat | printf "Max"

Max

cat | printf "%d\n" 2

lv2

cat | printf "Min"

Min

12

23

49

cat | printf "Max"

Max

cat | printf "%d\n" 1

lv1

cat | printf "Min"

Min

12

23

49

82

98

cat | printf "Max"

Max

cat | printf "%d\n" 0

lv0

cat | printf "Min"

Min

11

12

23

45

49

71

82

98

cat | printf "Max"

Max

Skip list (5 levels)

Insert(82)

flipCoin(): 1,0

Insert(12)

flipCoin(): 1,1,0

trougnouf@tp:~/pres

[20] 5283

[19] Done

[trougnouf@tp pres]\$ xpad &

[21] 5286

[20] Done

[trougnouf@tp pres]\$ scrot

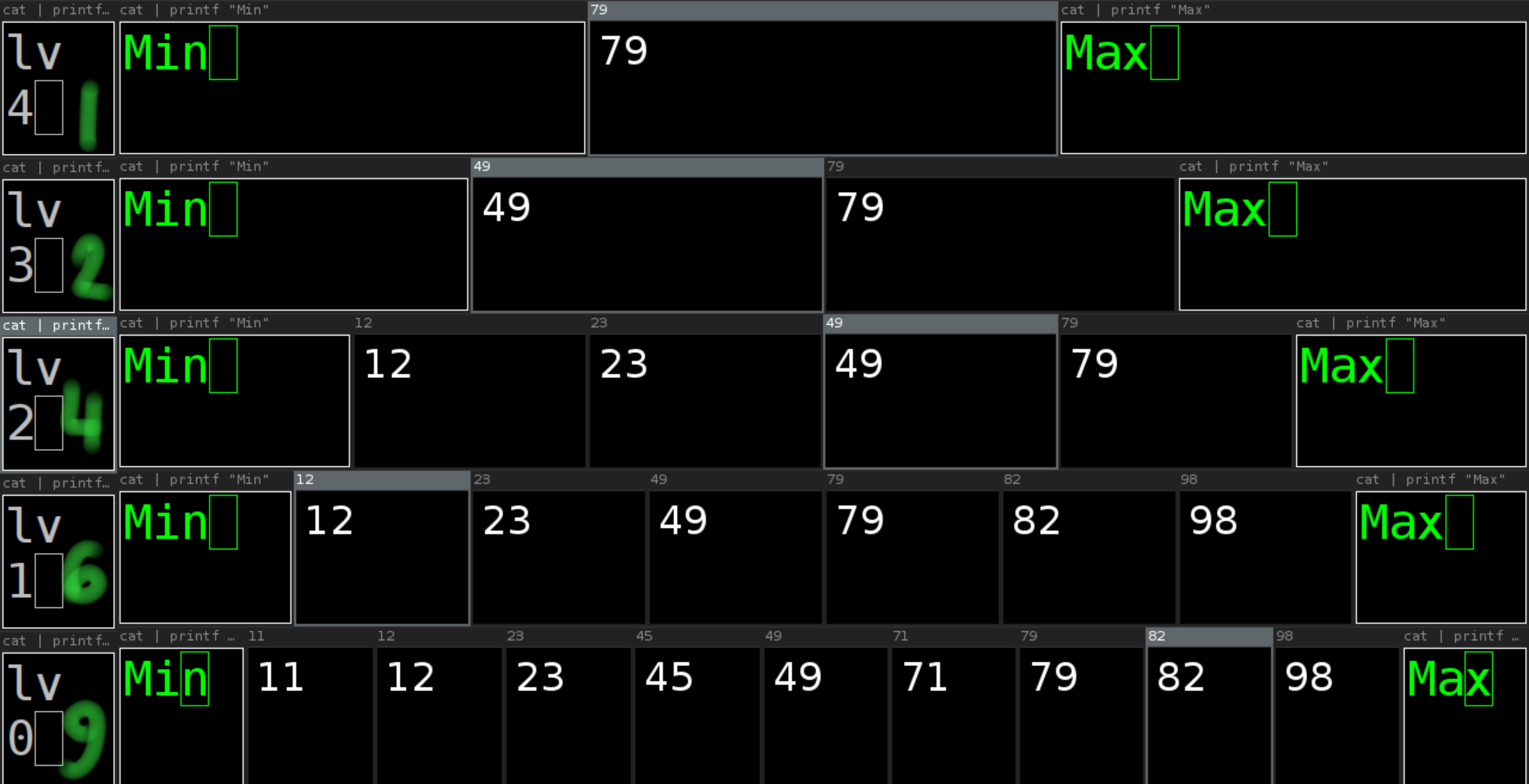
1

2

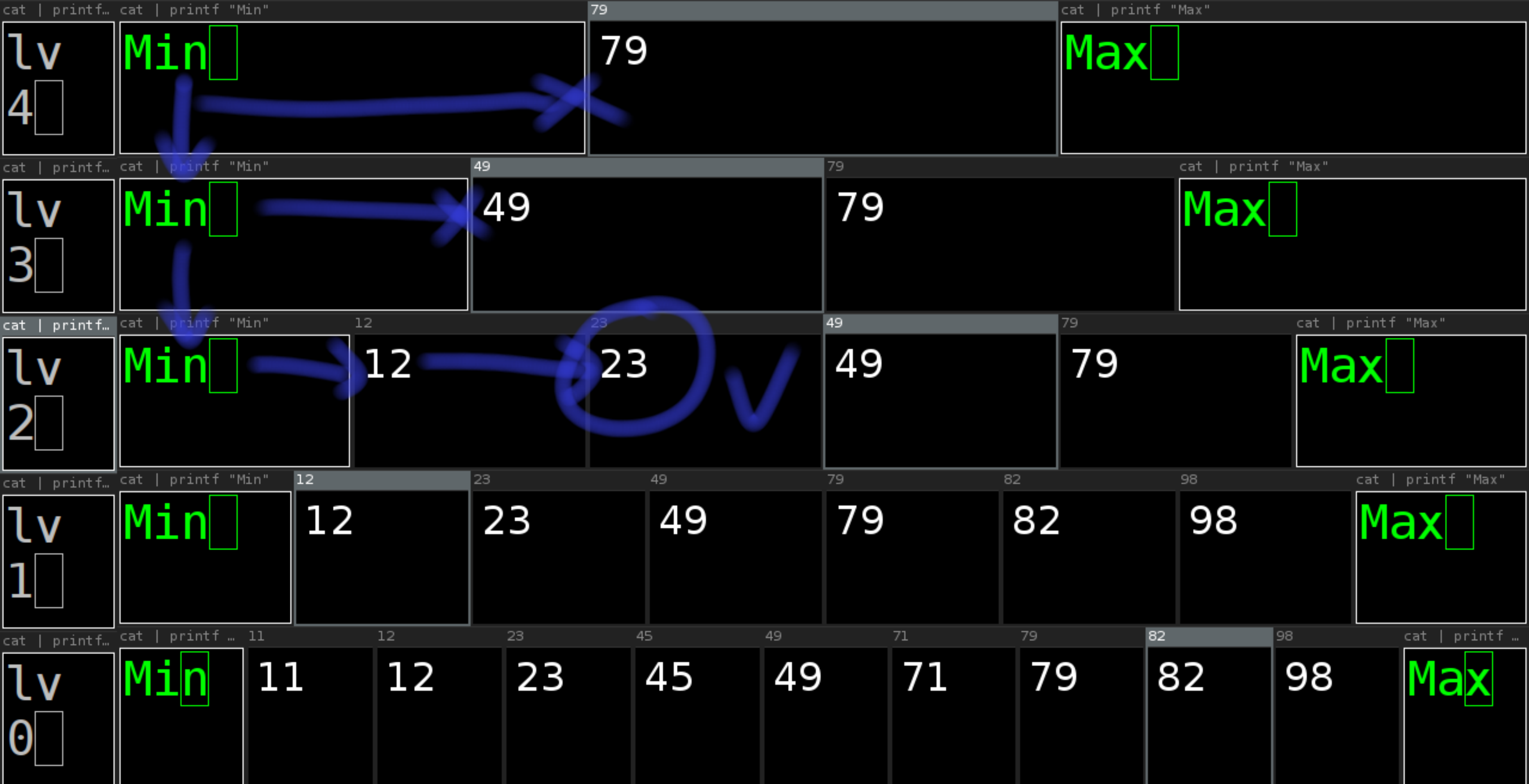
3

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (077% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.10 | 2016-03-16 10:56:20

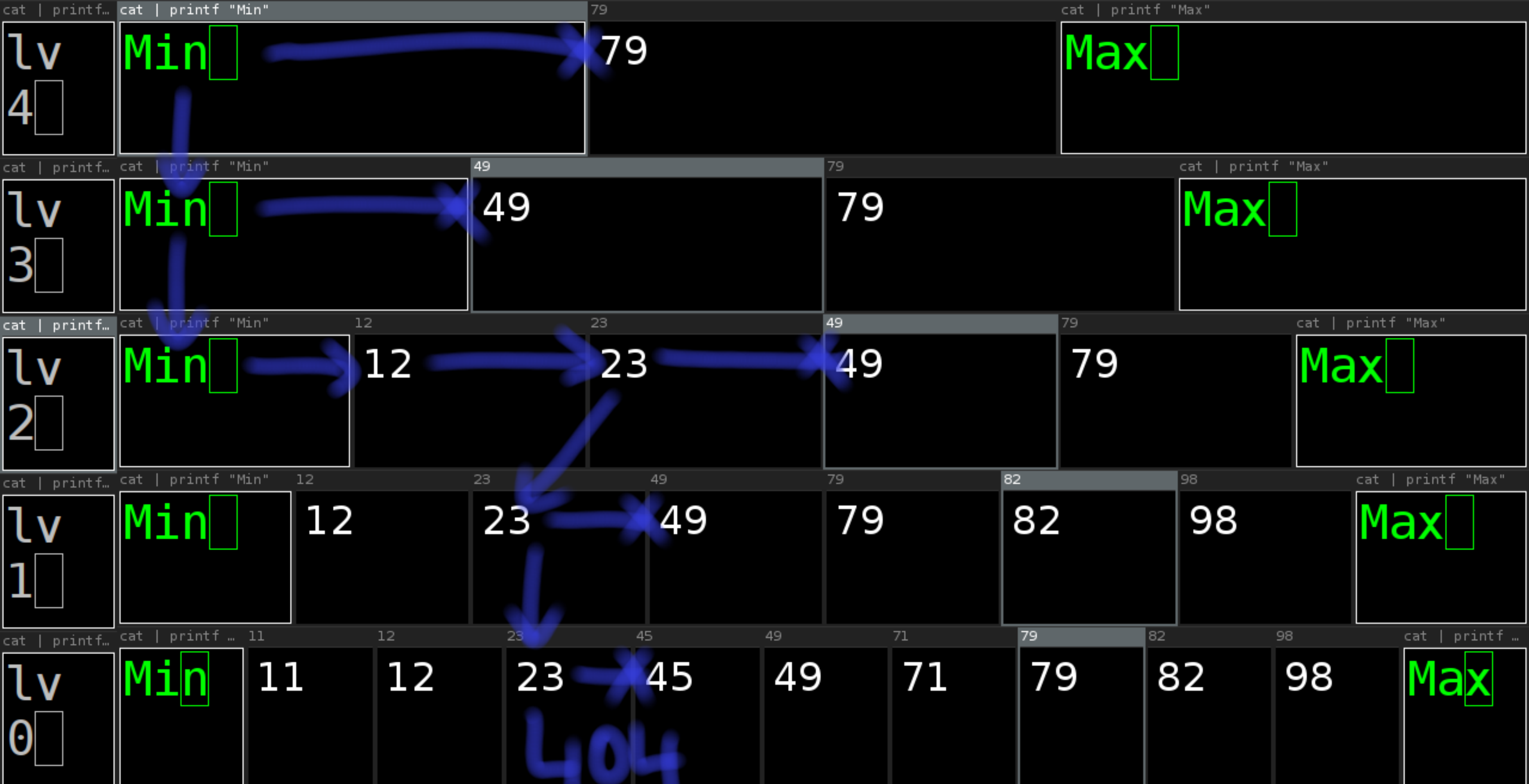










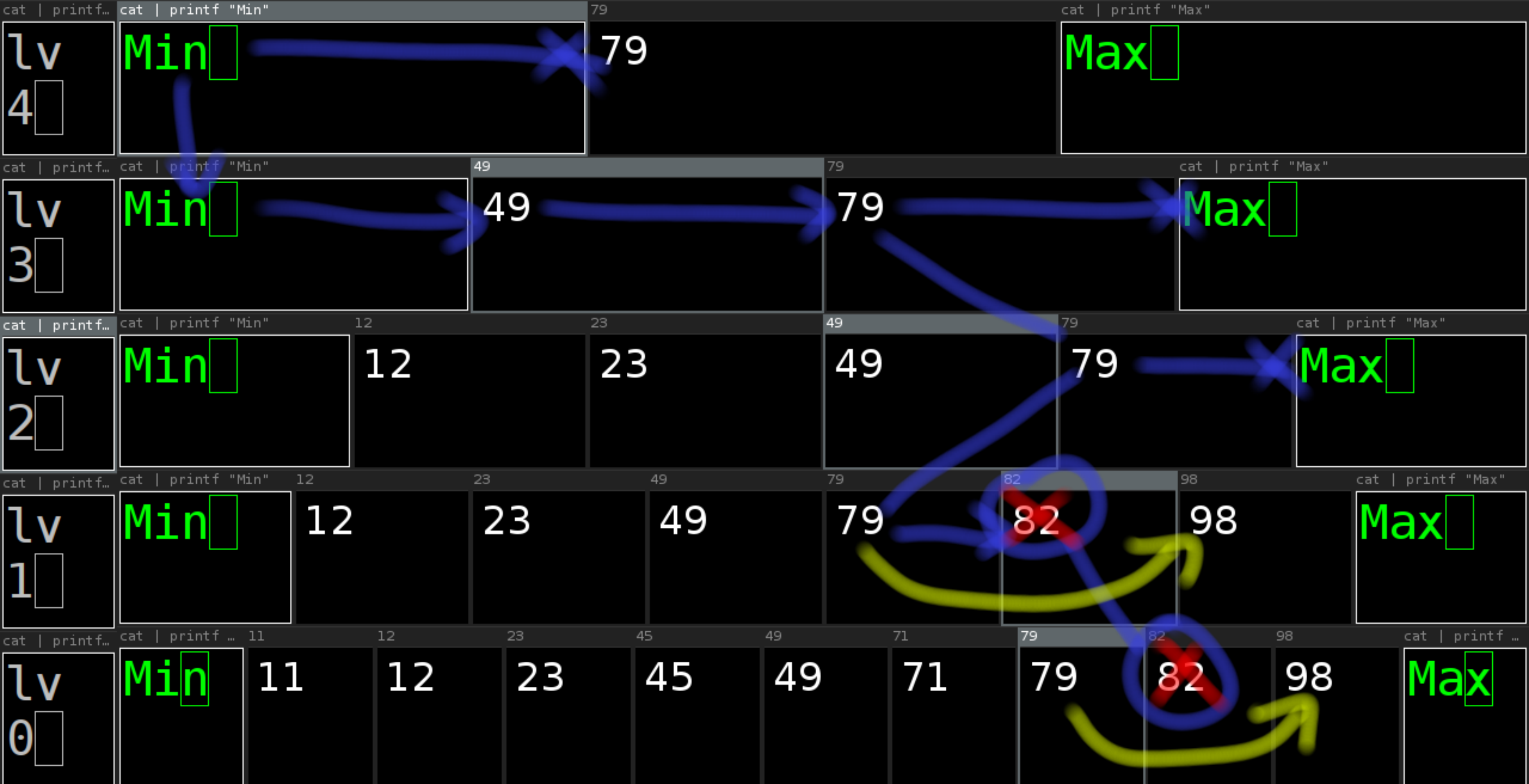


Skip list (5 levels)

Find(23)  
Find(26)

trougnouf@tp:~/pres  
[trougnouf@tp pres]\$ scrot  
[23]+ Done xpad  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot

1 2 3 no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (078% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.91 | 2016-03-16 11:05:00



Skip list (5 levels)

Find(26)

Remove(82)

123

trougnouf@tp:~/pres

[23]+ Done

xpad

[trougnouf@tp pres]\$ scrot

[trougnouf@tp pres]\$ scrot

[trougnouf@tp pres]\$ scrot

[trougnouf@tp pres]\$ scrot

[trougnouf@tp pres]\$ scrot

[trougnouf@tp pres]\$ scrot

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (074% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.16 | 2016-03-16 11:06:50

cat | printf...

lv4

cat | printf "Min"

Min

79

cat | printf "Max"

Max

cat | printf...

lv3

cat | printf "Min"

Min

49

79

cat | printf "Max"

Max

cat | printf...

lv2

cat | printf "Min"

Min

12

23

49

79

cat | printf "Max"

Max

cat | printf...

lv1

cat | printf "Min"

Min

12

23

49

79

98

cat | printf "Max"

Max

cat | printf...

lv0

cat | printf "M.. 11"

Min

11

12

23

45

49

71

79

98

cat | printf "M.. 11"

Max

Skip list (5 levels)

Find(26)

Remove(82)

123

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (068%

: 40

Open

+

\*Unsaved Do...

Save

≡

-

□

×

```
typedef struct slNode_ {
    uint32_t key;
    struct slNode_ ** next;
} slNode;
```

cat   printf... cat   printf "Min"	lv 4	Min	cat   printf "Max"	Max
cat   printf... cat   printf "Min"	lv 3	Min	cat   printf "Max"	Max
cat   printf... cat   printf "Min"	lv 2	Min	cat   printf "Max"	Max
cat   printf... cat   printf "Min"	lv 1	Min	cat   printf "Max"	Max
cat   printf... cat   printf "Min"	lv 0	Min	cat   printf "Max"	Max

Skip list (5 levels)

Skip list (5 levels)

```
trougnouf@tp:~/pres
(xpad:5189): Gtk-WARNING **: Unknown tag '('
(xpad:5189): Gtk-WARNING **: Unknown tag ')'
(xpad:5189): Gtk-WARNING **: Unknown tag '('
[trougnouf@tp pres]$ scrot
```

cat | printf "%d\n" 79

lv4

Min

79

Max

cat | printf "%d\n" 49

lv3

Min

49

79

Max

cat | printf "%d\n" 12

lv2

Min

12

23

49

79

Max

cat | printf "%d\n" 11

lv1

Min

11

12

23

45

49

71

79

98

Max

Skip list (5 levels)

Find(26)

Remove(82)

123

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: 16:10

Open

\*Unsaved Document

Save

typedef struct sListNode\_ {  
    uint32\_t key;  
    struct sListNode\_ \*\* next;  
    struct sListNode\_ \* previous;  
} sListNode;

lv4

cat | printf "Min"

79

cat | printf "Max"

lv3

cat | printf "Min"

49

79

cat | printf "Max"

lv2

cat | printf "Min"

12

23

49

79

cat | printf "Max"

lv1

cat | printf "Min"

12

23

49

79

98

cat | printf "Max"

lv0

cat | printf "Min"

11

12

23

45

cat | printf "Max"

Skip list (5 levels)

Insert(45)

Open

\*Unsaved Document 1

Save

flipCoin()  
Generate one random integer  
// 255248010  
Use each bit as a coin  
// 1111001101101100011010001010  
// 1,1,1,1,0

1

2

3

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (076% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.11 | 2016-03-16 11:23:05





Skip list (5 levels)

Insert(23)

trougnouf@tp:~/pres

(xpad:5189): Gtk-WARNING \*\*: Unknown tag '')

(xpad:5189): Gtk-WARNING \*\*: Unknown tag '('

[trougnouf@tp pres]\$ scrot

[trougnouf@tp pres]\$ scrot



cat | printf...

lv4

cat | printf "Min"

Min

79

cat | printf "Max"

Max

cat | printf...

lv3

cat | printf "Min"

Min

49

79

cat | printf "Max"

Max

cat | printf...

lv2

cat | printf "Min"

Min

12

23

49

79

cat | printf "Max"

Max

cat | printf...

lv1

cat | printf "Min"

Min

12

23

49

79

98

cat | printf "Max"

Max

cat | printf...

lv0

cat | printf "M...

Min

11

12

23

45

49

71

79

98

cat | printf "M...

Max

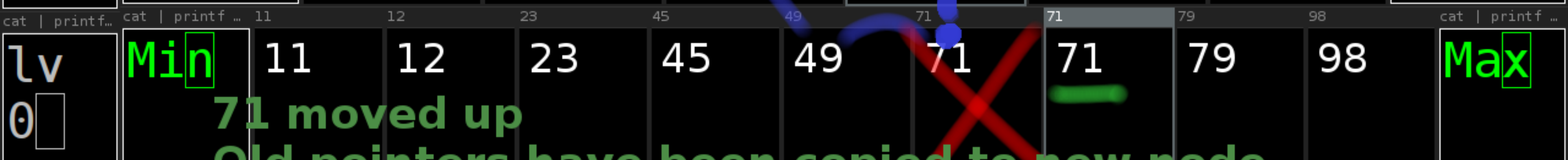
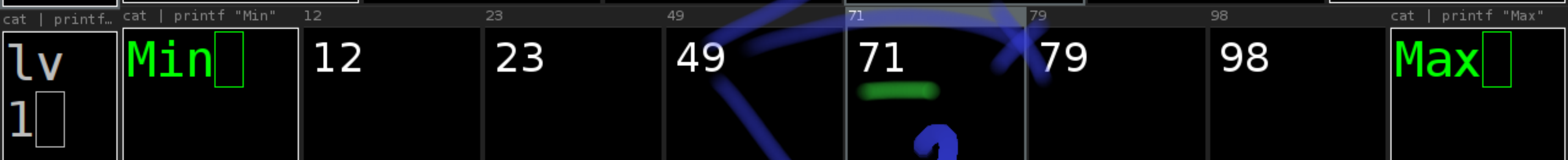
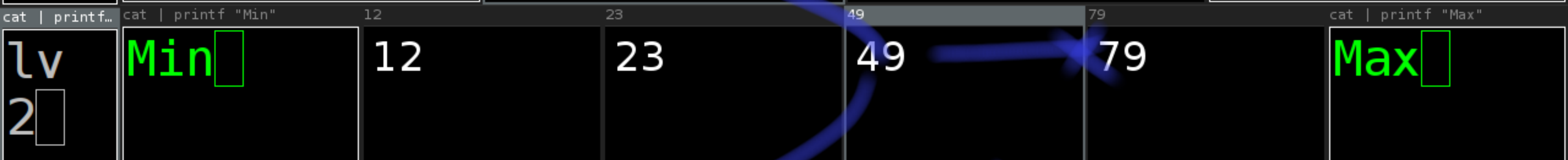
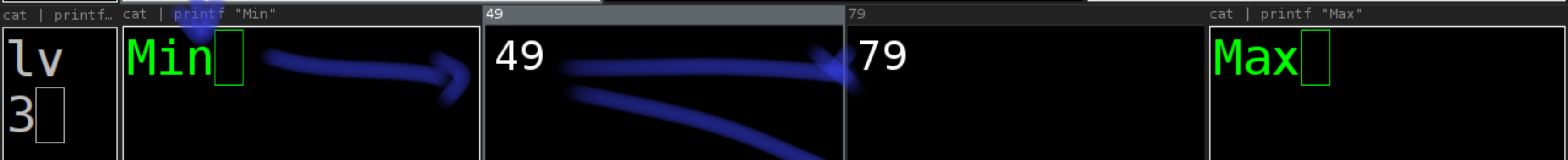
Skip list (5 levels)

troughnouf@tp: ~/pres

[troughnouf@tp pres]\$ scrot  
[troughnouf@tp pres]\$ scrot  
[troughnouf@tp pres]\$ scrot  
[troughnouf@tp pres]\$ scrot  
[troughnouf@tp pres]\$ scrot  
[troughnouf@tp pres]\$ scrot

123

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (075% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.20 | 2016-03-16 11:24:55



Skip list (5 levels)

Insert(71)

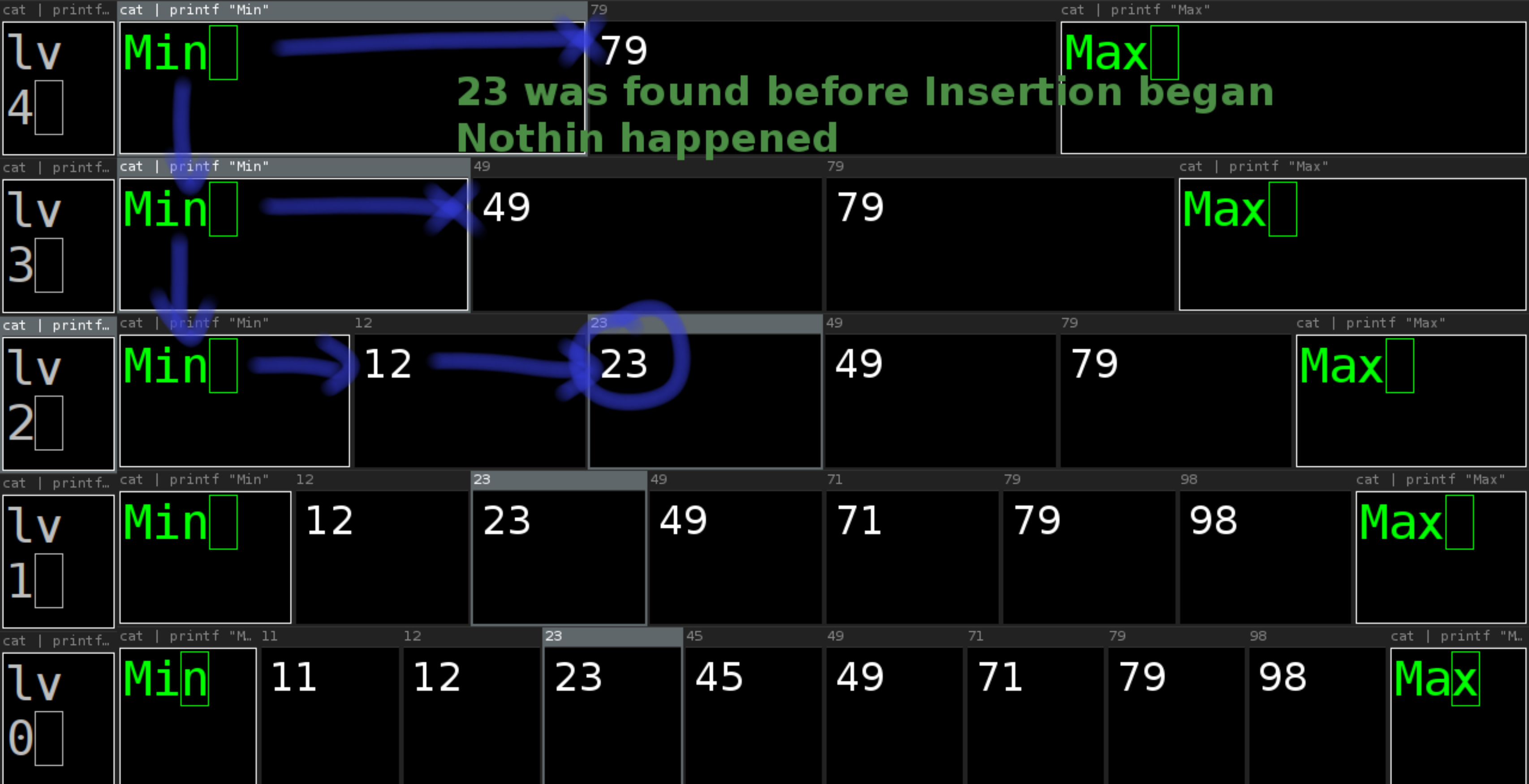
InsertMerge(71) flipCoins():1,0

71 moved up

Old pointers have been copied to new node

Old node is freed

```
trougnouf@tp:~/pres
[19] 5433
[trougnouf@tp pres]$ scrot
[19]+  Done
[trougnouf@tp pres]$ xpad &
[19] 5439
[trougnouf@tp pres]$ scrot
```



```
Skip list (5 levels)
InsertMerge(71)    flipCoins():1,0
InsertMerge(23)    flipCoins():1,0

trougnouf@tp:~/pres
[trougnouf@tp pres]$ xpad &
[19] 5439
[trougnouf@tp pres]$ scrot
[19]+  Done                  xpad
[trougnouf@tp pres]$ scrot
[trougnouf@tp pres]$ scrot
```

cat | printf...  
lv  
4

cat | printf "Min"  
Min

79

cat | printf "Max"  
Max

5 was inserted without wasting time finding it beforehand

cat | printf...  
lv  
3

cat | printf "Min"  
Min

49

79

cat | printf "Max"  
Max

cat | printf...  
lv  
2

cat | printf "Min"  
Min

12

23

49

79

cat | printf "Max"  
Max

cat | printf...  
lv  
1

cat | printf "Min"  
Min

5

12

23

49

71

79

98

cat | printf "Max"  
Max

cat | printf...  
lv  
0

cat | printf "Min"  
Min

5

11

12

23

45

49

71

79

98

cat | printf...  
Max

Skip list (5 levels)

InsertMerge(23)  
InsertMerge(5)

flipCoins():1,0  
flipCoins(1,0)

trounouf@tp:~/pres  
[19]+ Done xpad  
[trounouf@tp pres]\$ scrot  
[trounouf@tp pres]\$ scrot  
[trounouf@tp pres]\$ xpad &  
[19] 5468  
[trounouf@tp pres]\$ scrot

cat | printf...  
lv  
4

cat | printf "Min"  
Min

79

cat | printf "Max"  
Max

cat | printf...  
lv  
3

cat | printf "Min"  
Min

49

79

cat | printf "Max"  
Max

cat | printf...  
lv  
2

cat | printf "Min"  
Min

12

23

49

79

cat | printf "Max"  
Max

cat | printf...  
lv  
1

cat | printf "Min"  
Min

12

23

49

cat | printf...  
lv  
0

cat | printf ...  
Min

5

11

12

23

45

Skip list (5 levels)

InsertMerge(23)  
InsertMerge(5)

flipCoins():1,0  
flipCoins():0

123

no IPv6 | 132.5 GiB | DHCP: yes | VPN:

Open

\*Unsaved Document 1

Save

```
typedef struct sListNode_ {  
    uint32_t key;  
    atomic_uintptr_t * next;  
    struct sListNode_ * previous;  
    uint8_t stopflag  
} sListNode;  
  
typedef struct sListNode_obsolete {  
    uint32_t key;  
    struct sListNode_ ** next;  
    struct sListNode_ * previous;  
} sListNode;
```

36:35





Open

```
slRemove(slHead, key):
Local pointers: curNode, target, nextNode

- Find target (and its highest level), mark it for deletion
For each level:
- Mark target's next pointer
  atomic_fetch_or(&target->next[lv], 1)
- set curNode->next to (unmarked) target->next if curNode->next==target
  CAS(curNode->next[lv], target, target->next[lv])
- Free target
  free(target->next), free(target)
```



Open
Save
\*Unsaved Document 1

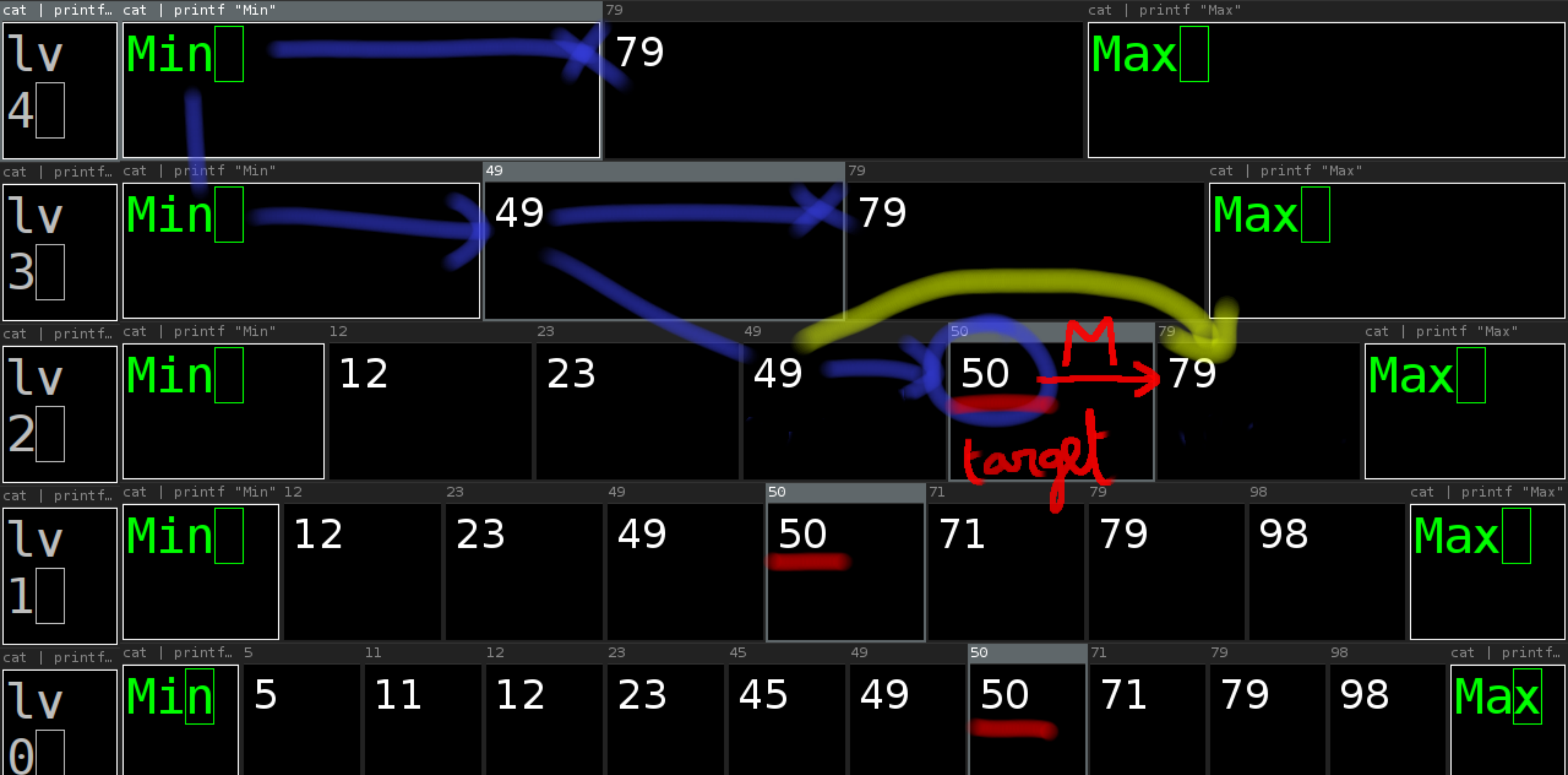
```

slRemove(slHead, key):
Local pointers: curNode, target, nextNode

- Find target (and its highest level), mark it for deletion
For each level:
  - Mark target's next pointer
    atomic_fetch_or(&target->next[lv], 1)
  - set curNode->next to (unmarked) target->next if curNode->next==target
    CAS(curNode->next[lv], target, target->next[lv])
- Free target
  free(target->next), free(target)
  
```



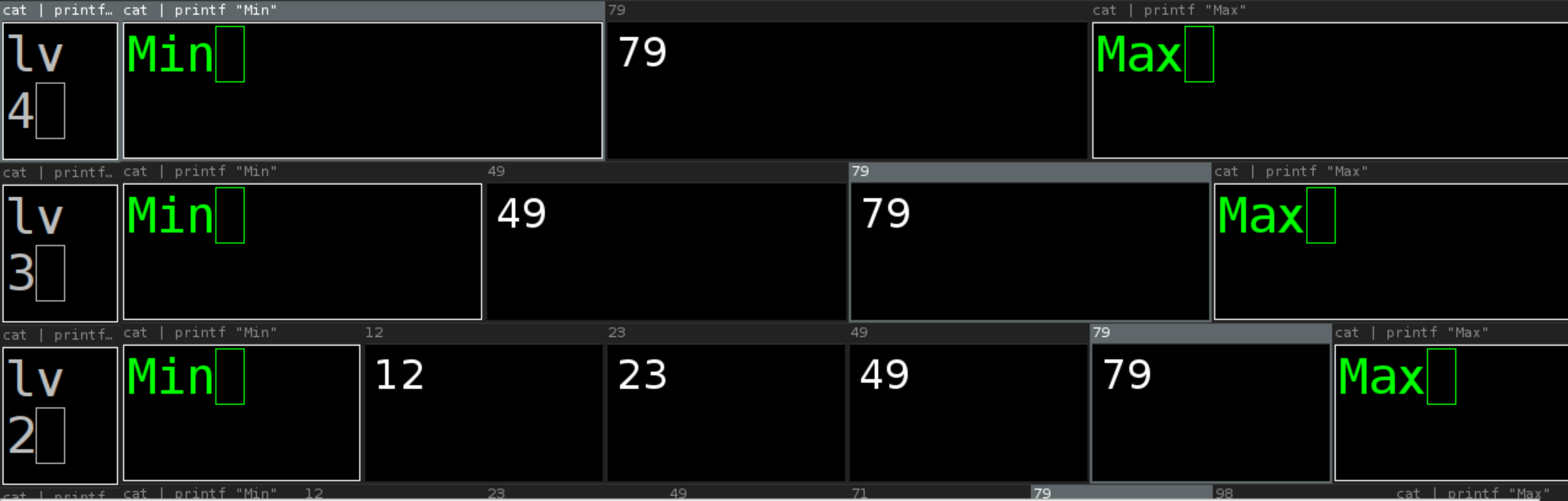









use CAS to move curNode's next pointer to target's (unmarked) next iff curNode->next = target fails if curNode(->next) has been marked for deletion or curNode->next no longer points to target

Skip list (5 levels)

InsertMerge  
RemoveCon



Open  \*Unsaved Document 1  Save   

```
slInsert(slHead, key)
Local pointers: curNode, newNode, nextNode
For each level:
- Find curNode s.t. curNode < newNode < nextNode and curN->next=nextNode
- Set newNode->next to nextNode
- Set curNode->next to newNode if curNode->next == nextNode
  // CAS fails if curNode->next has been marked
  // or nextNode is no longer next
Failure? Find curNode and nextNode again using next
Repeated failure? Reset curNode
```

```
slInsert(slHead, key)
```

```
Local pointers: curNode, newNode, nextNode
```

```
For each level:
```

- Find curNode s.t.  $\text{curNode} < \text{newNode} < \text{nextNode}$  and  $\text{curNode} \rightarrow \text{next} = \text{nextNode}$
- Set  $\text{curNode} \rightarrow \text{next}$  to newNode **if**  $\text{curNode} \rightarrow \text{next} == \text{nextNode}$ 
  - // CAS fails if  $\text{curNode} \rightarrow \text{next}$  has been marked
  - // or nextNode is no longer next

```
Failure? Find curNode and nextNode again using curNode's next pointer
```

```
Repeated failure? Reset curNode
```

```
eg:
```

cur	cur->next	next	new
5	->	10	8

```
set new->next to next
```

cur	cur->next	next	new	new->next
5	->	10	8	10

```
CAS(curnode->next, nextnode, newnode)
```

cur	cur->next	new	new->next	next
5	->	8	->	10

```
// curNode is marked for deletion? Fail.
```

```
// nextNode is no longer next? Fail.
```

```
[ttroughnouv@tp School]$ scrot
```

cat | printf... cat | printf "Min"

lv4

Min

cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv3

Min

cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv2

Min

cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv1

Min

cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv0

Min

23

cat | printf "Max"

Max

Skip list (5 levels)

Insert(23)

trougnouf@tp:~/pres

(xpad:5189): Gtk-WARNING \*\*: Unknown tag '  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ xpad &  
[19] 5200  
[trougnouf@tp pres]\$ scrot

123

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (073% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.34 | 2016-03-16 10:46:20



cat | printf... cat | printf "Min"

lv4

Min

cat | printf... cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv3

Min

cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv2

Min

cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv1

Min

23

23

cat | printf "Max"

Max

cat | printf... cat | printf "Min"

lv0

Min

23

23

cat | printf "Max"

Max

Skip list (5 levels)

Insert(23) flipCoin(): 1

trougnouf@tp:~/pres

[trougnouf@tp pres]\$ scrot  
[19]+ Done xpad  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ xpad &  
[19] 5206  
[trougnouf@tp pres]\$ scrot

1 2 3

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (073% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.19 | 2016-03-16 10:47:10

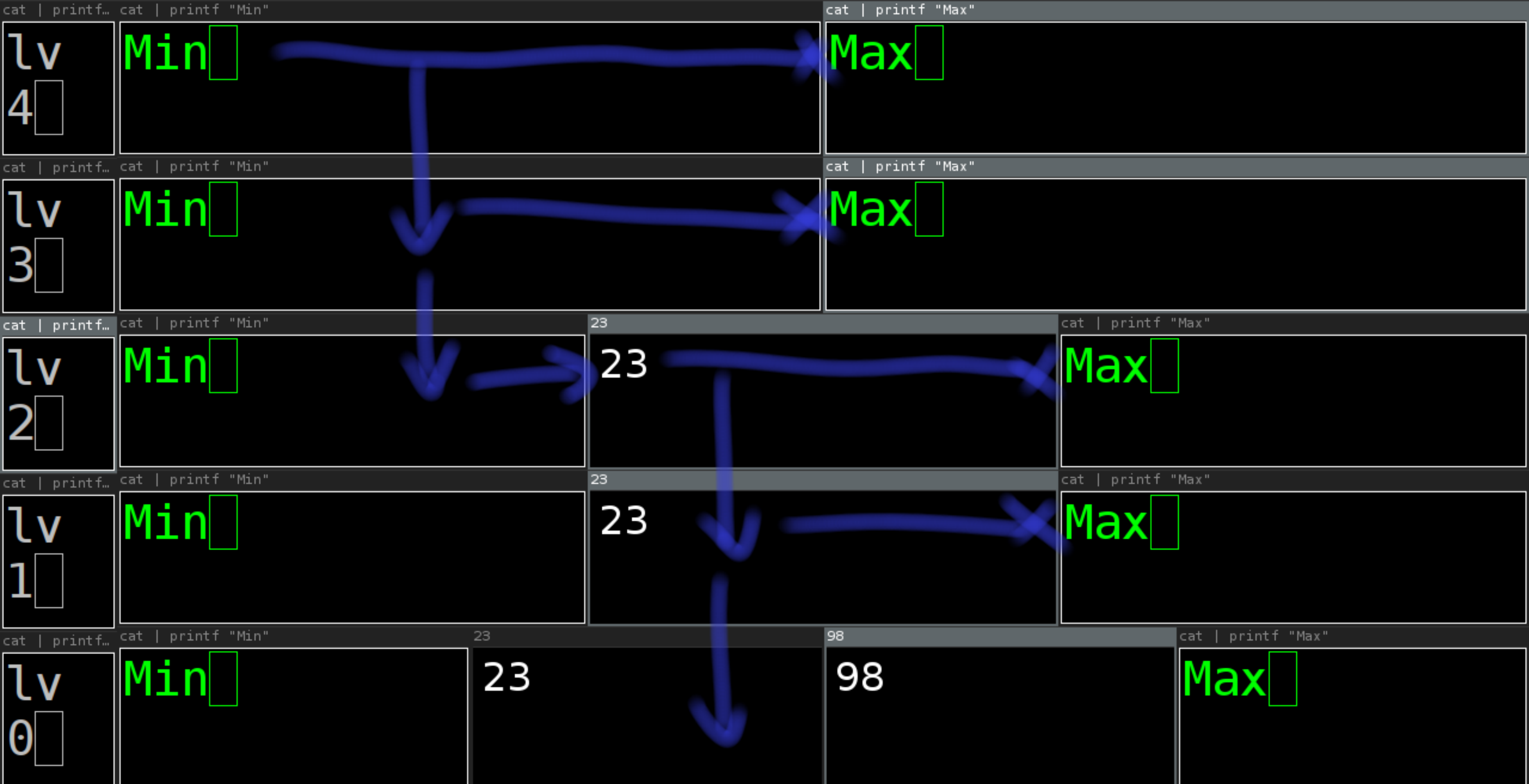
cat   printf "%d\n" 4	cat   printf "Min"		cat   printf "Max"	
cat   printf "%d\n" 3	cat   printf "Min"		cat   printf "Max"	
cat   printf "%d\n" 2	cat   printf "Min"	23	cat   printf "Max"	
cat   printf "%d\n" 1	cat   printf "Min"	23	cat   printf "Max"	
cat   printf "%d\n" 0	cat   printf "Min"	23	cat   printf "Max"	

Skip list (5 levels)

Insert(23)      flipCoin(): 1,1,0

```
trougnouf@tp:~/pres
[trougnouf@tp pres]$ scrot
[trougnouf@tp pres]$ xpad &
[19] 5213
[trougnouf@tp pres]$ scrot
[19]+  Done                  xpad
[trougnouf@tp pres]$ scrot
```





Skip list (5 levels)

Insert(23)      flipCoin(): 1,1,0

Insert(98)

```
trougnouf@tp:~/pres
[trougnouf@tp pres]$ scrot
[19]+  Done                                xpad
[trougnouf@tp pres]$ scrot
[trougnouf@tp pres]$ xpad &
[19] 5225
[trougnouf@tp pres]$ scrot
```

cat   printf "%d\n" 4	cat   printf "Min"	cat   printf "Max"		
lv 4	Min	Max		
cat   printf "%d\n" 3	cat   printf "Min"	cat   printf "Max"		
lv 3	Min	Max		
cat   printf "%d\n" 2	cat   printf "Min"	23	cat   printf "Max"	
lv 2	Min	23	Max	
cat   printf "%d\n" 1	cat   printf "Min"	23	98	cat   printf "Max"
lv 1	Min	23	98	Max
cat   printf "%d\n" 0	cat   printf "Min"	23	98	cat   printf "Max"
lv 0	Min	23	98	Max

Skip list (5 levels)

Insert(23)

Insert(98)

flipCoin(): 1,1,0

flipCoin(): 1,0

ttrougnouf@tp:~/pres

2016-03-16-104739\_1280x800\_scrout.png  
2016-03-16-104750\_1280x800\_scrout.png  
2016-03-16-104809\_1280x800\_scrout.png  
2016-03-16-104853\_1280x800\_scrout.png  
2016-03-16-104942\_1280x800\_scrout.png  
[trougnouf@tp pres]\$ scrot

cat   printf "%d\n" 4	cat   printf "Min"			cat   printf "Max"	
lv 4	Min			Max	
cat   printf "%d\n" 3	cat   printf "Min"			cat   printf "Max"	
lv 3	Min			Max	
cat   printf "%d\n" 2	cat   printf "Min"	23		cat   printf "Max"	
lv 2	Min	23		Max	
cat   printf "%d\n" 1	cat   printf "Min"	23	98	cat   printf "Max"	
lv 1	Min	23	98	Max	
cat   printf "%d\n" 0	cat   printf "Min"	23	45	98	cat   printf "Max"
lv 0	Min	23	45	98	Max

Skip list (5 levels)

Insert(98)  
Insert(45)

flipCoin(): 1,0  
flipCoin(): 0

trougnouf@tp:~/pres  
2016-03-16-104853\_1280x800\_scrout.png  
2016-03-16-104942\_1280x800\_scrout.png  
[trougnouf@tp pres]\$ scrot  
[trougnouf@tp pres]\$ xpad &  
[19] 5238  
[trougnouf@tp pres]\$ scrot

cat | printf "%d\n" 4

lv4

cat | printf "Min"

Min

cat | printf "Max"

Max

cat | printf "%d\n" 3

lv3

cat | printf "Min"

Min

cat | printf "Max"

Max

cat | printf "%d\n" 2

lv2

cat | printf "Min"

Min

23

23

cat | printf "Max"

Max

cat | printf "%d\n" 1

lv1

cat | printf "Min"

Min

23

98

cat | printf "Max"

Max

cat | printf "%d\n" 0

lv0

cat | printf "Min"

Min

23

45

71

98

cat | printf "Max"

Max

Skip list (5 levels)

Insert(45)

flipCoin(): 0

Insert(71)

flipCoin(): 0

trougnouf@tp:~/pres

[19] 5238  
[trougnouf@tp pres]\$ scrot  
[19]+ Done  
[trougnouf@tp pres]\$ xpad &  
[19] 5242  
[trougnouf@tp pres]\$ scrot

123

no IPv6 | 132.5 GiB | DHCP: yes | VPN: no | W: (078% at OnNetworks11) 192.168.1.4 | E: down | FULL 102.23% | 0.26 | 2016-03-16 10:51:35