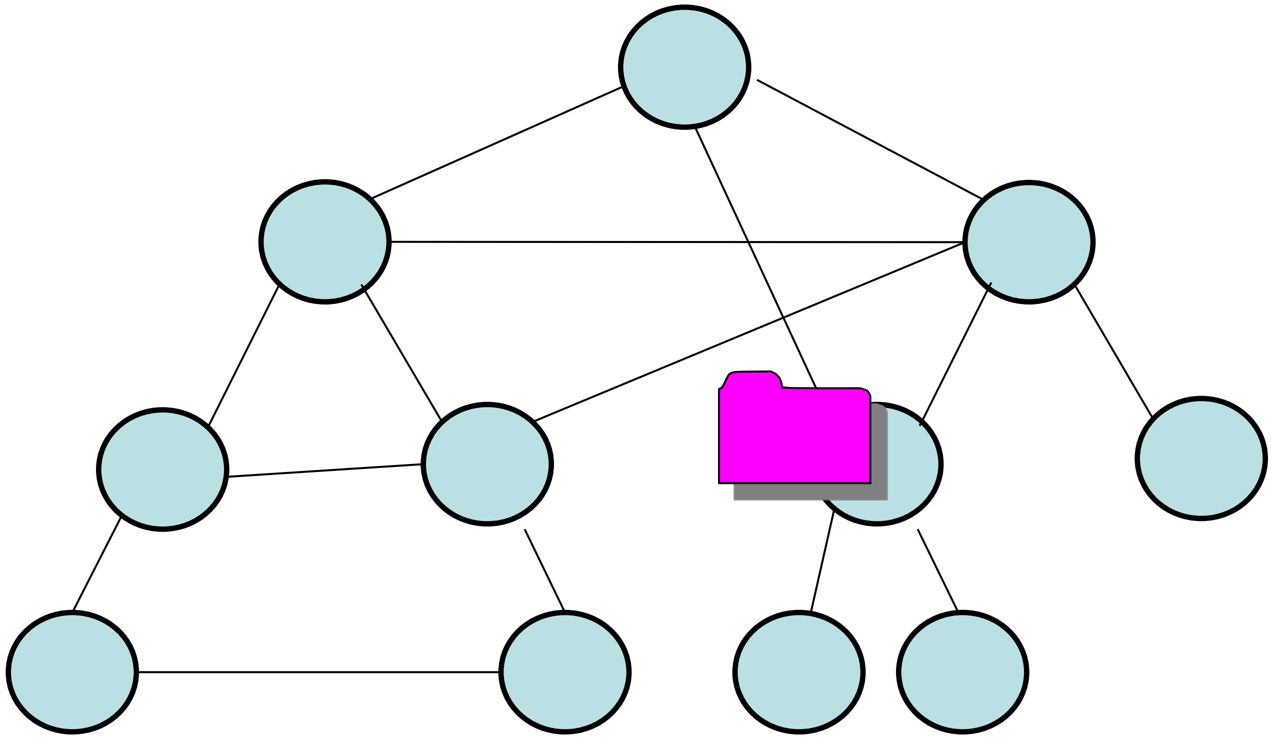
Network Algorithms

Mutual Exclusion in Networks

Shared Objects

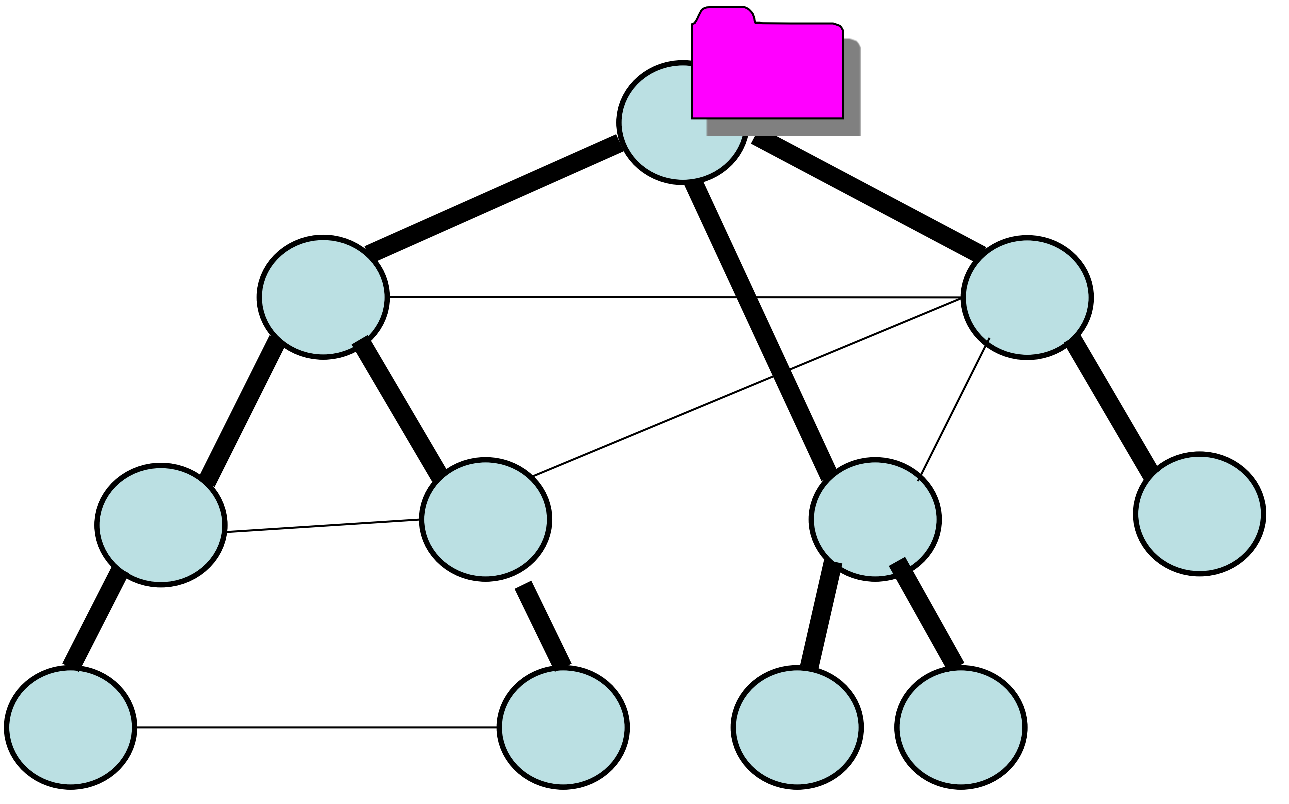
Common variable or datastructure:



Needs to be accessed, but not concurrently! How?

Shared Objects

Idea: store at central location, e.g., root of spanning tree



Access: send message to root, root processes request, result sent back down the tree.

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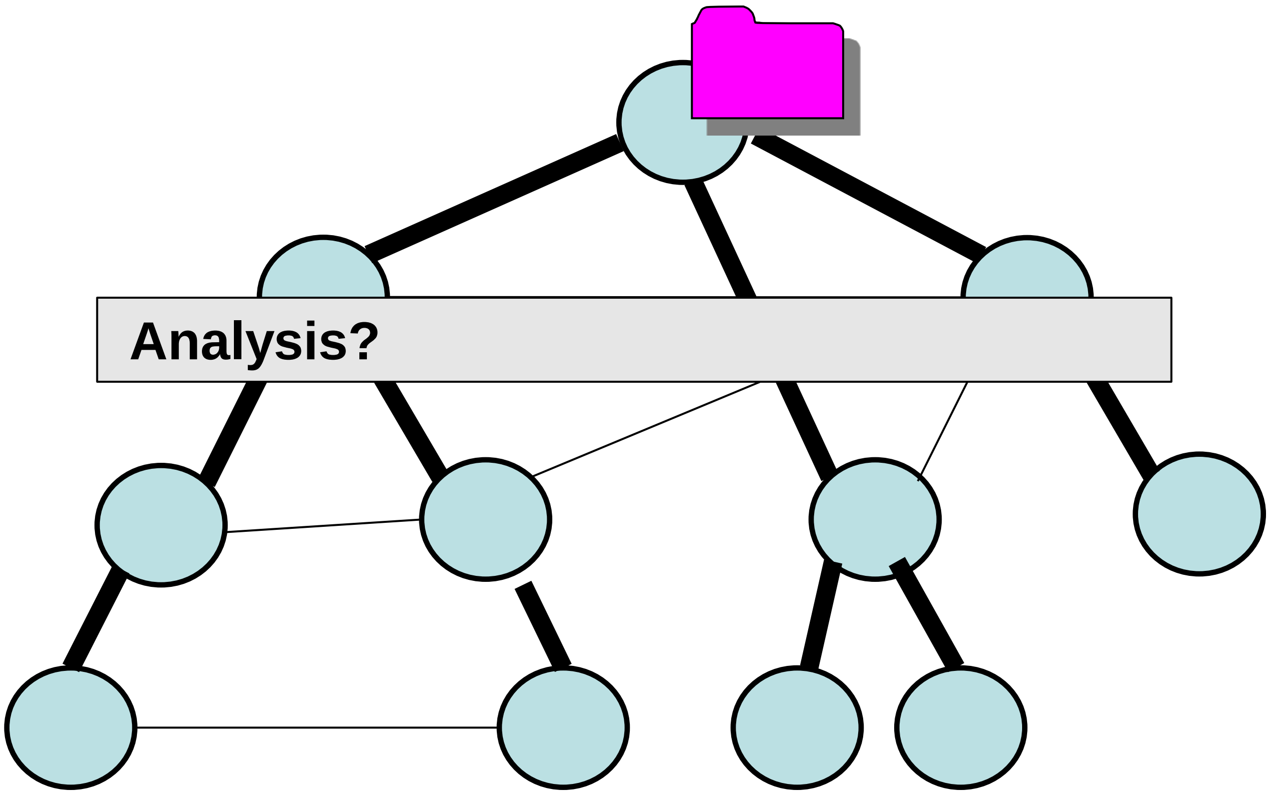

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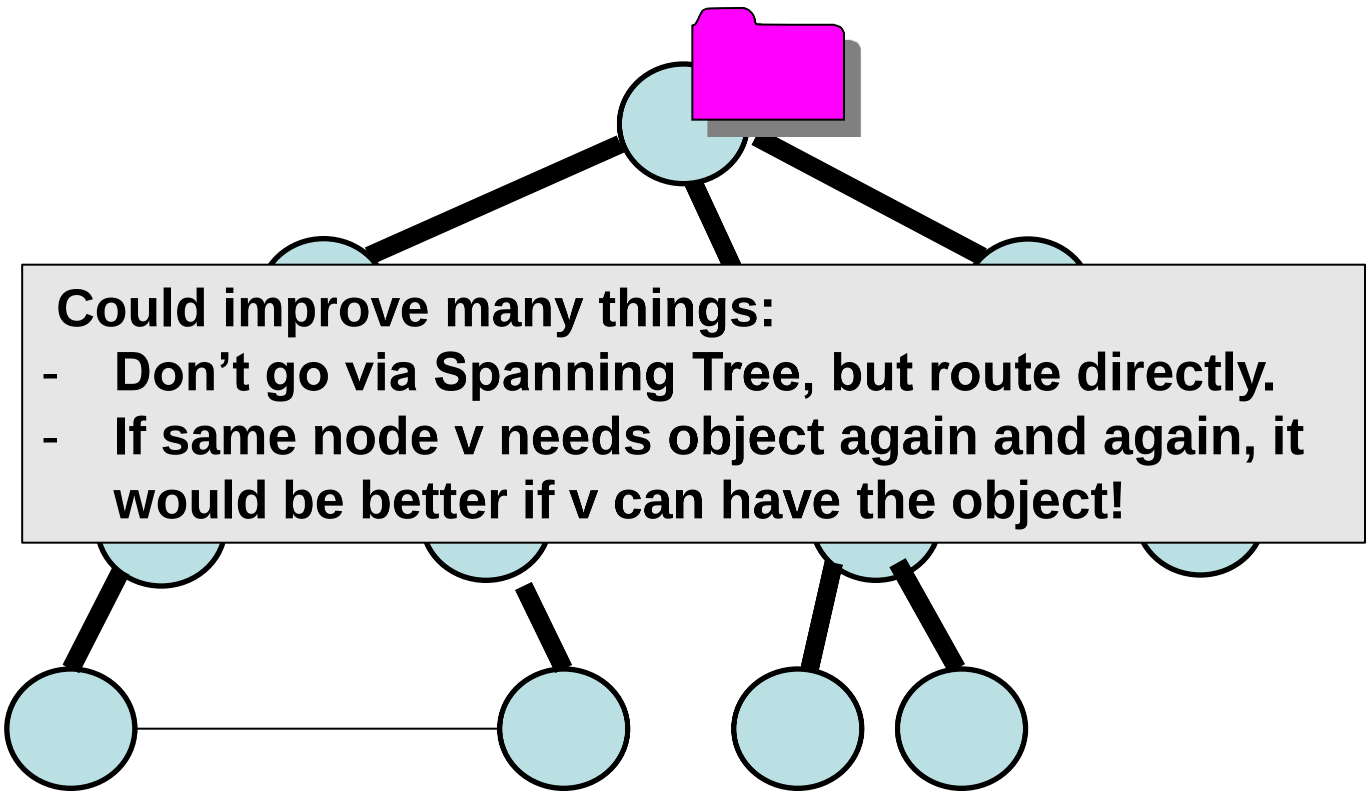


Could improve many things:

- **Don’t go via Spanning Tree, but route directly.**
- **If same node v needs object again and again, it would be better if v can have the object!**

Access: send message to root, root processes request, result sent back down the tree.

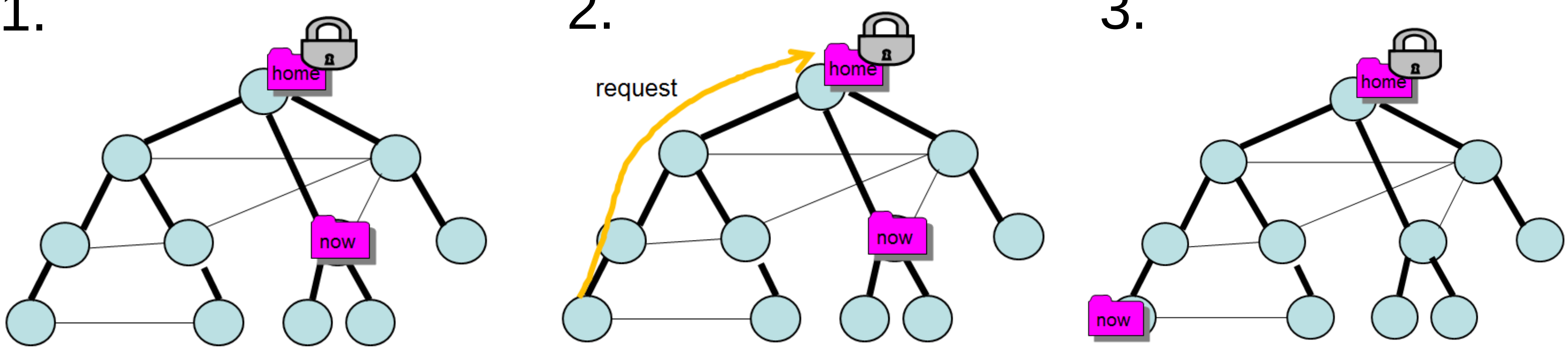
Home-Based Solution

Idea that object has «home base»:

- processes get lock from there
- then retrieve object and process locally!

Similar to Mobile IP!

1. 2. 3.



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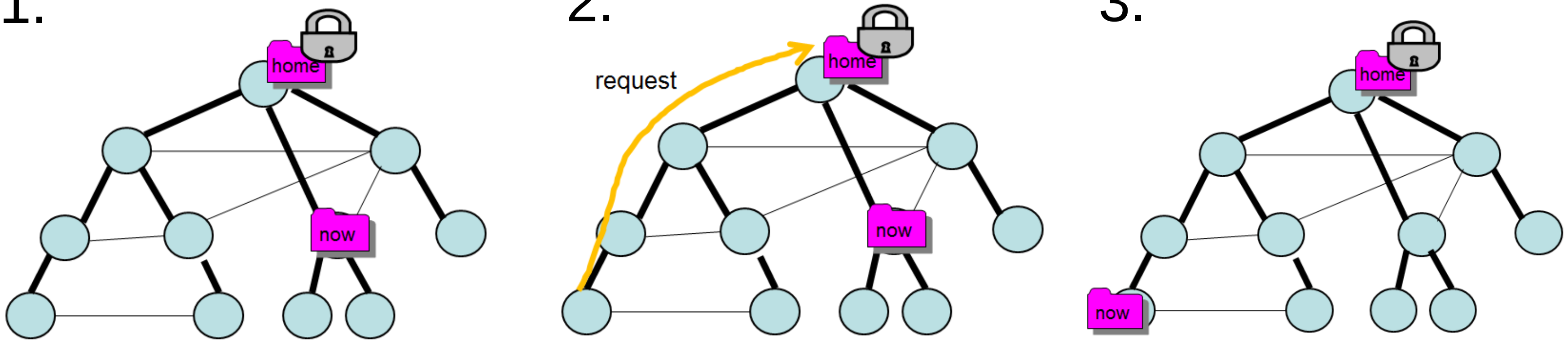

Problem?

Home-Based Solution

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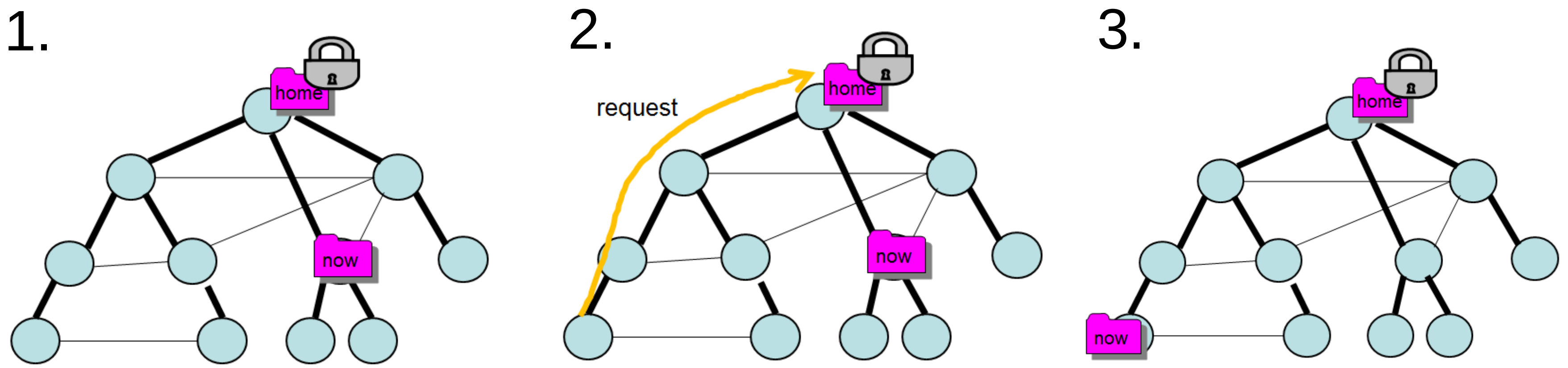

Problem?

Triangle Routing if accessing nodes are close but root is far.

The Arrow Protocol

Idea: Make accessor responsible for object, i.e. the new «root».

How can this be achieved?

The Arrow Protocol

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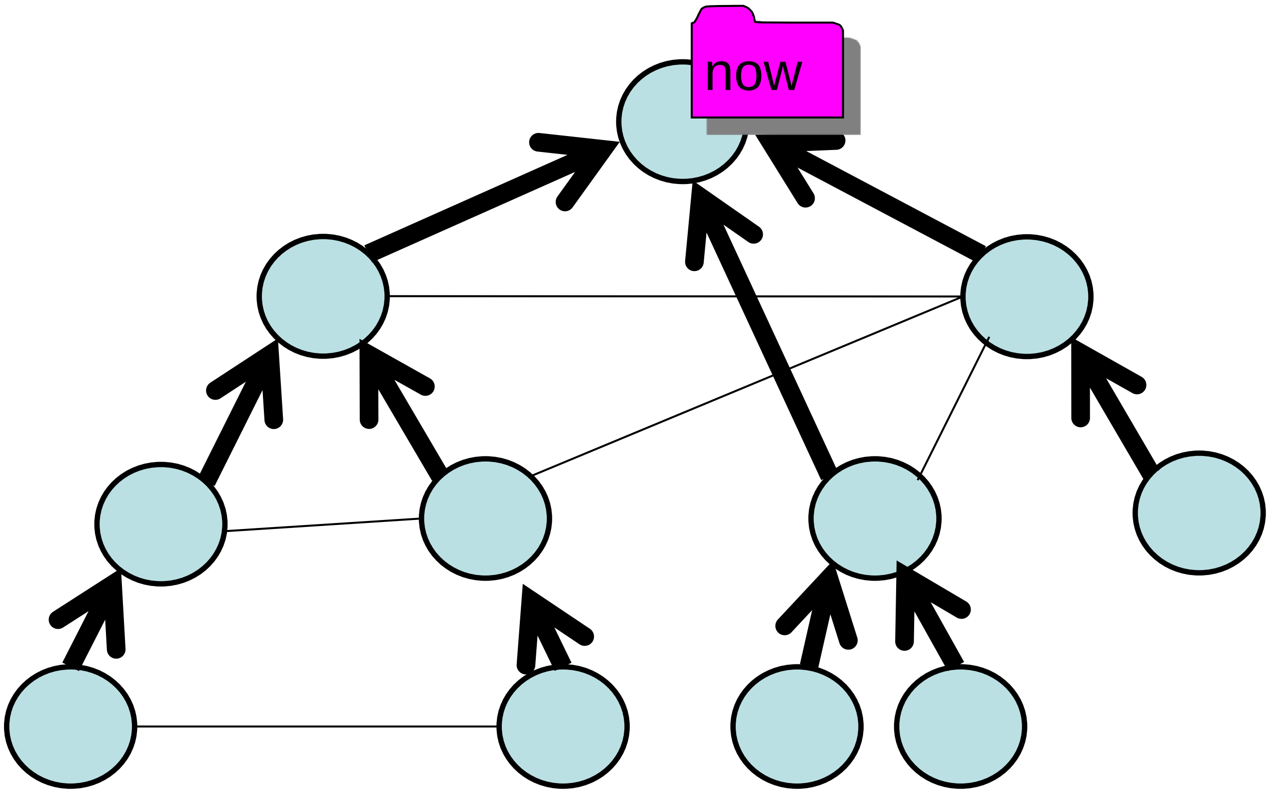
(1) Make tree directed



I want access!

The Arrow Protocol

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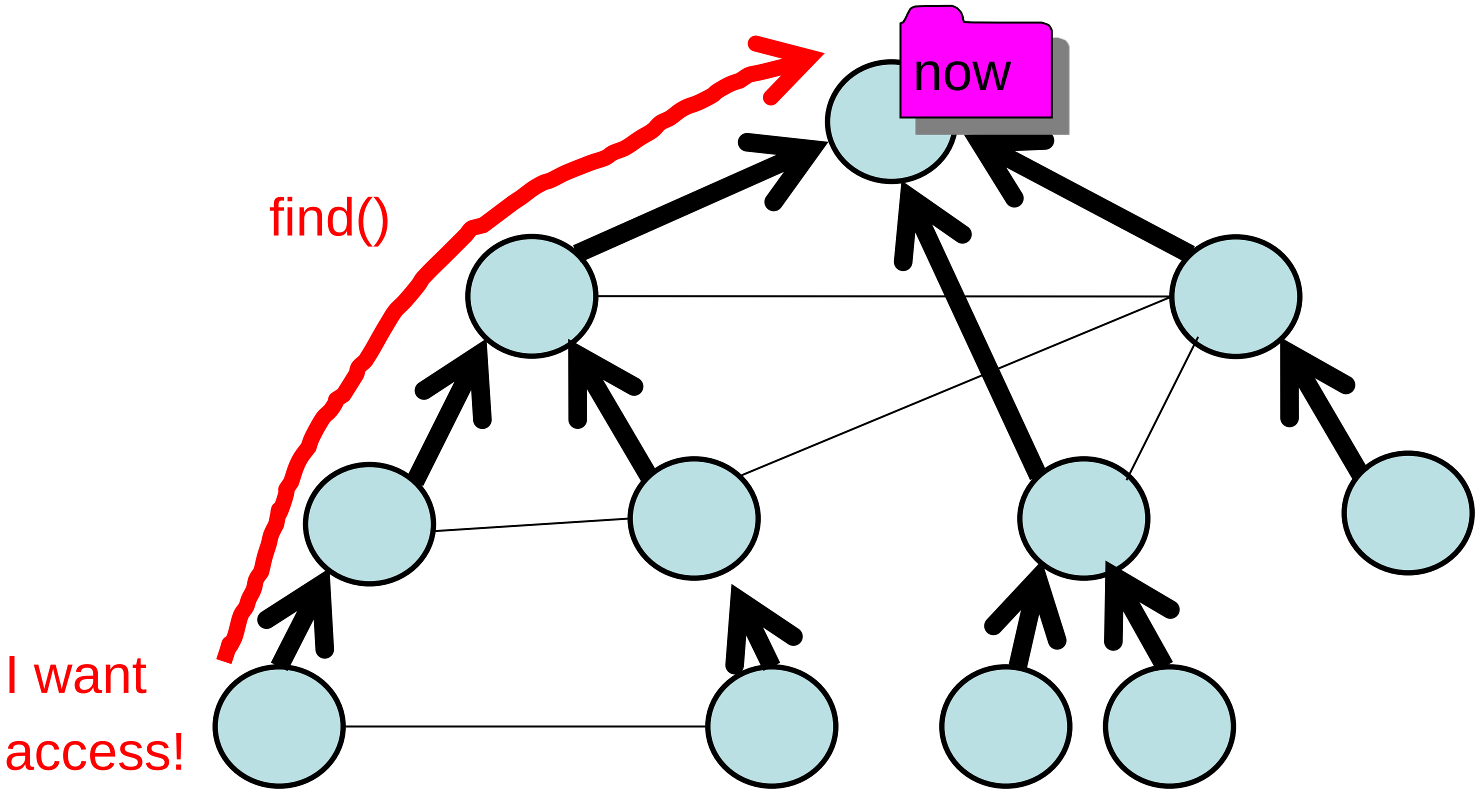

The Arrow Protocol

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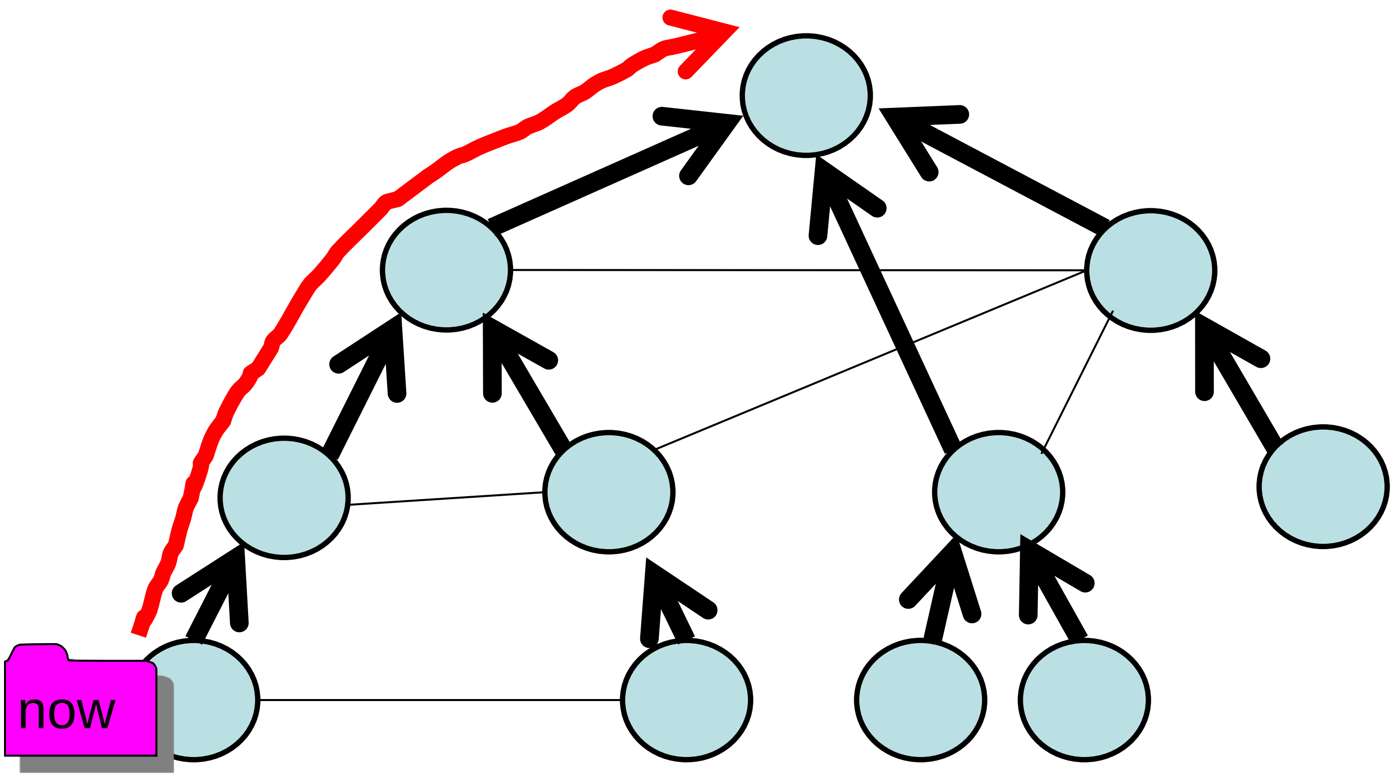
(2) Give object to accessor, new root!



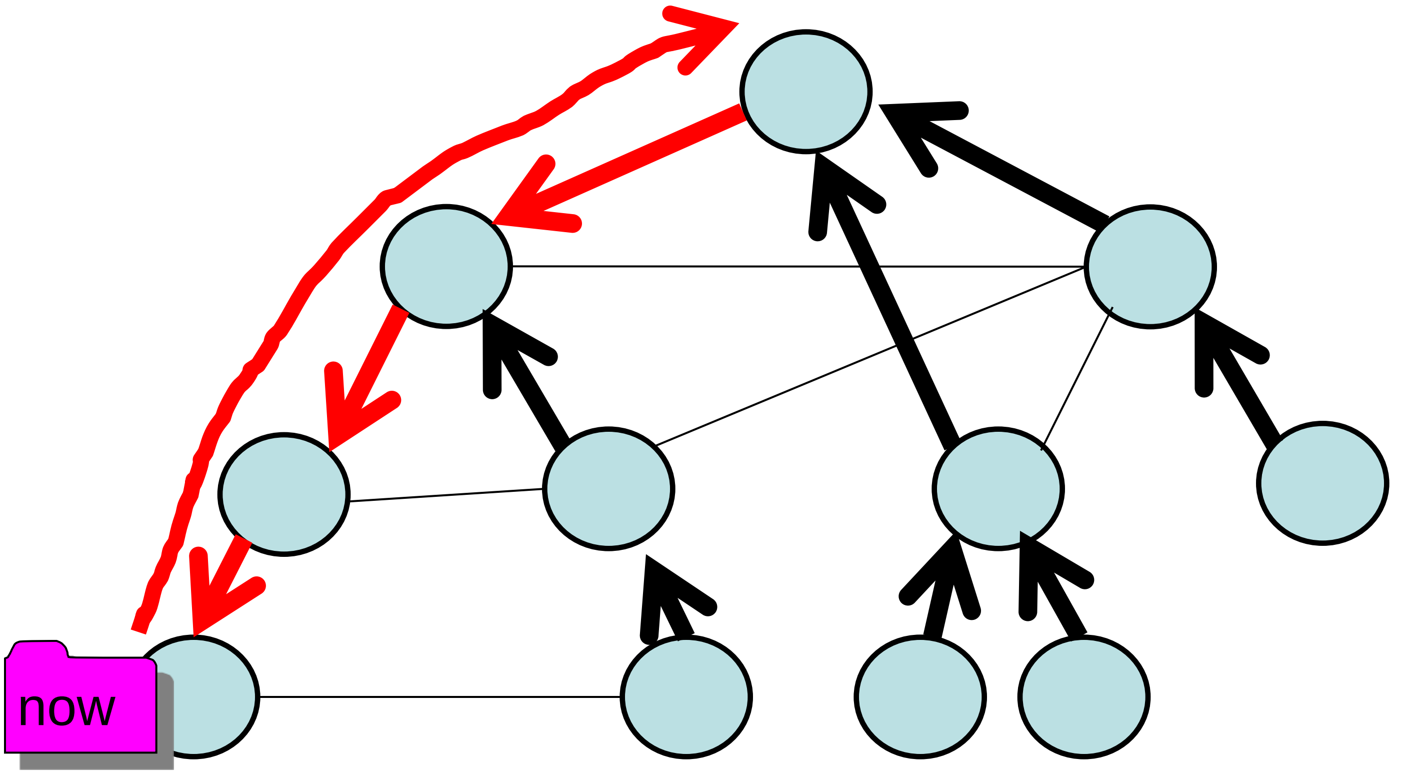
The Arrow Protocol

Idea: Make accessor responsible for object, i.e. the new «root».

(1) Make tree directed

(2) Give object to accessor, new root!

(3) Invert pointers along the find path in spanning tree!



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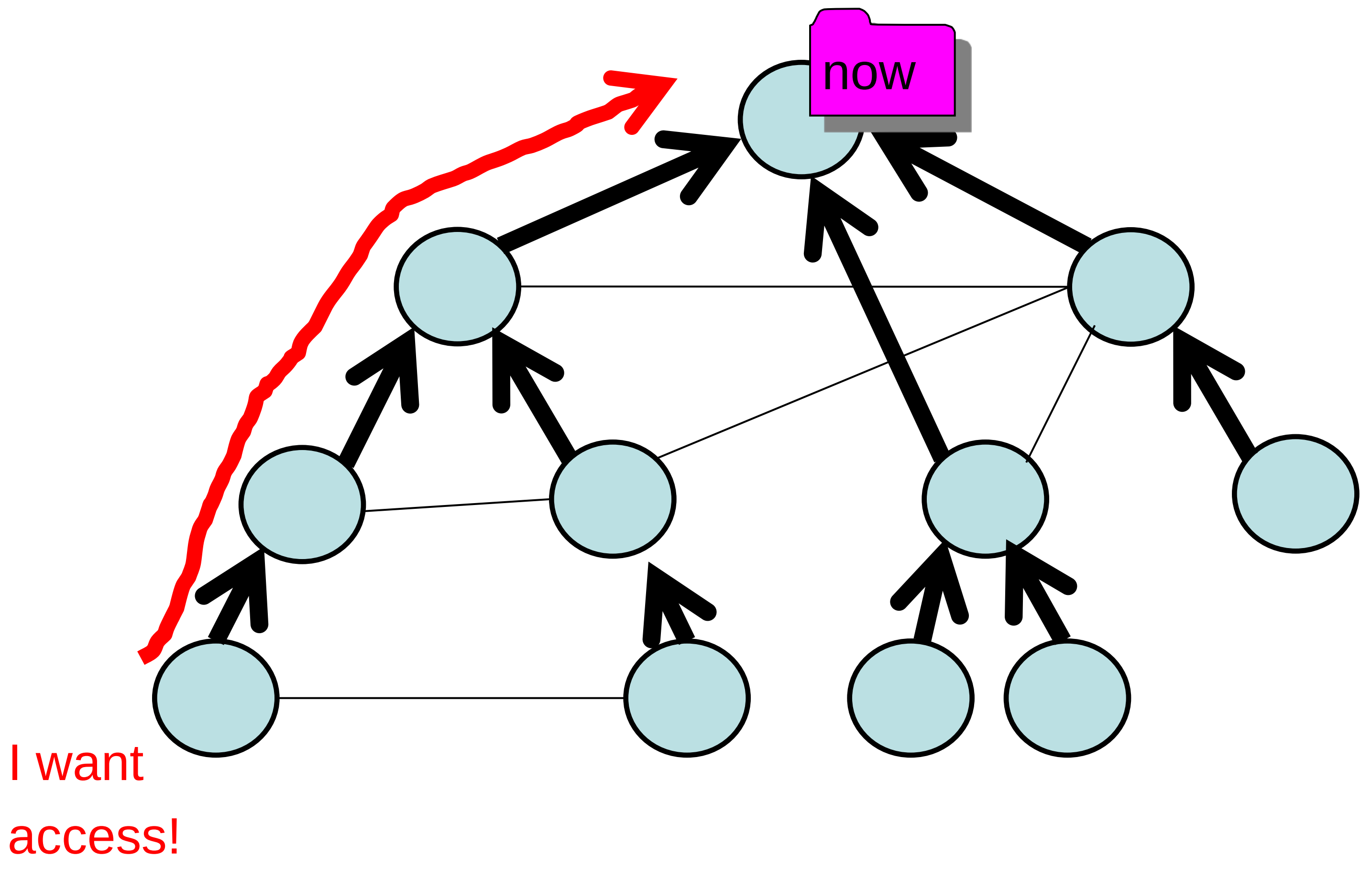

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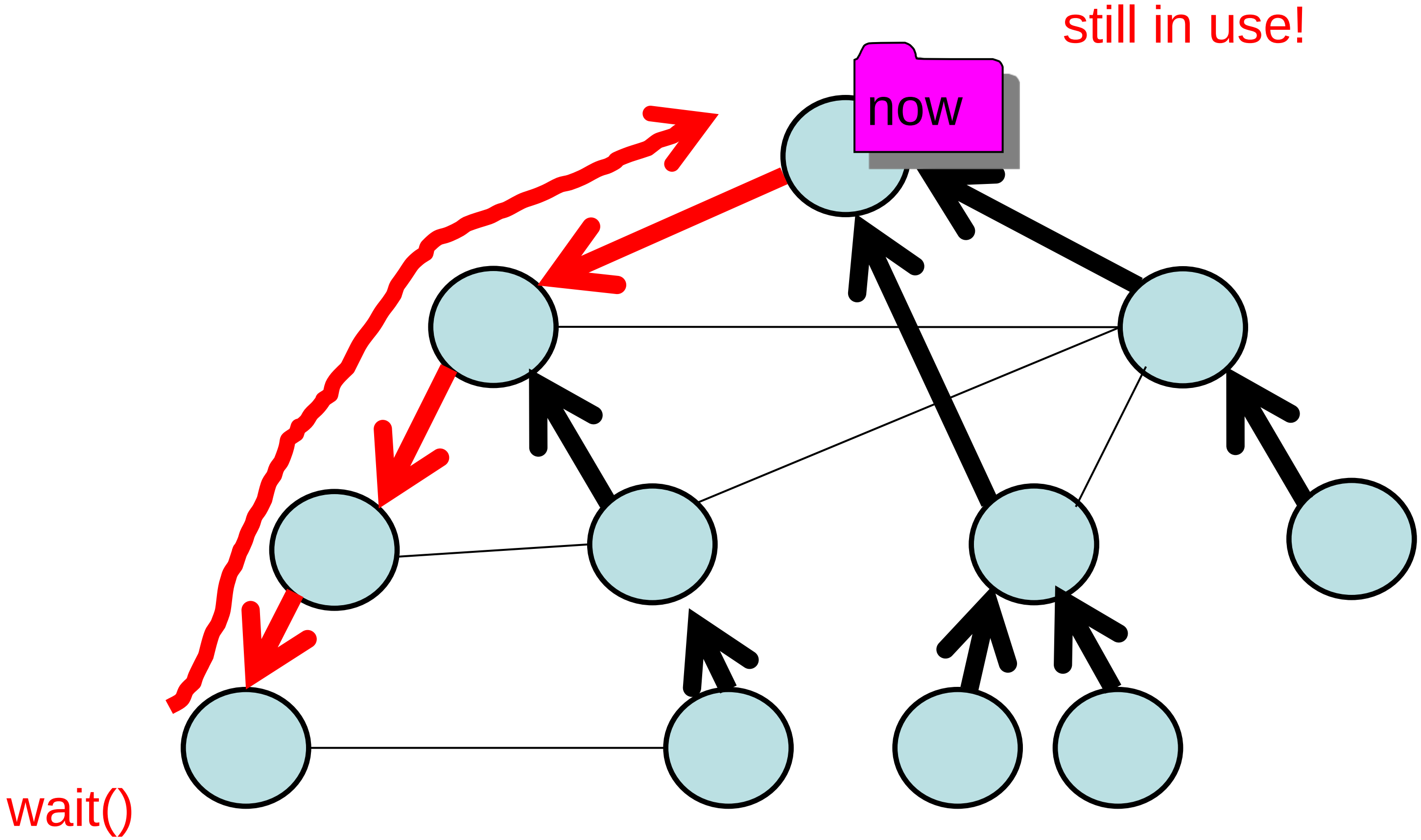

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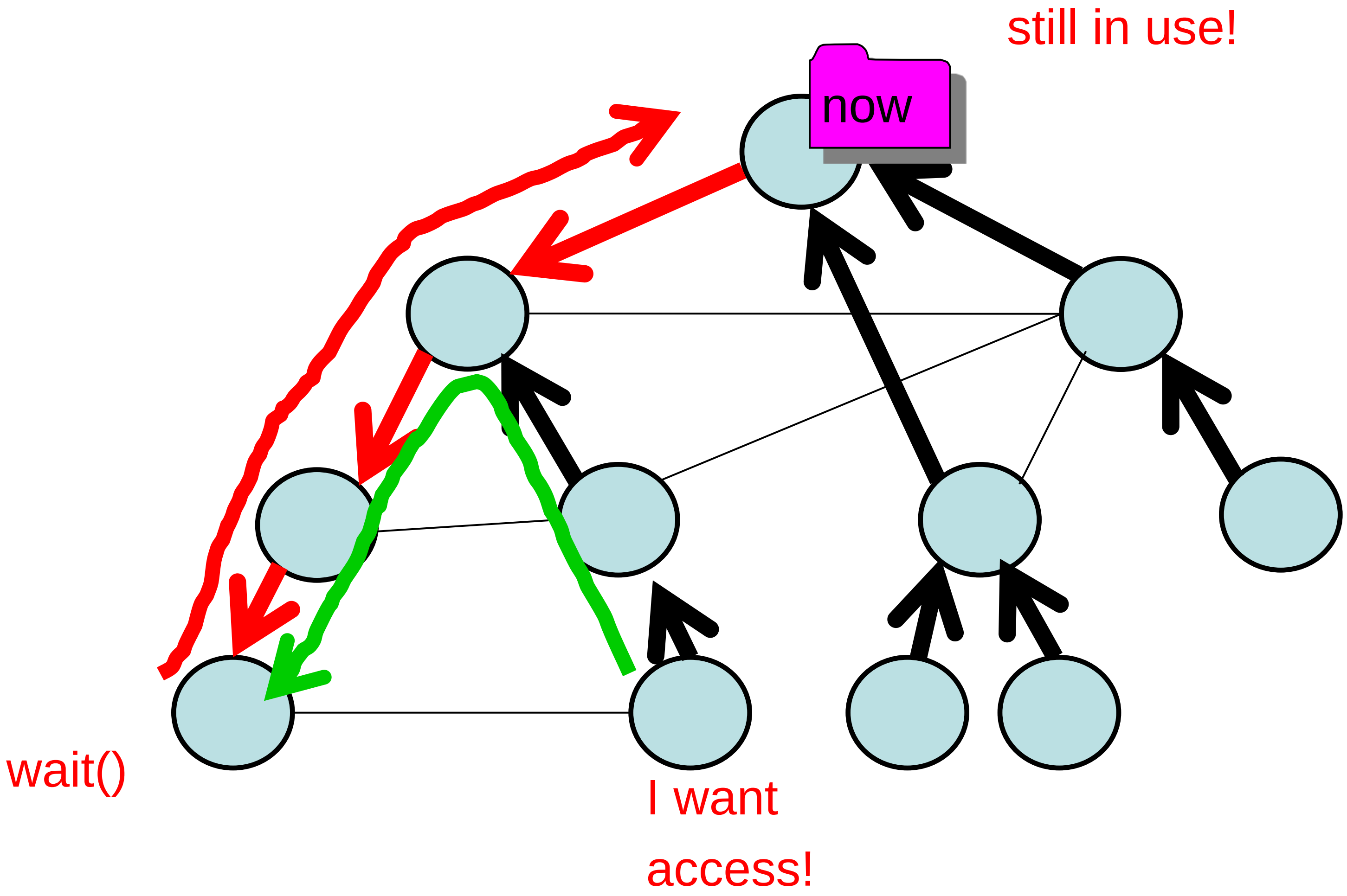

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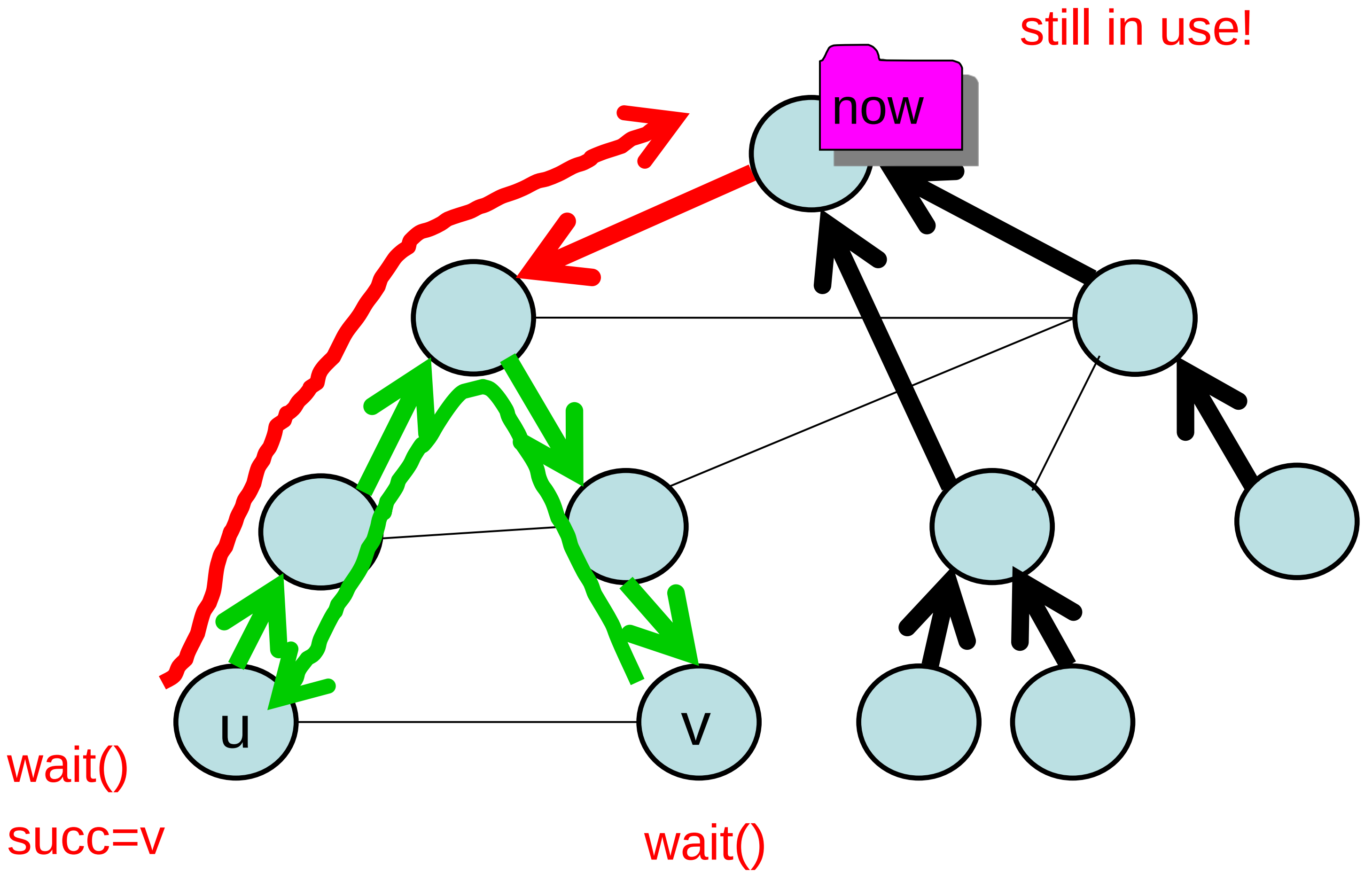

Perfect: tree automatically rooted at node v now! Distributed queue.

Node u can just send it directly to v («out-of-band») when done.

Arrow

Start Find Request at Node *u*:

```
do atomically
   u sends "find by u" message to parent node
   u.parent := u
   u.wait := true
end do
```

Upon *w* Receiving "Find by *u*" Message from Node *v*:

```
do atomically
   if w.parent ≠ w then
      w sends "find by u" message to parent
      w.parent := v
   else
      w.parent := v        invert edge!
      if not w.wait then
         send variable to u      // w holds var. but does not need it any more
      else
         w.successor := u               // w will send variable to u a.s.a.p.
      end if
   end if                  wait myself?
end do
```

Upon *w* Receiving Shared Object:

```
perform operation on shared object
do atomically
   w.wait := false
   if w.successor ≠ null then
      send variable to w.successor
      w.successor := null
   end if
end do
```

Arrow

Arrow is correct: find() terminates with message and time complexity D, where D is the diameter of the spanning tree. Completely asynchronous and concurrent environments!

Proof.

- Each edge {u,v} in the spanning tree is in one of four states:
  - (A) u points to v, no message on the edge, v does not point to u
  - (B) Message on the move from u to v (no pointer along edge)
  - (C) v points to u, no message on edge, u does not point to v
  - (D) Message on the move from v to u (no pointer along edge)
- So message will only travel on static tree!
- And can never traverse an edge twice (in opposite direction).

QED

End of Lecture