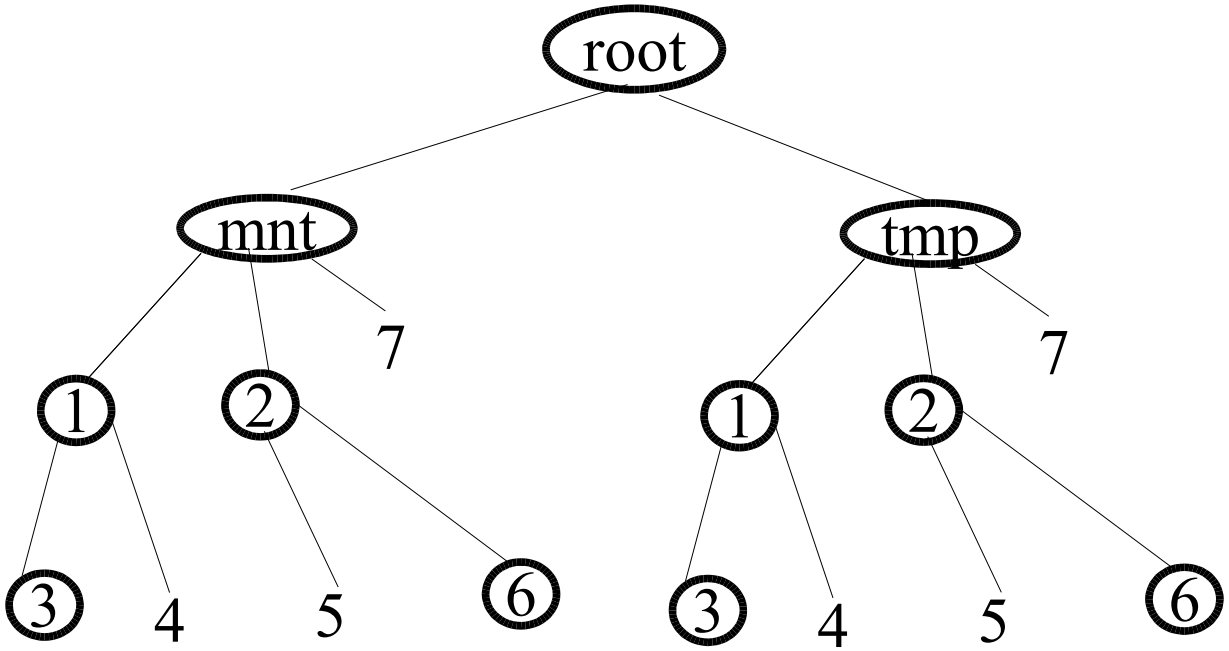
OTTAWA LINUX SYMPOSIUM 2006

Shared Subtree Concept and Implementation and Applications in the Linux Kernel



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Al Viro
viro@ftp.linux.org.uk

Agenda

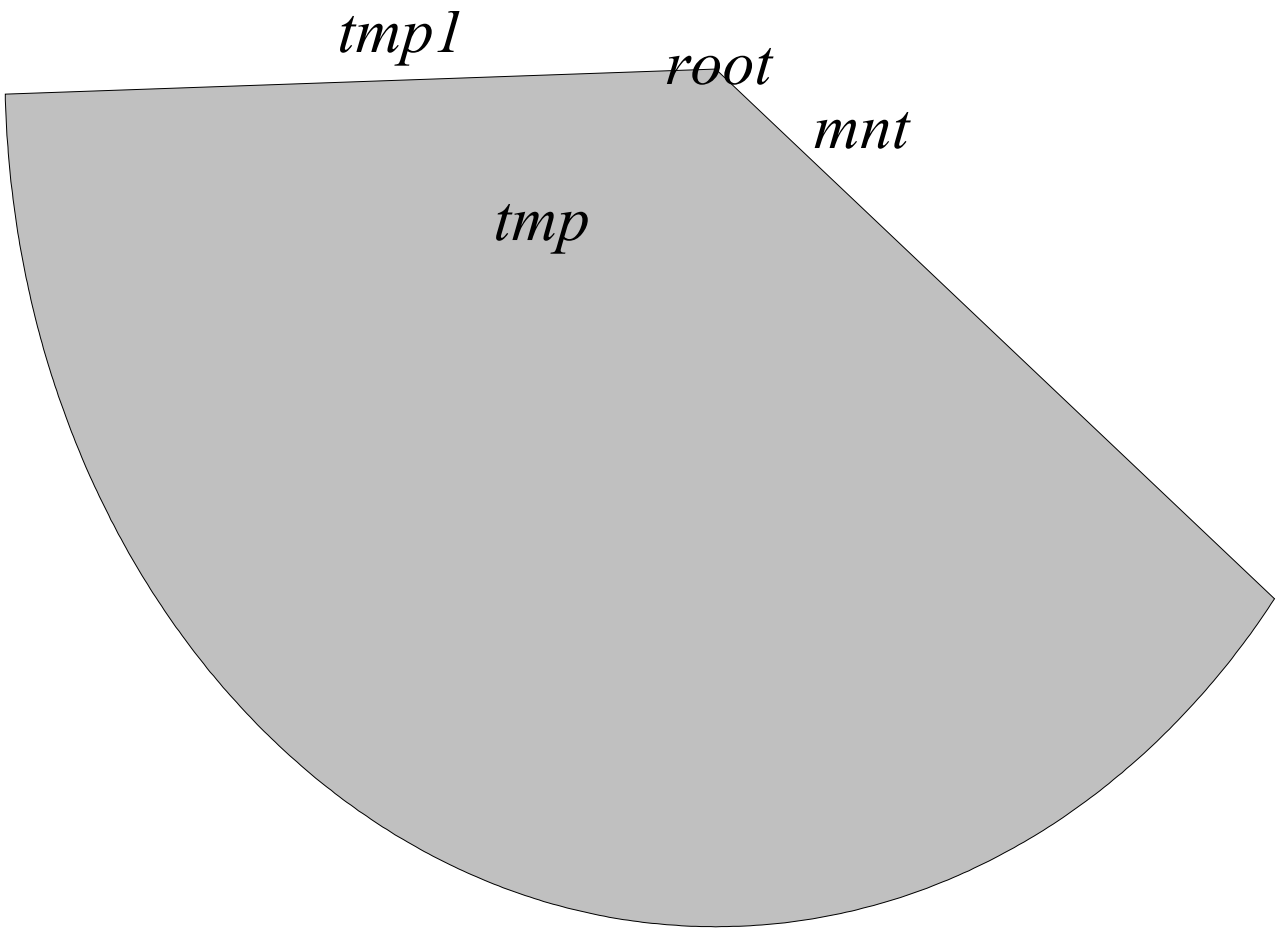
- Background.
- Requirement/Applications.
- Shared subtree solution.
- Shared subtree semantics.
- Implementation detail.
- Future work.

Background

mount semantics in Linux® VFS

- normal device mount (mount /dev/sda0 /mnt)
- bind mount (mount –bind /mnt /tmp)
- rbind mount (mount –rbind /mnt /tmp)
- move mount (mount –move /mnt /tmp)
- namespaces (*CLONE_NS* flag for *sys_clone()*)
- unmount (umount [-l] /mnt)

Background



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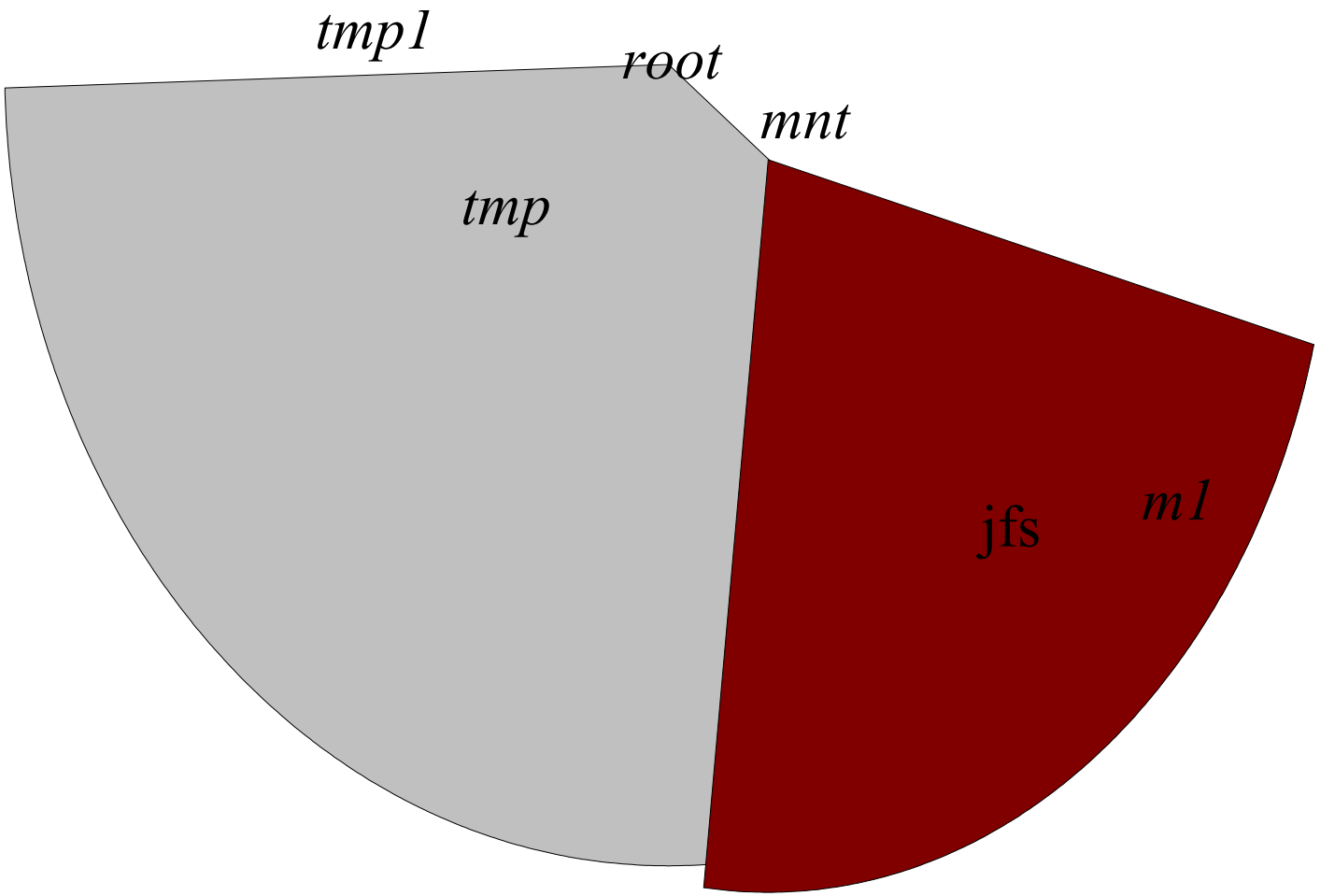

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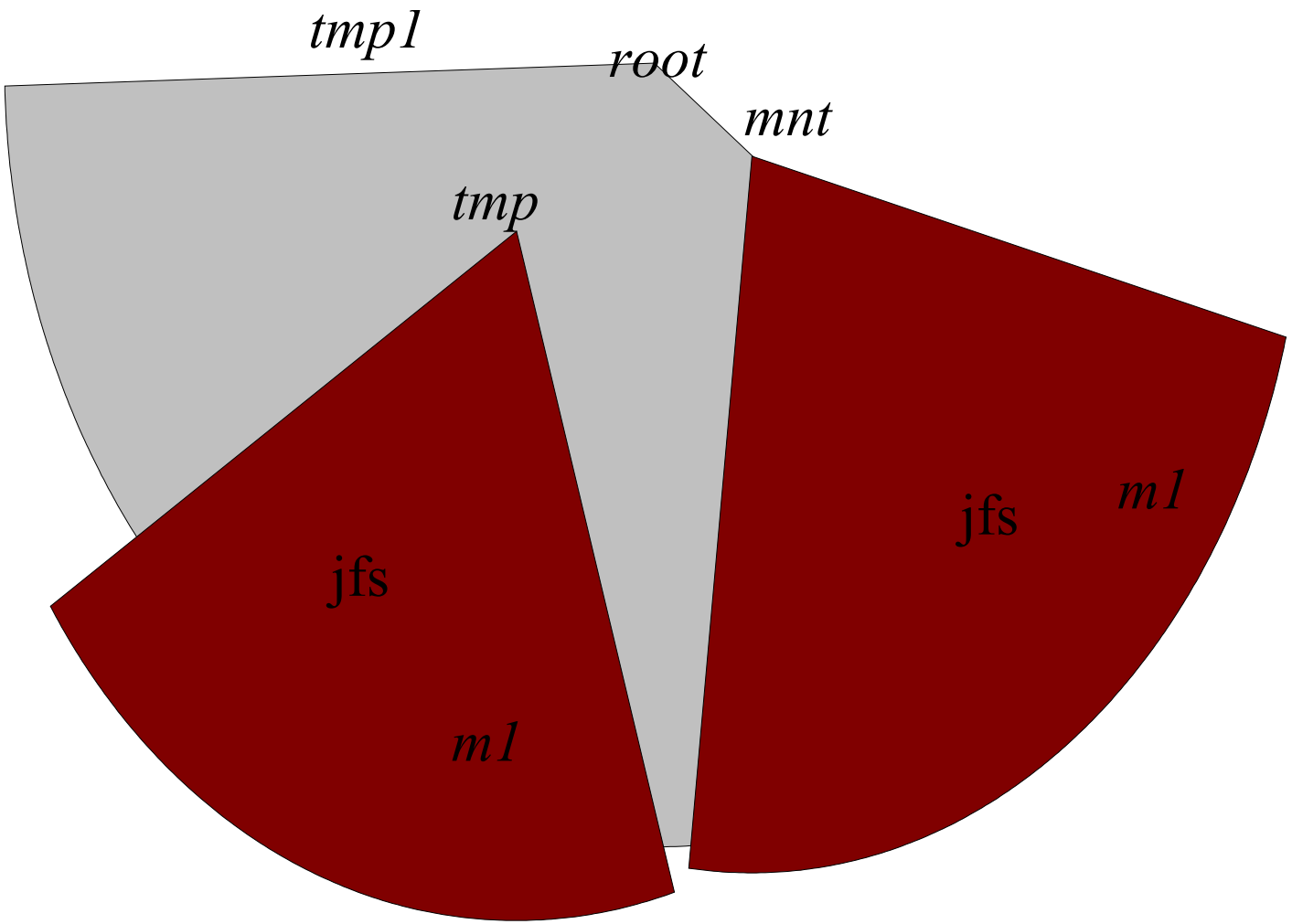

- bind mount (mount –bind /mnt /tmp)

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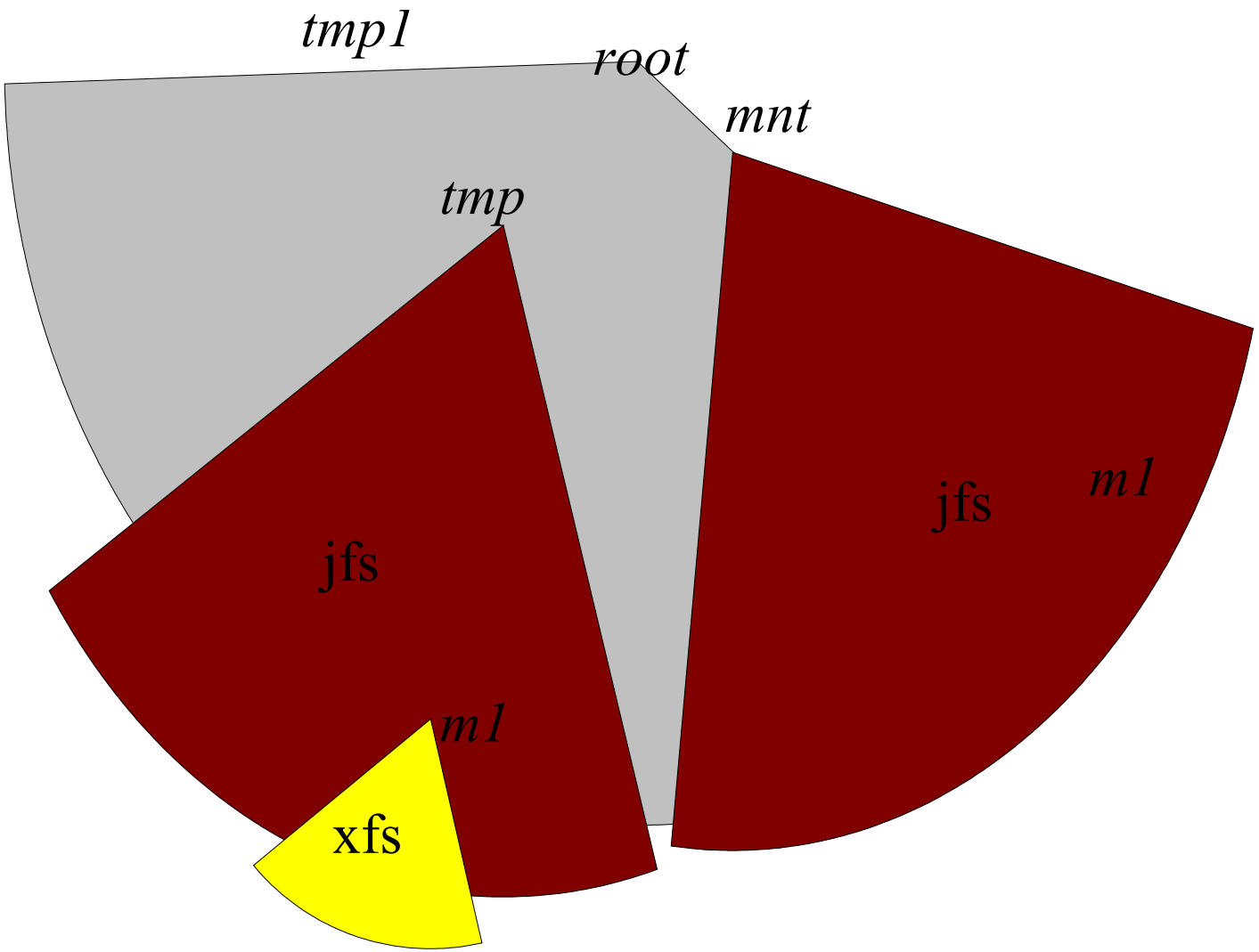

- normal device mount (mount /dev/sda1 /tmp/m1)

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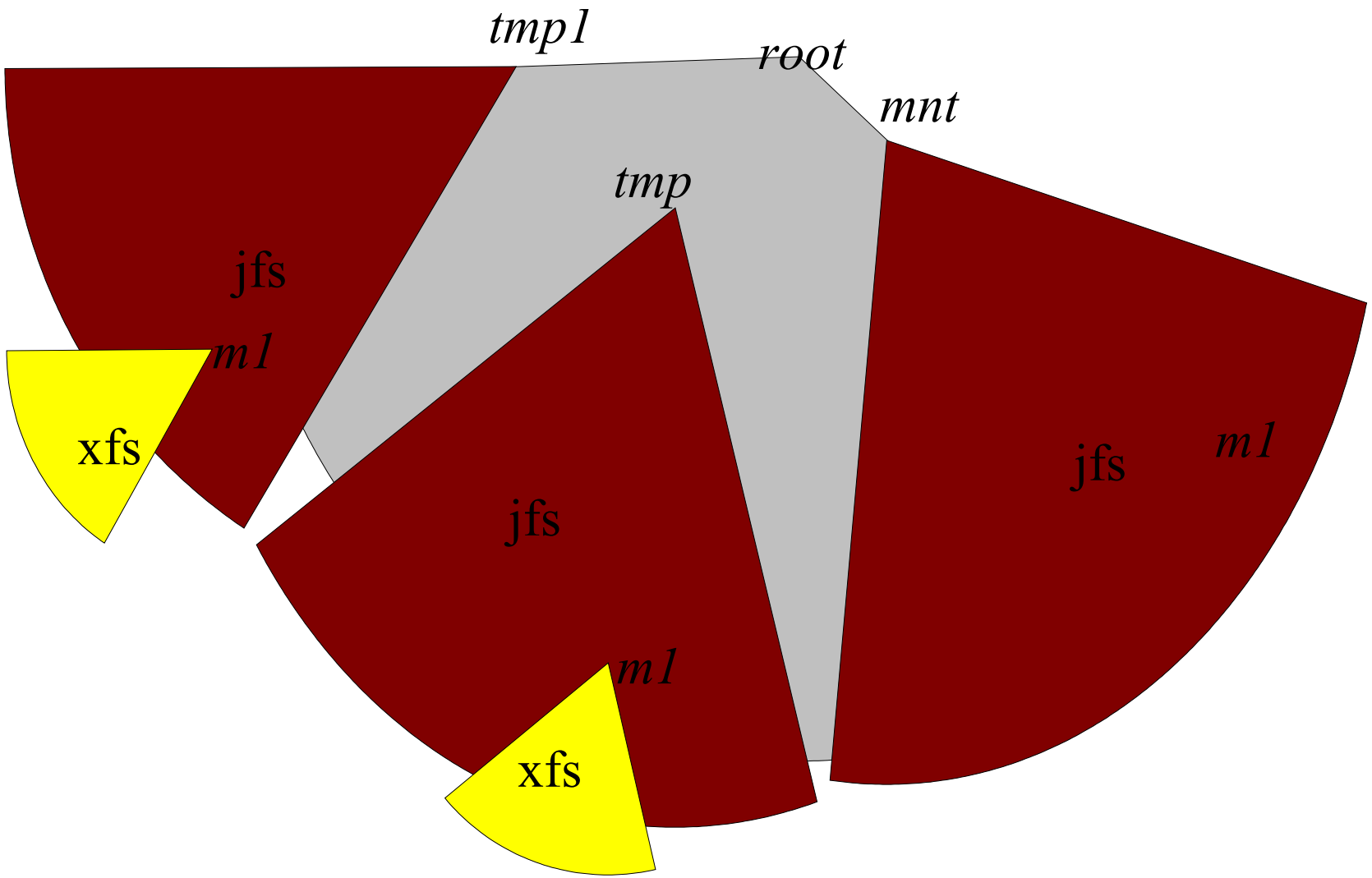

- rbind mount (mount –rbind /tmp /tmp1)

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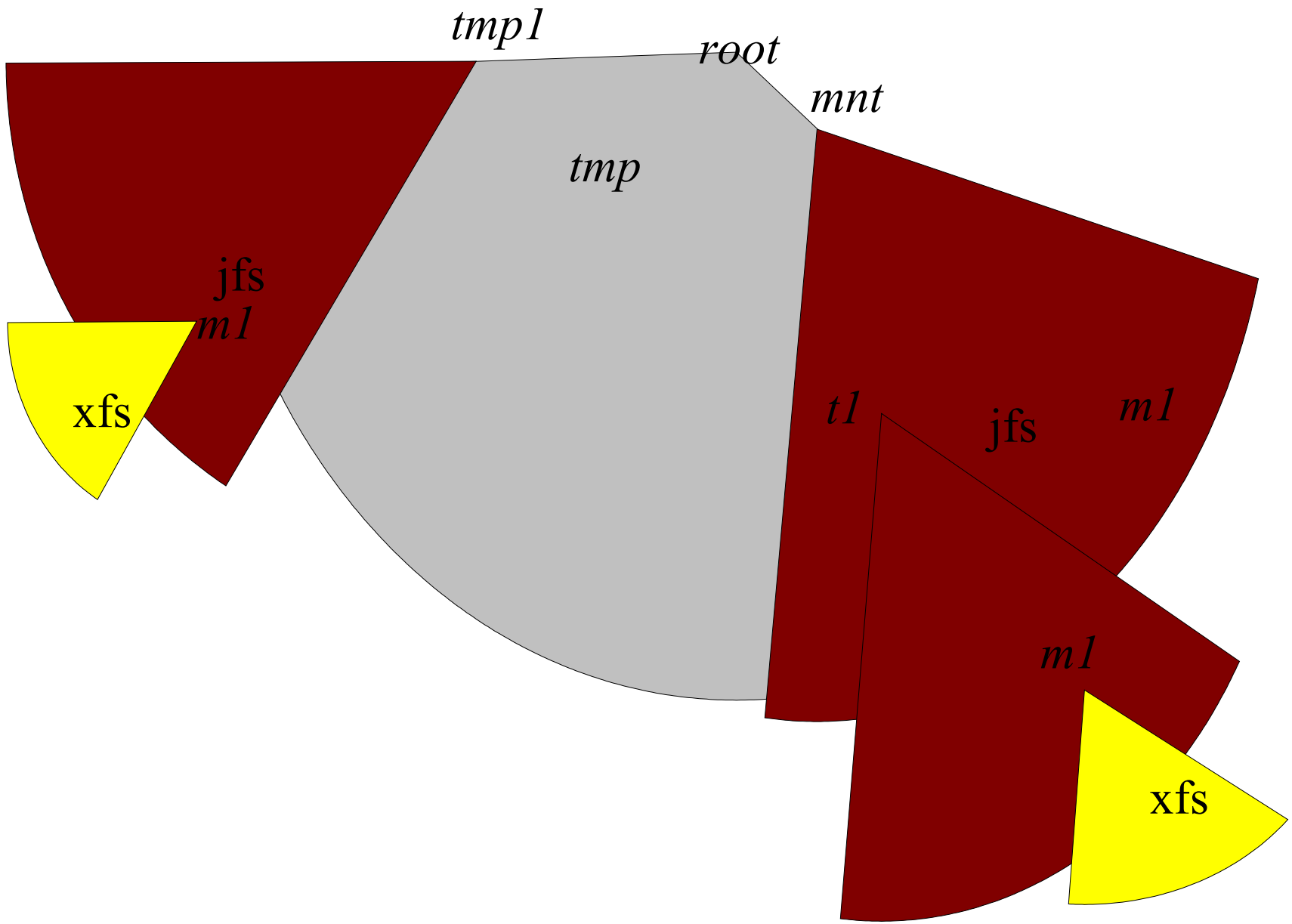

- rbind mount (mount –move /tmp /mnt/t1)

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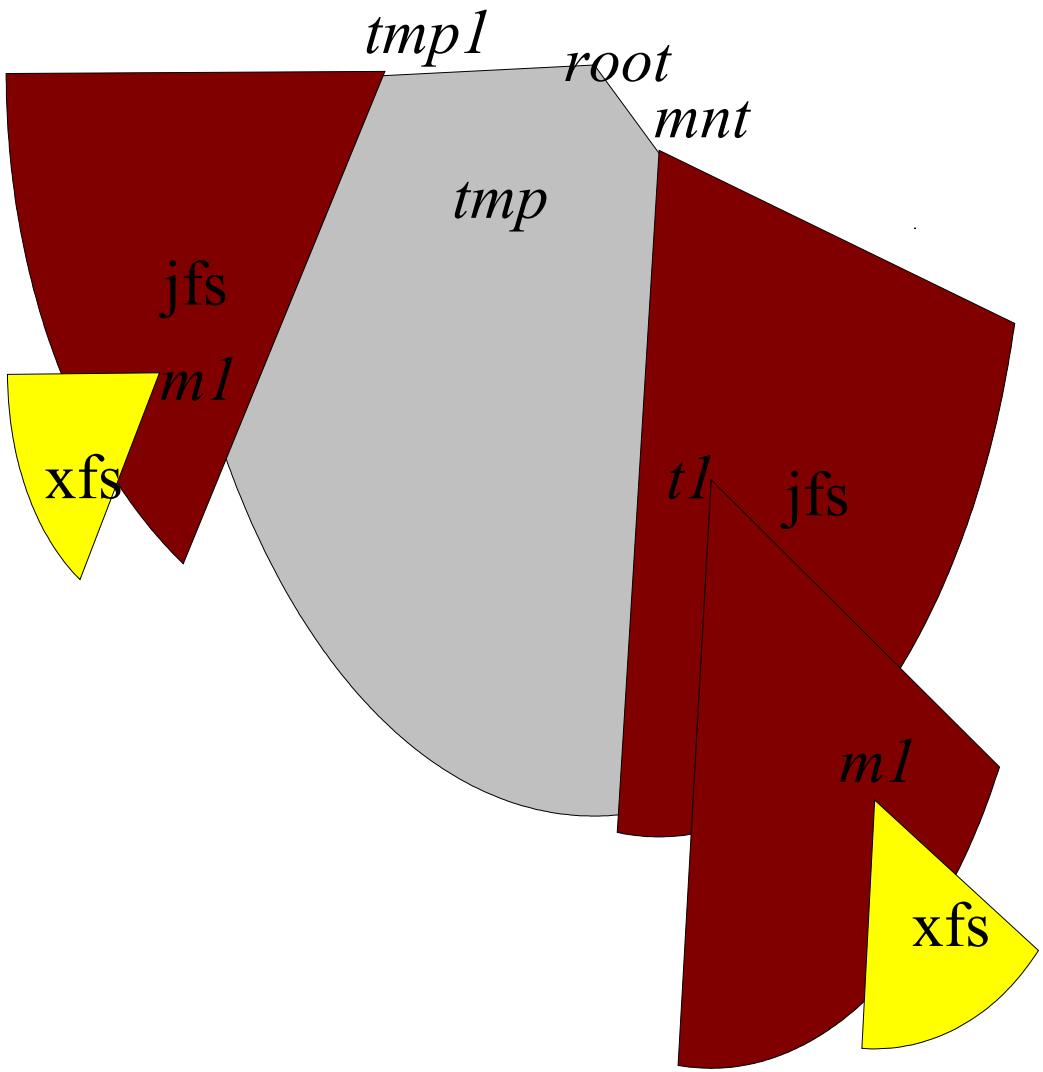
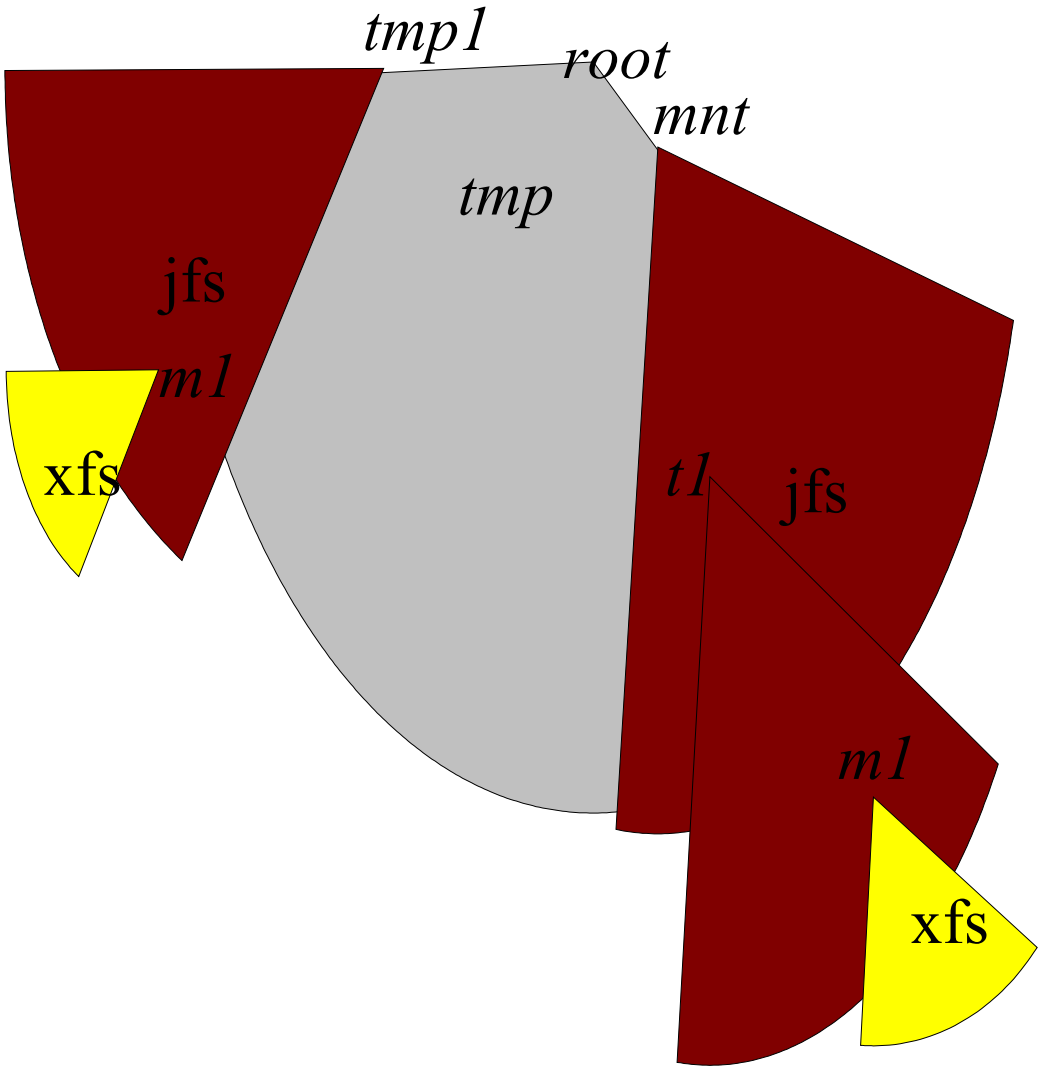




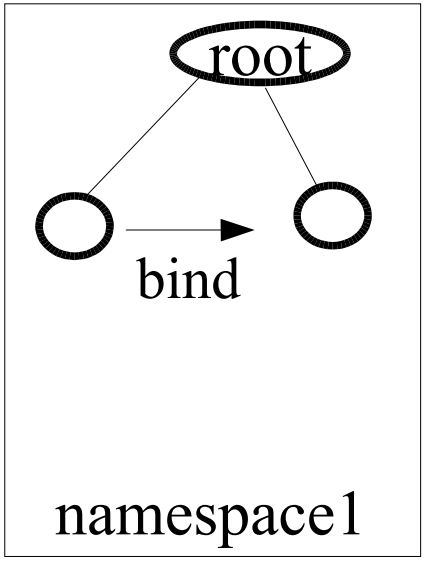
- clone namespace

Requirement

- share mount trees.
  - containers: all containers share the same mount tree
  - MVFS: all views share the same mount tree
  - automounter: mount automatically visible on all filesystem-namespaces
- Private changes to a mount-subtree.
  - FUSE: mount invisible to anybody else.
  - SeLinux LSPP: mount invisible to anybody else.
  - Containers: private mounts not visible to other containers.
- How?
  - clone-namespace (*CLONE_NEWNS in clone()*).
  - rbind (mount –rbind src dest)

Problem

- bind mounts are static.



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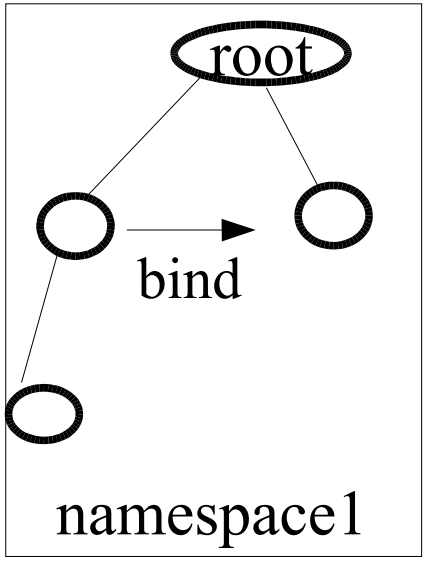

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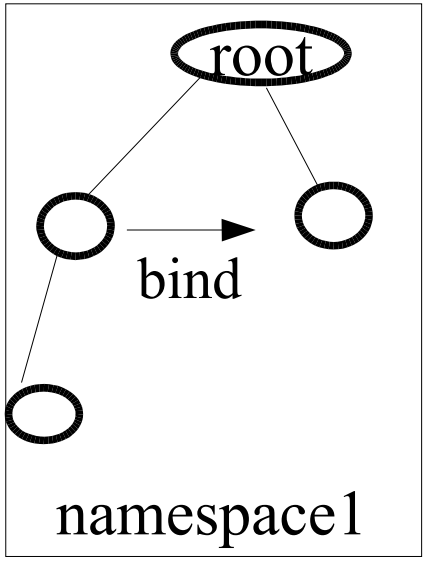
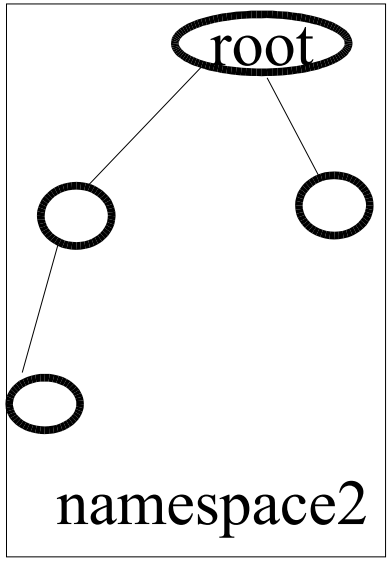


- filesystem-namespaces are isolated.
  - mounts in system namespace are invisible to cloned namespace.



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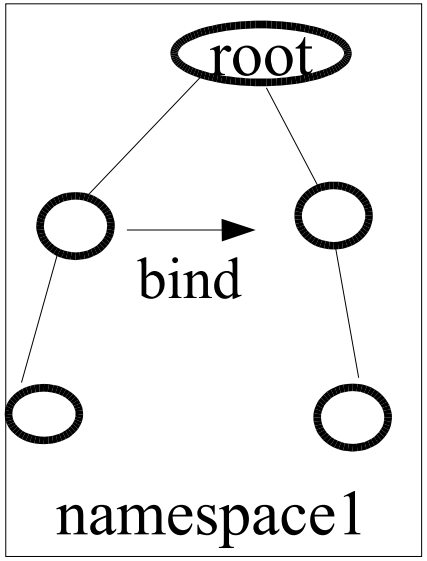

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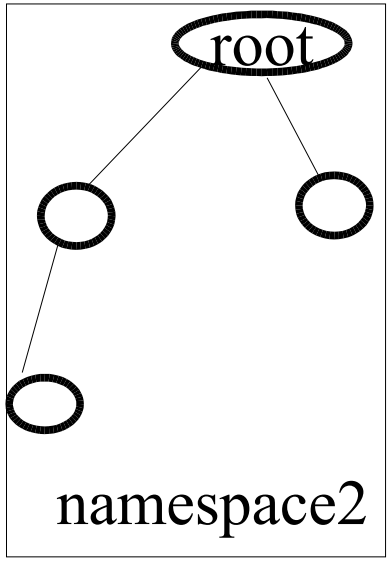


Shared subtree solution

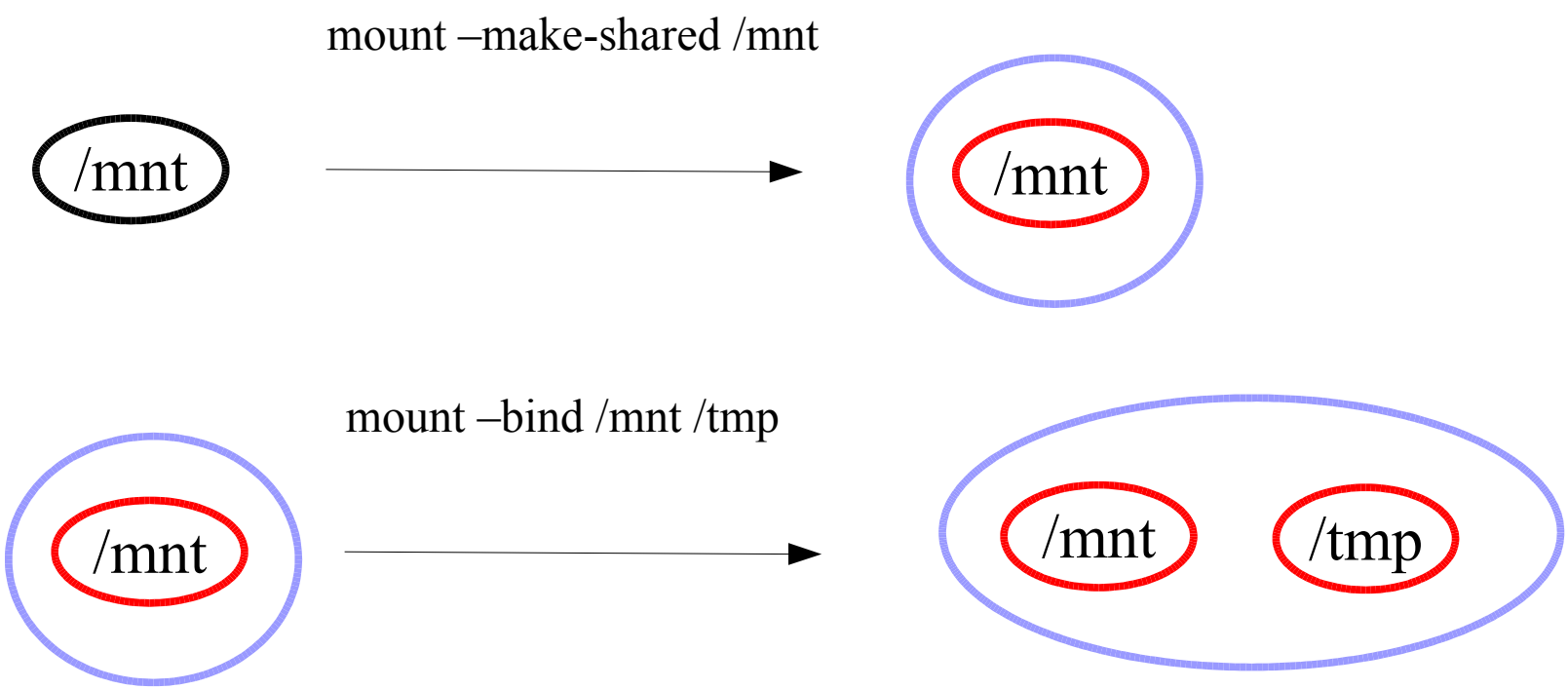
RFC proposed by Al Viro in Jan 2005

- http://lwn.net/Articles/119232/

Ram Pai provided the Linux implementation

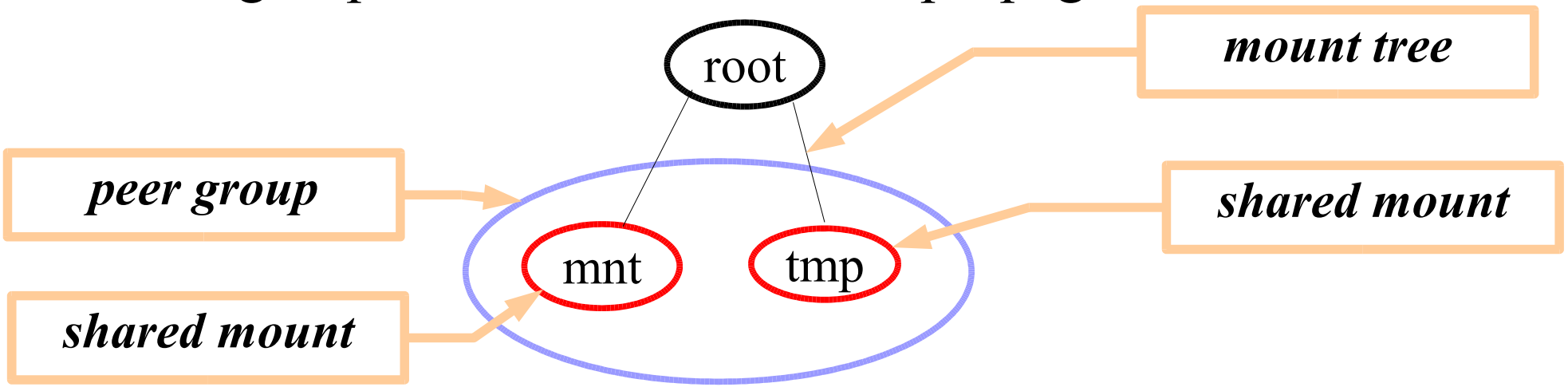
- feature accepted for 2.6.15 Linux kernel

Shared mount



Shared mount

- shared mount
  - mount, unmount events propagate to each other
- peer group
  - group of shared mounts that propagate to each other



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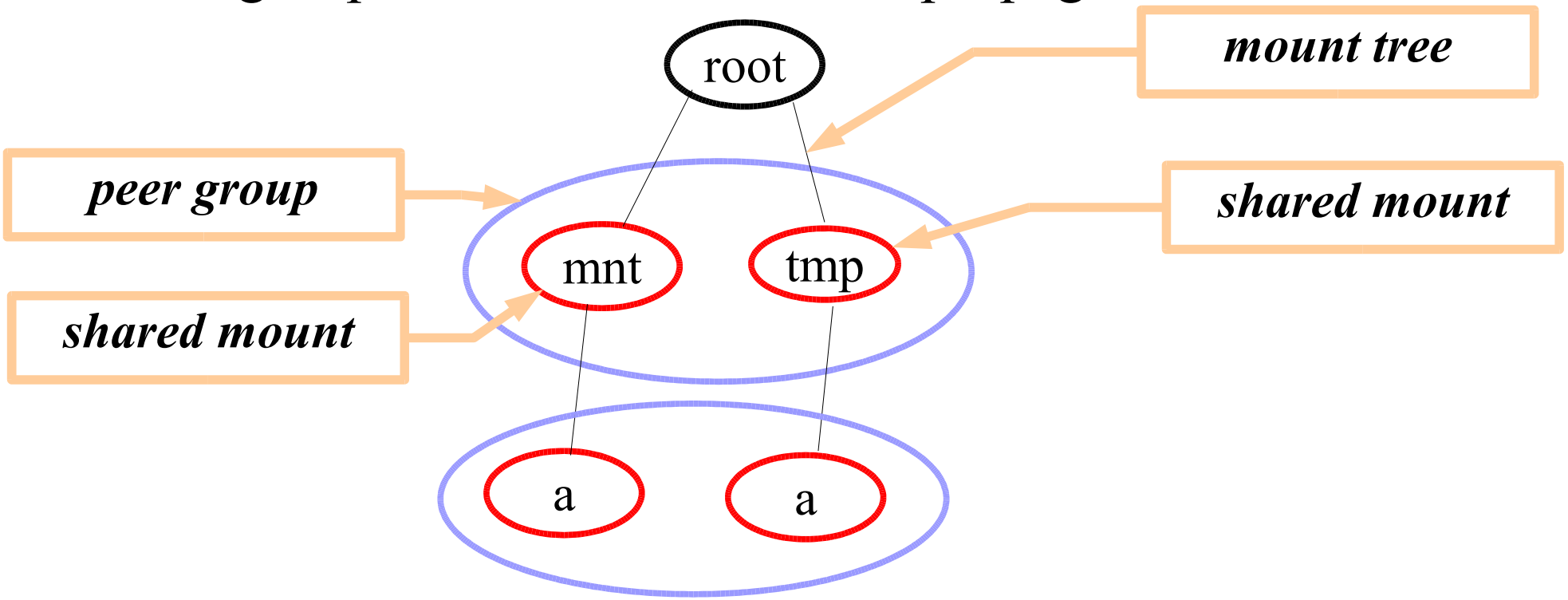
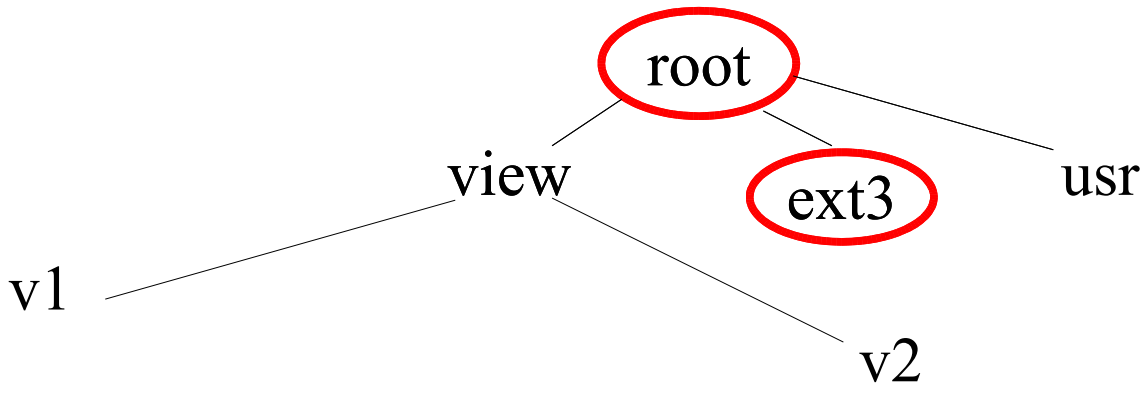


Shared mount application in MVFS



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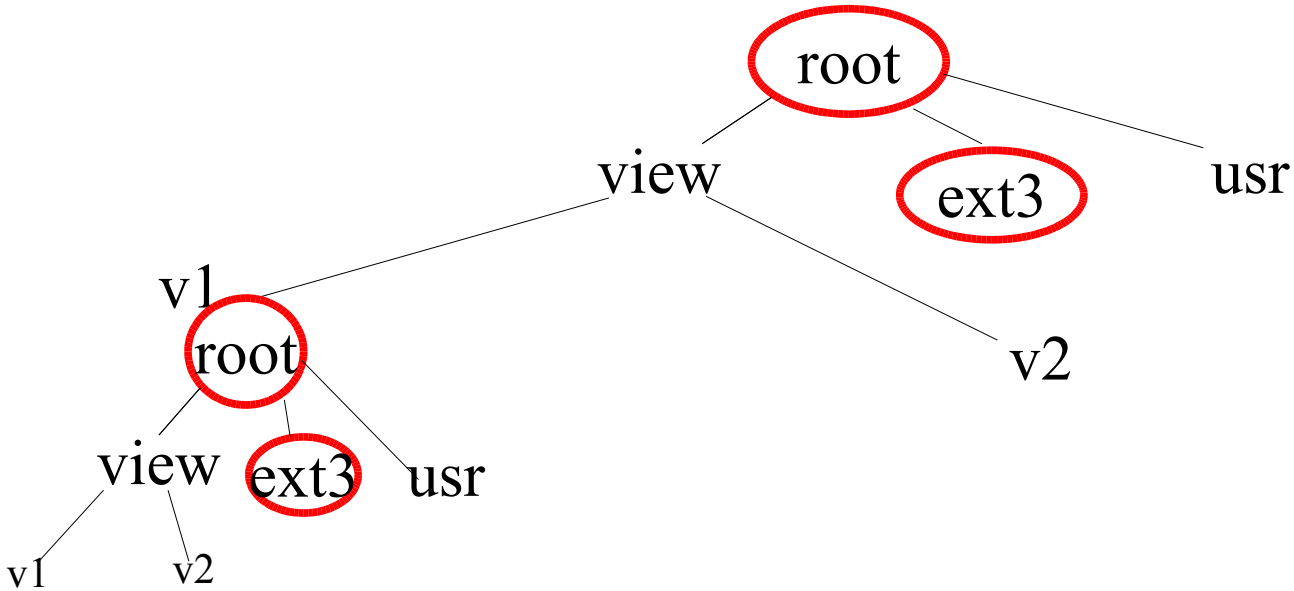

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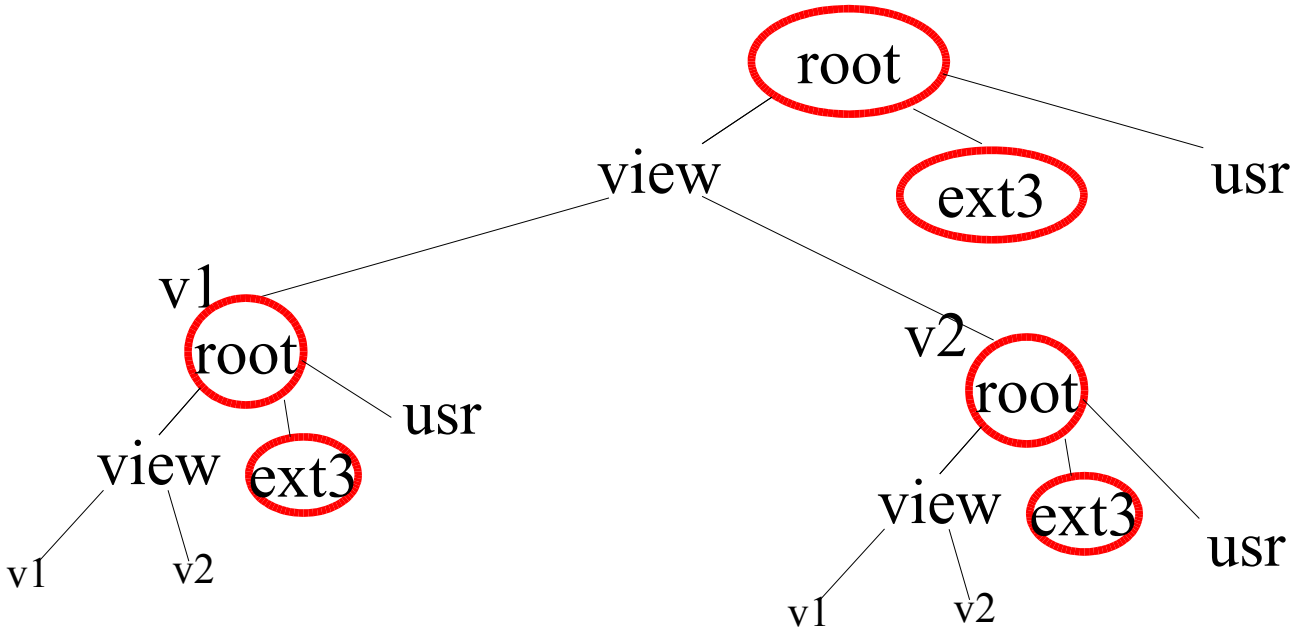

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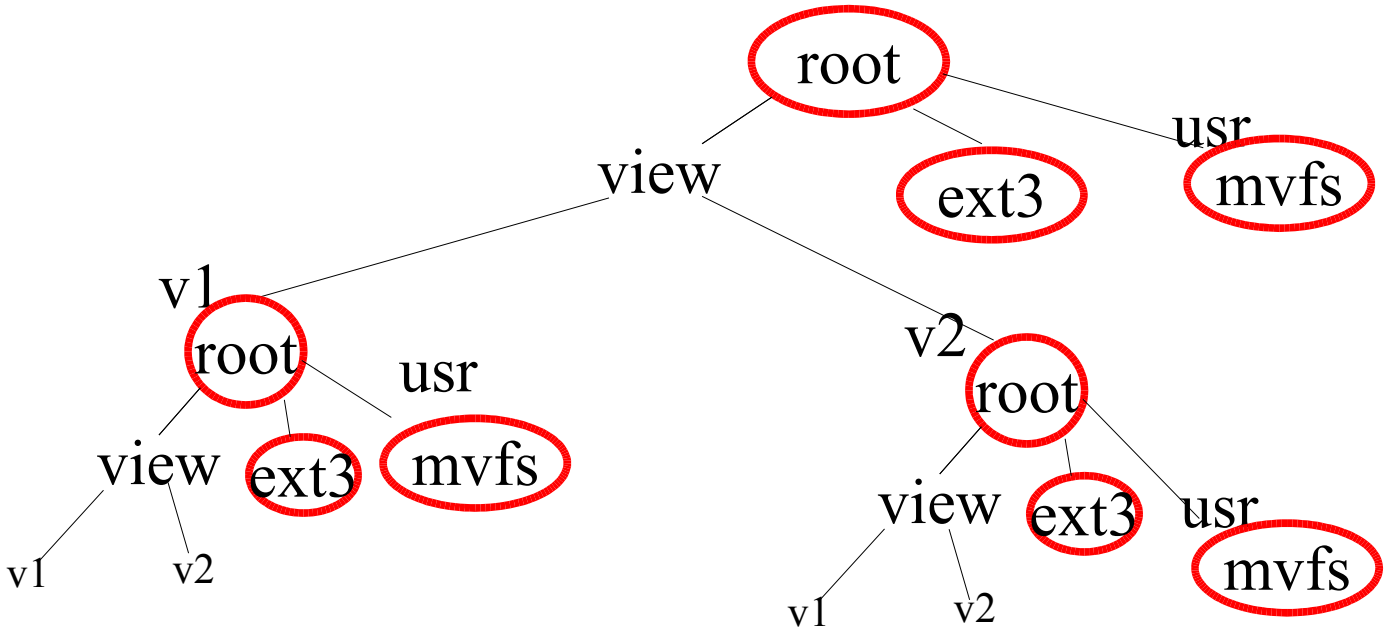
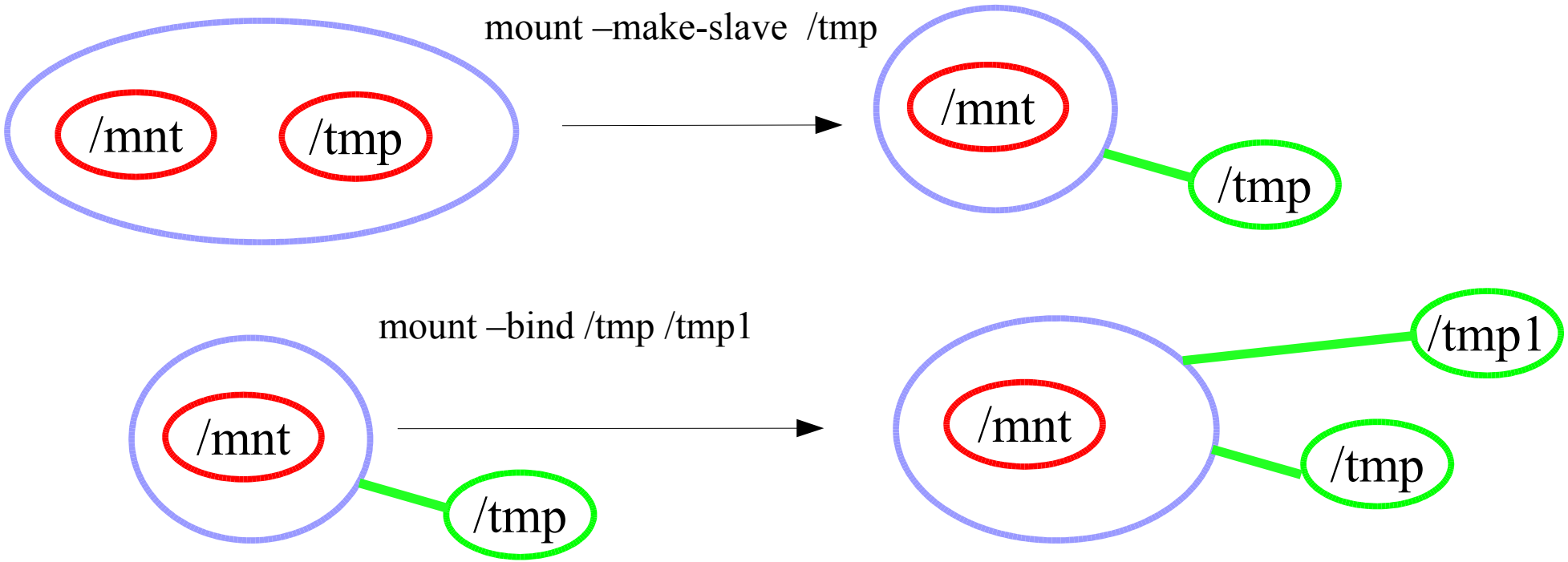
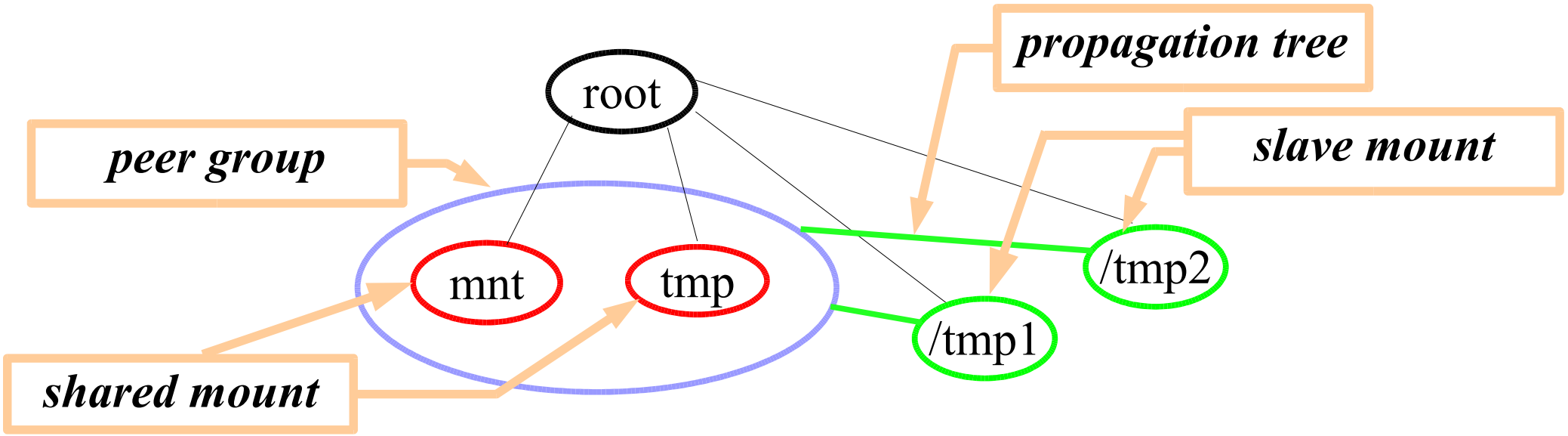


Slave mount


mount –make-slave /tmp
/mnt
/tmp
/mnt
/tmp
mount –bind /tmp /tmp1
/mnt
/tmp
/mnt
/tmp1
/tmp

Slave mount

- slave mount
  - mount,unmount events propagate towards it from master not vice-versa.
- propagation tree
  - dictates the flow of mount and unmount events.



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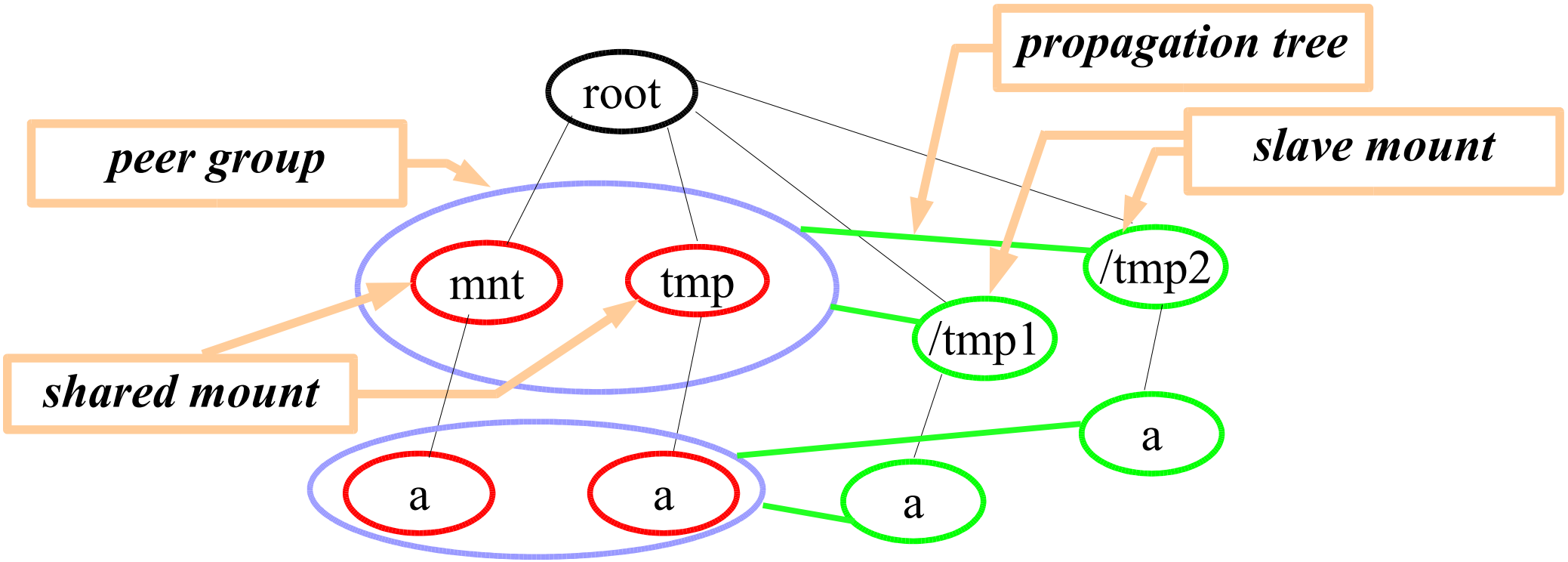

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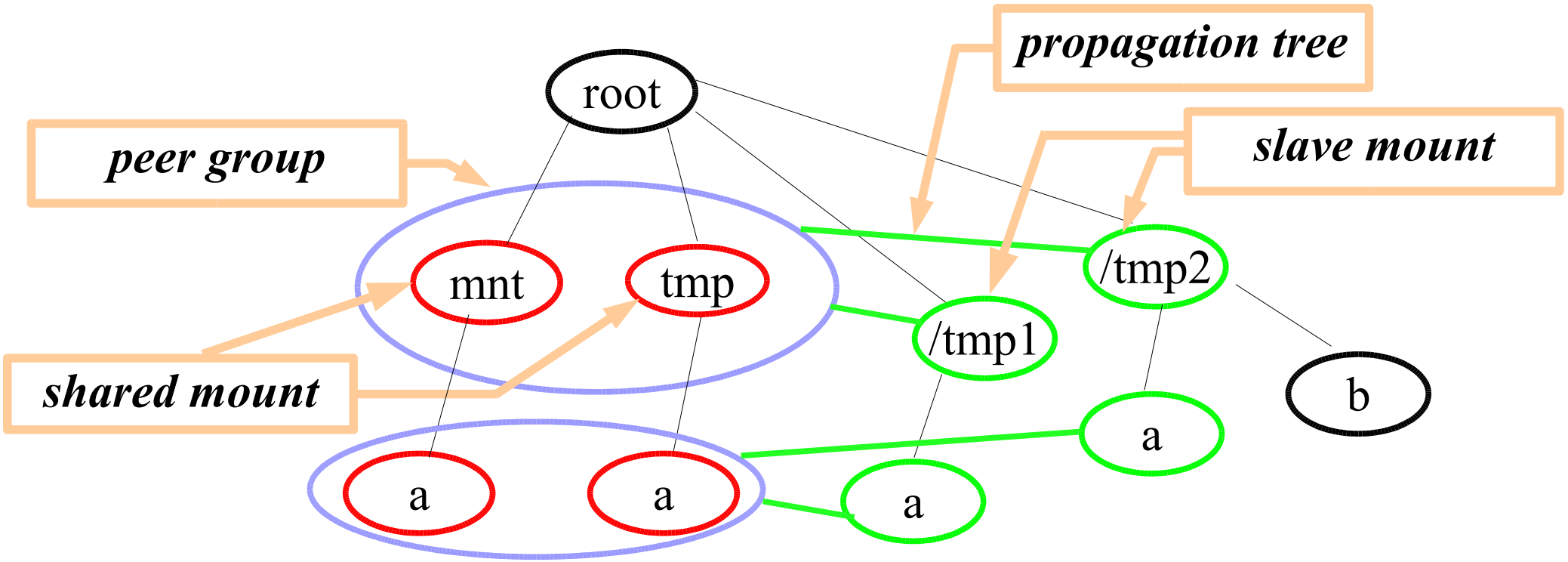
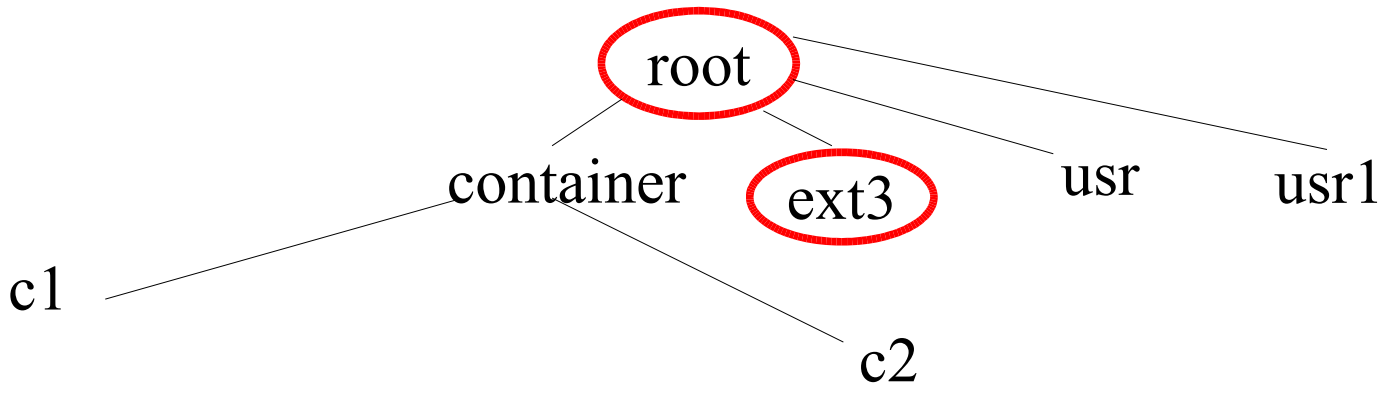


Slave mount application in Containers.



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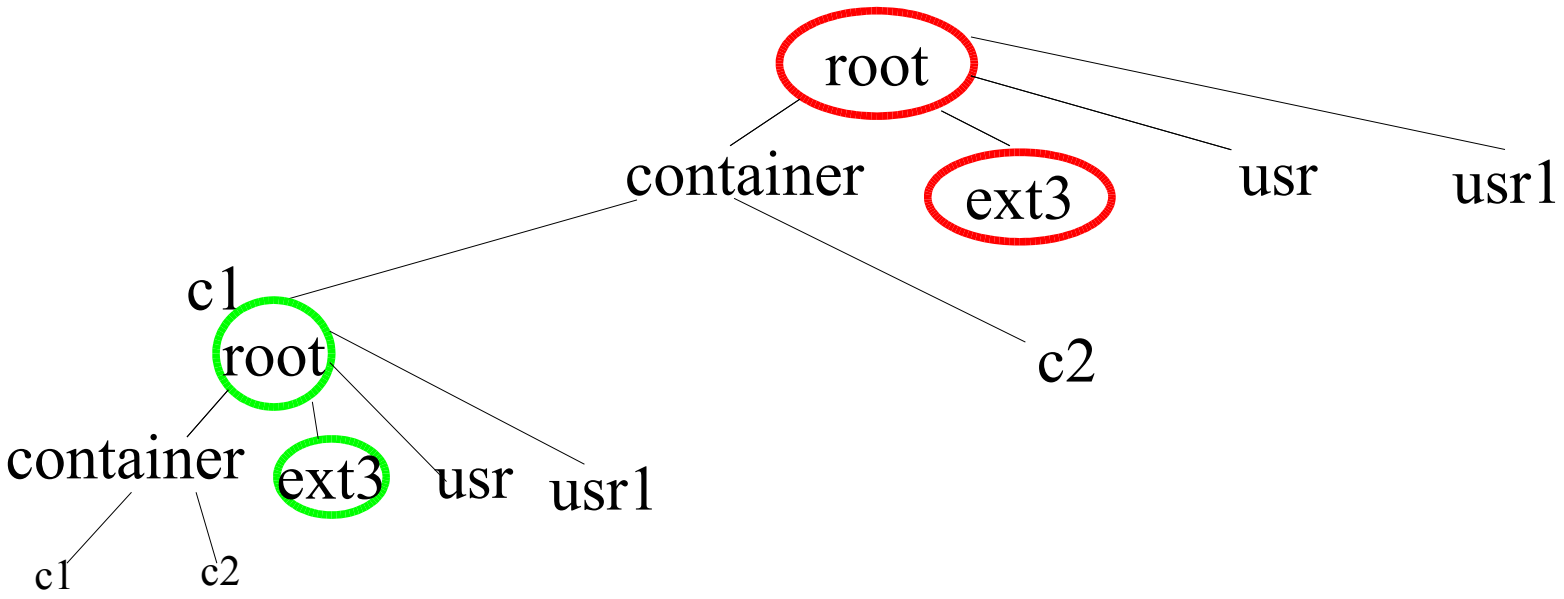

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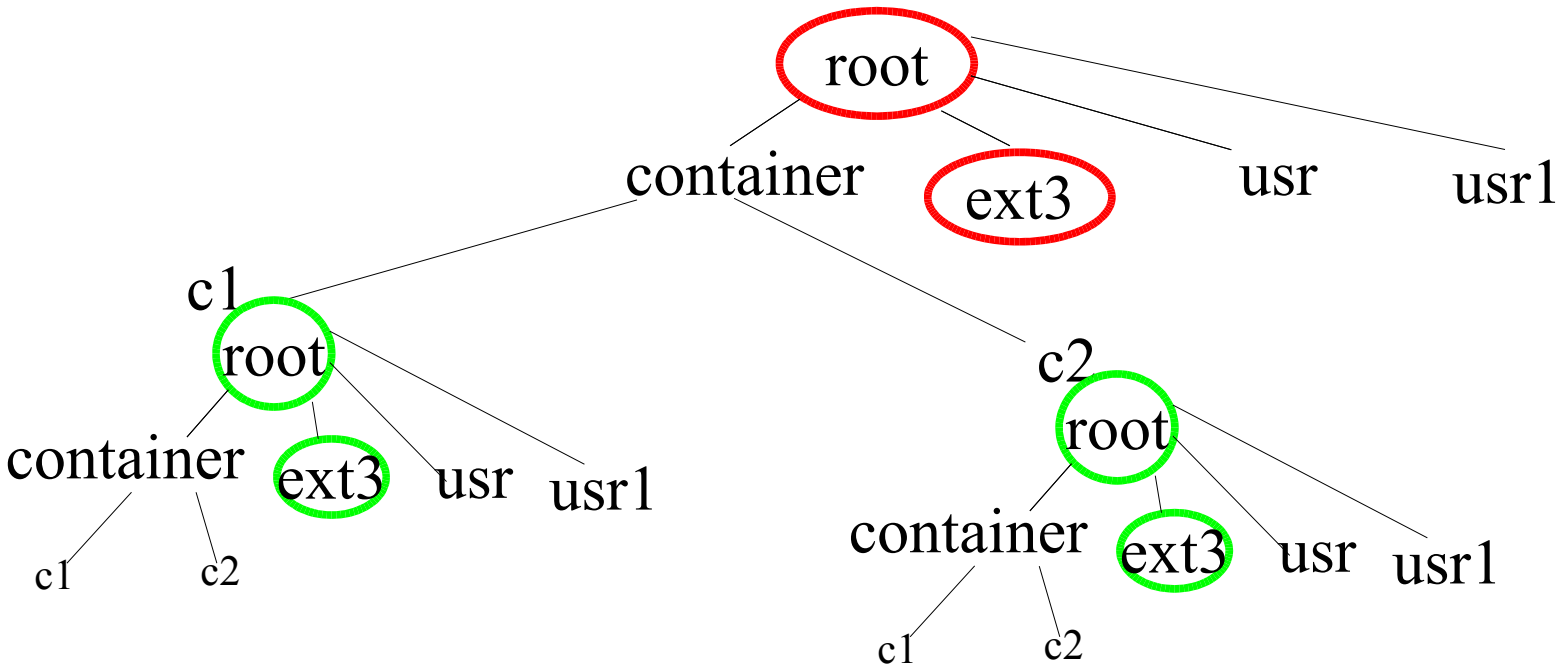

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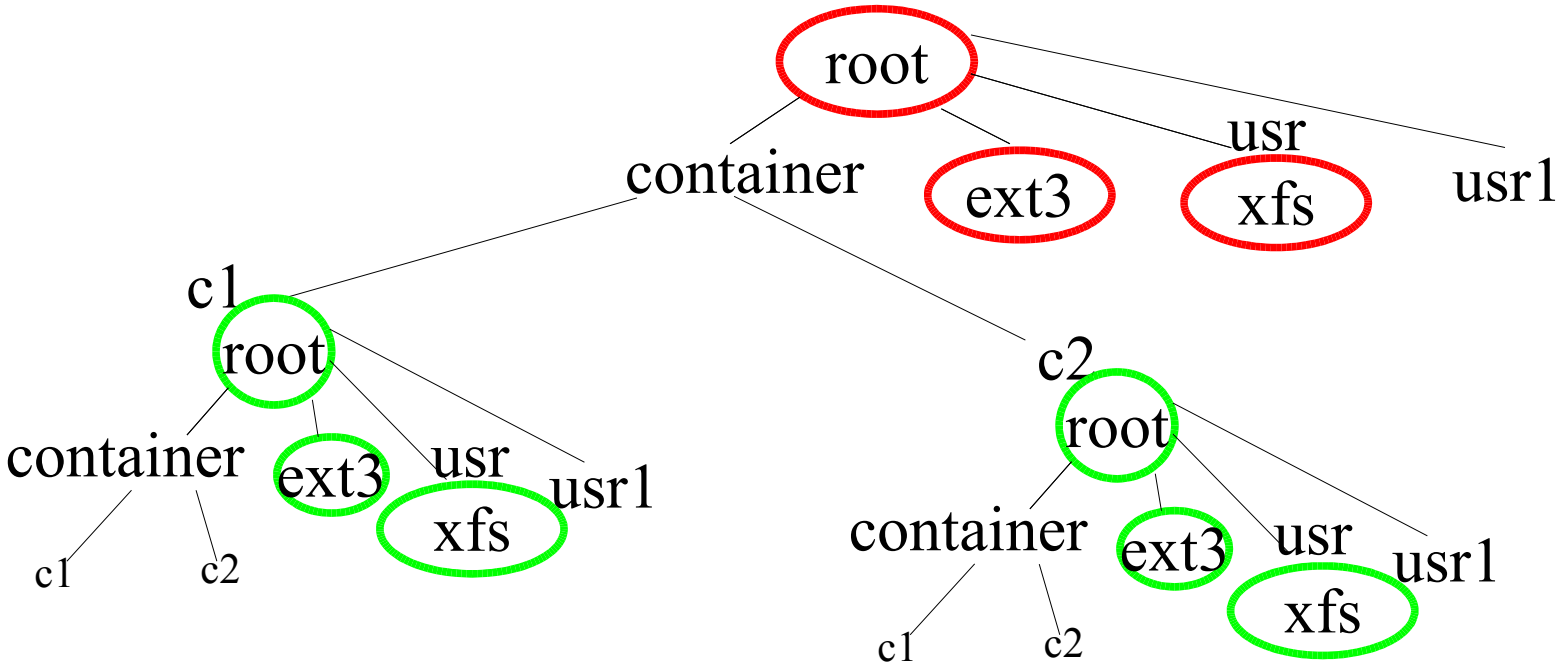

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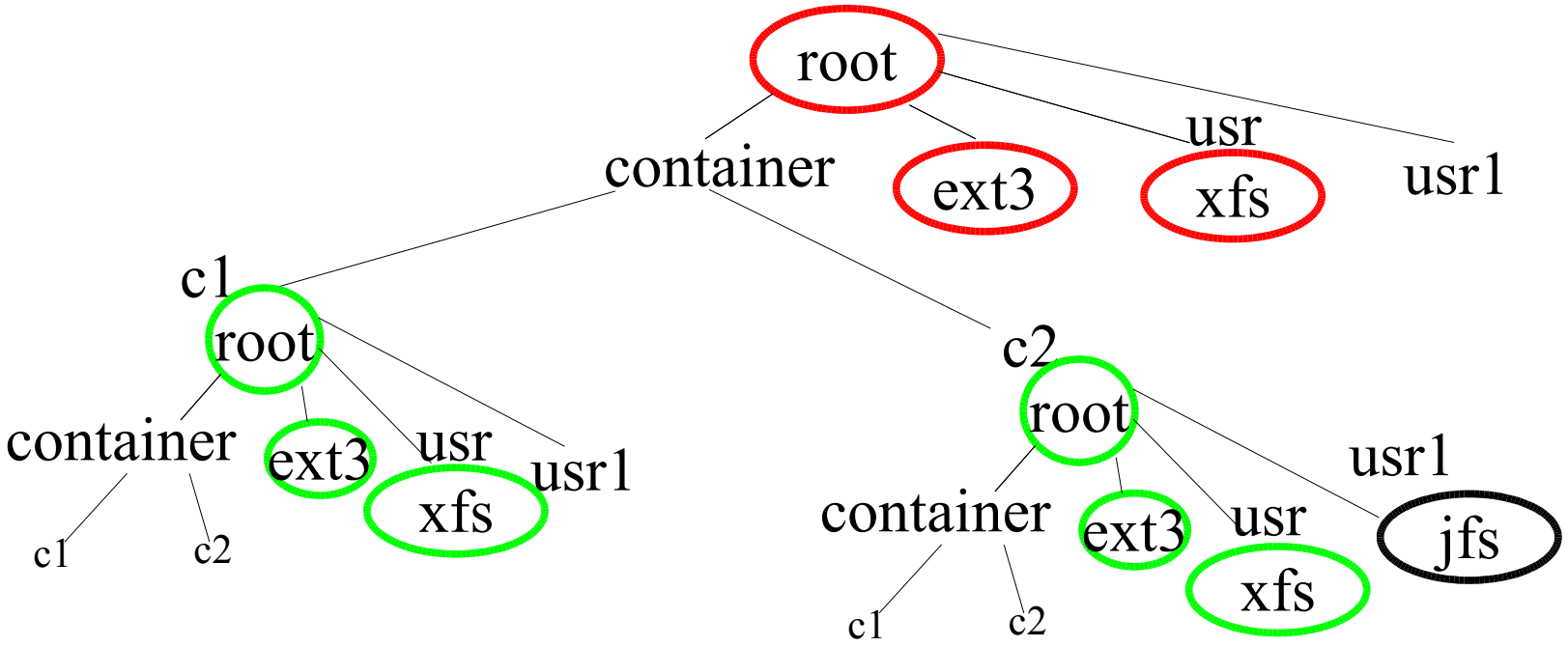
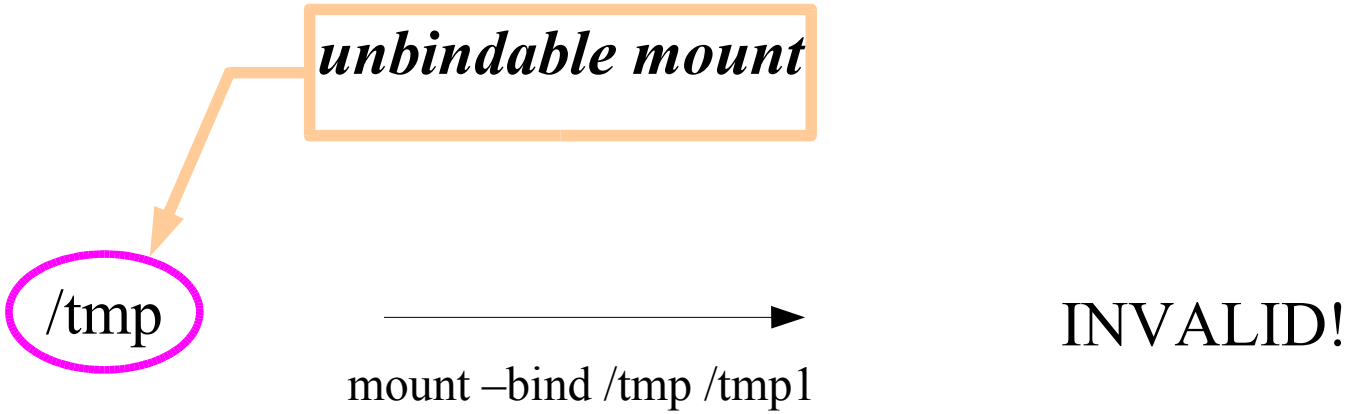
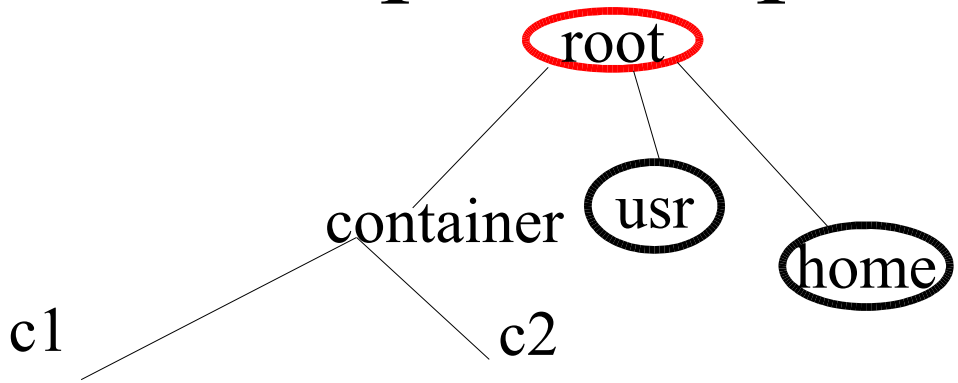


Unbindable mount

- unbindable mounts
  - no propagation.
  - not bindable.



Mount explosion problem



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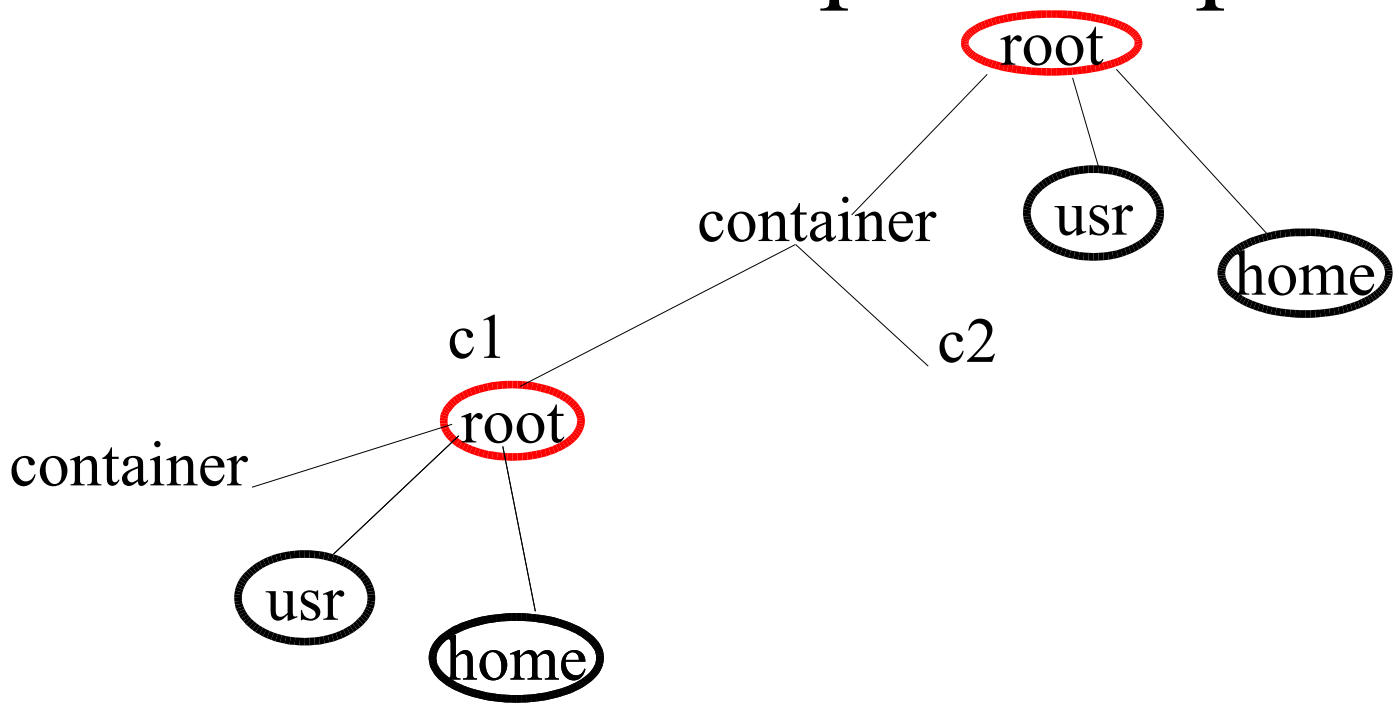

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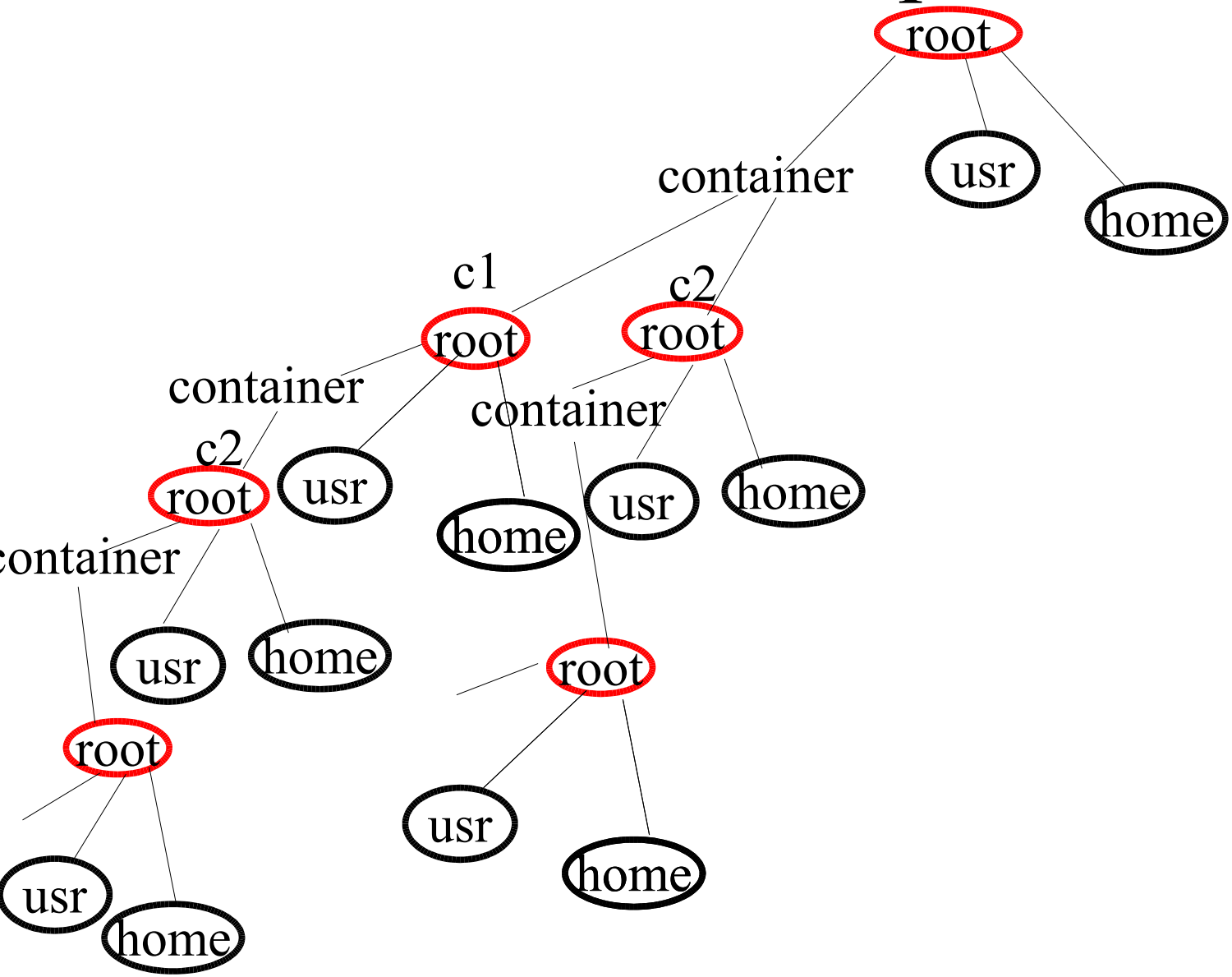

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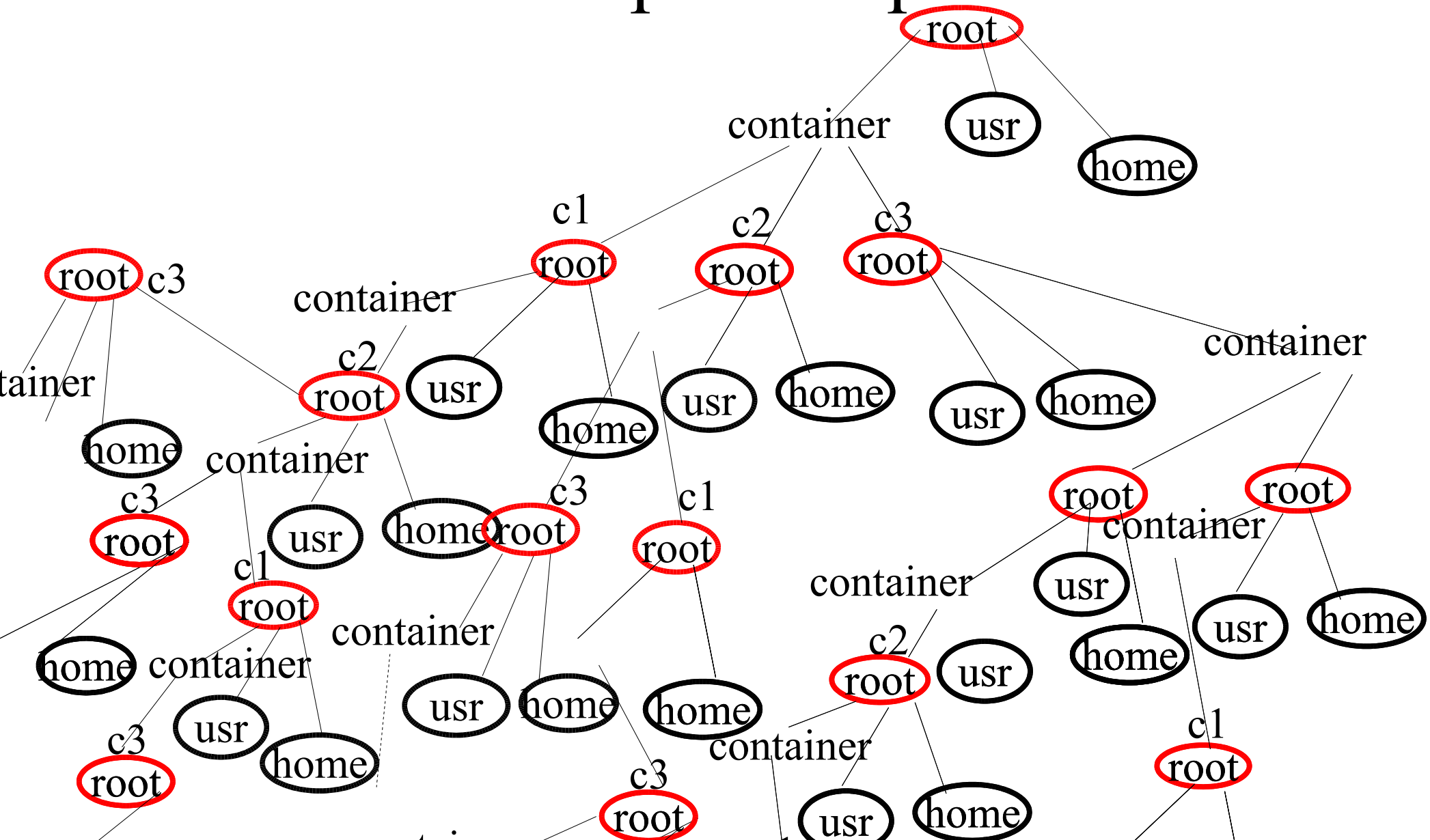

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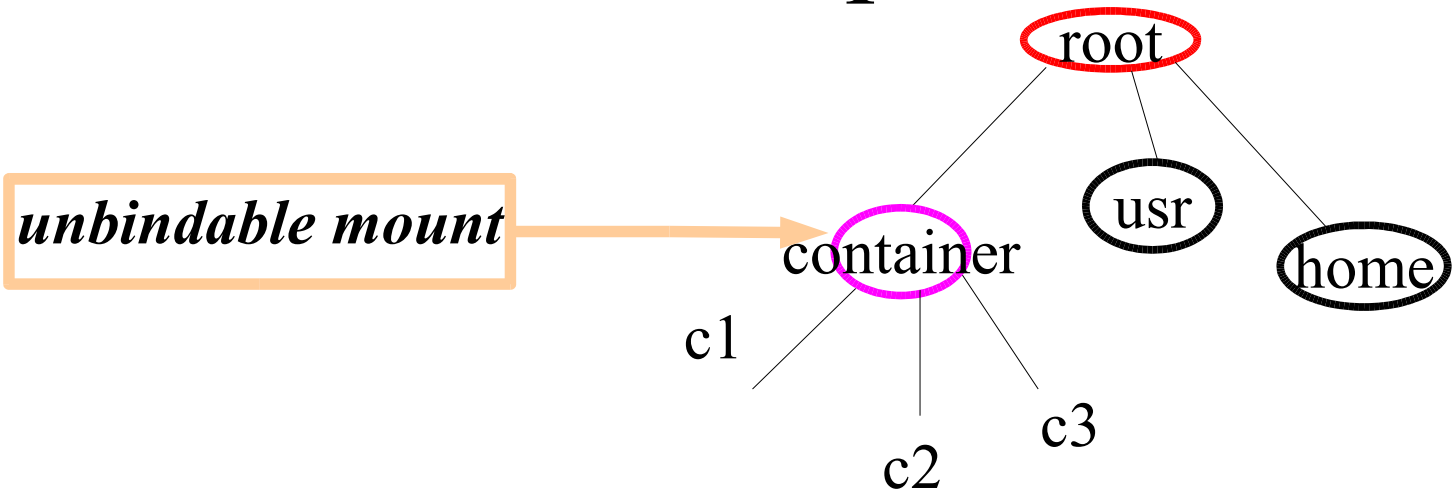

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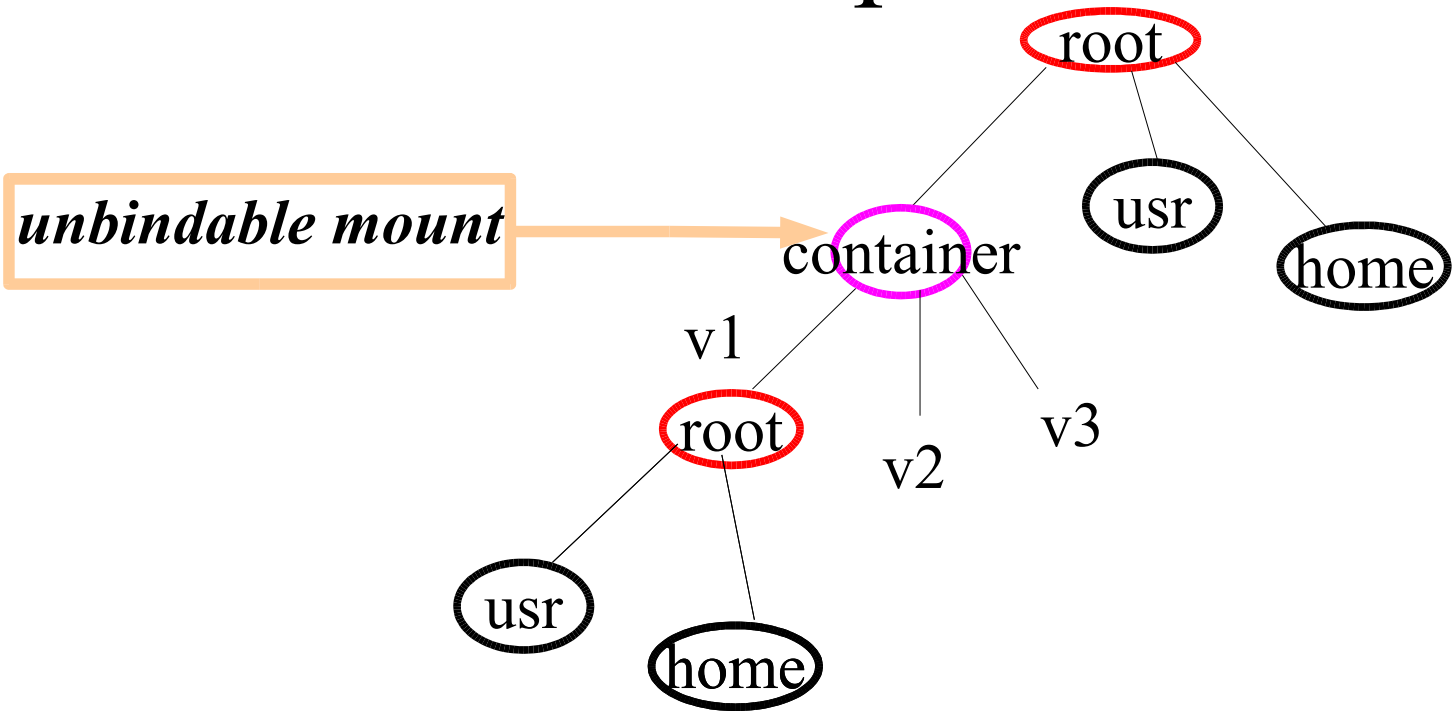

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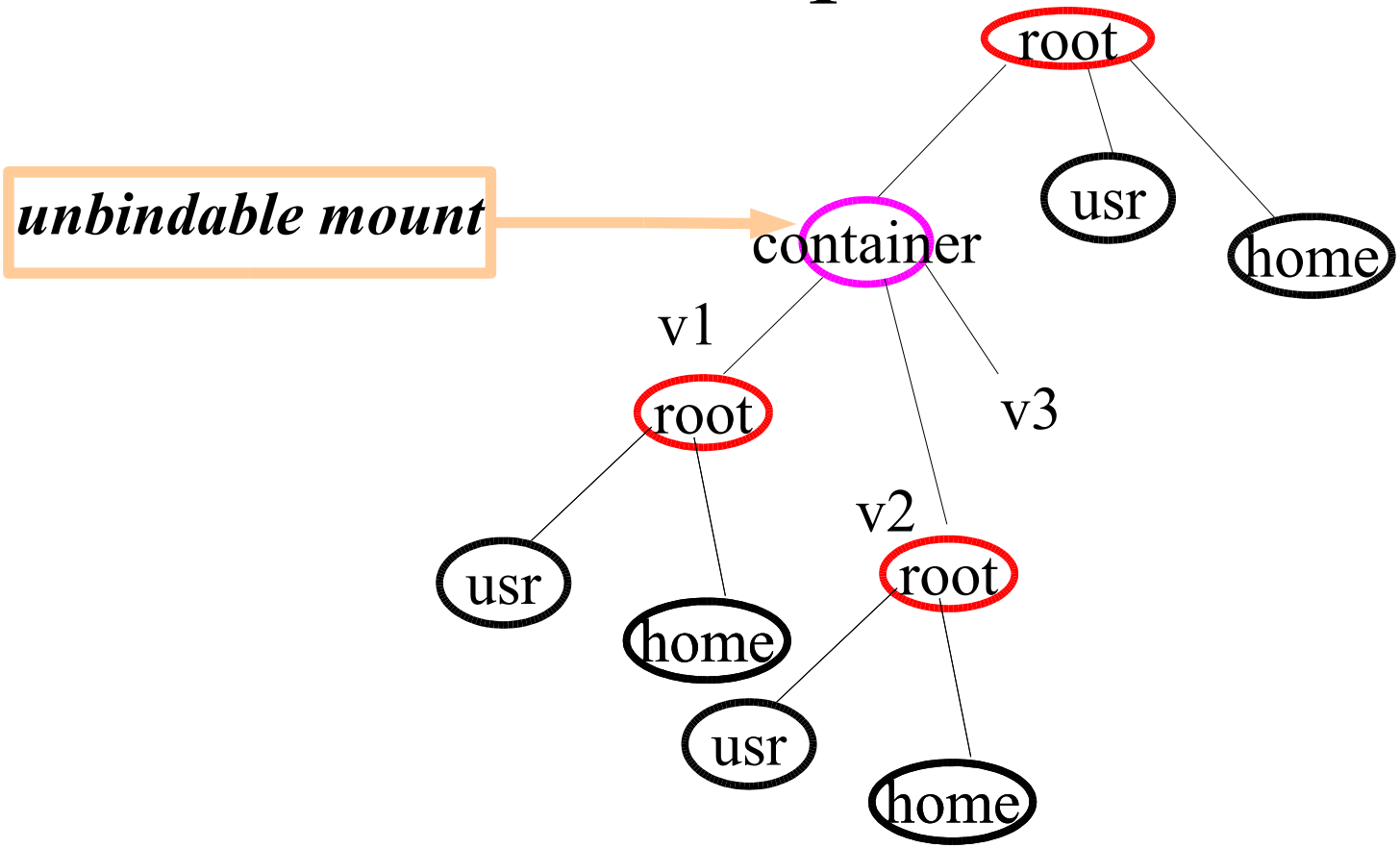

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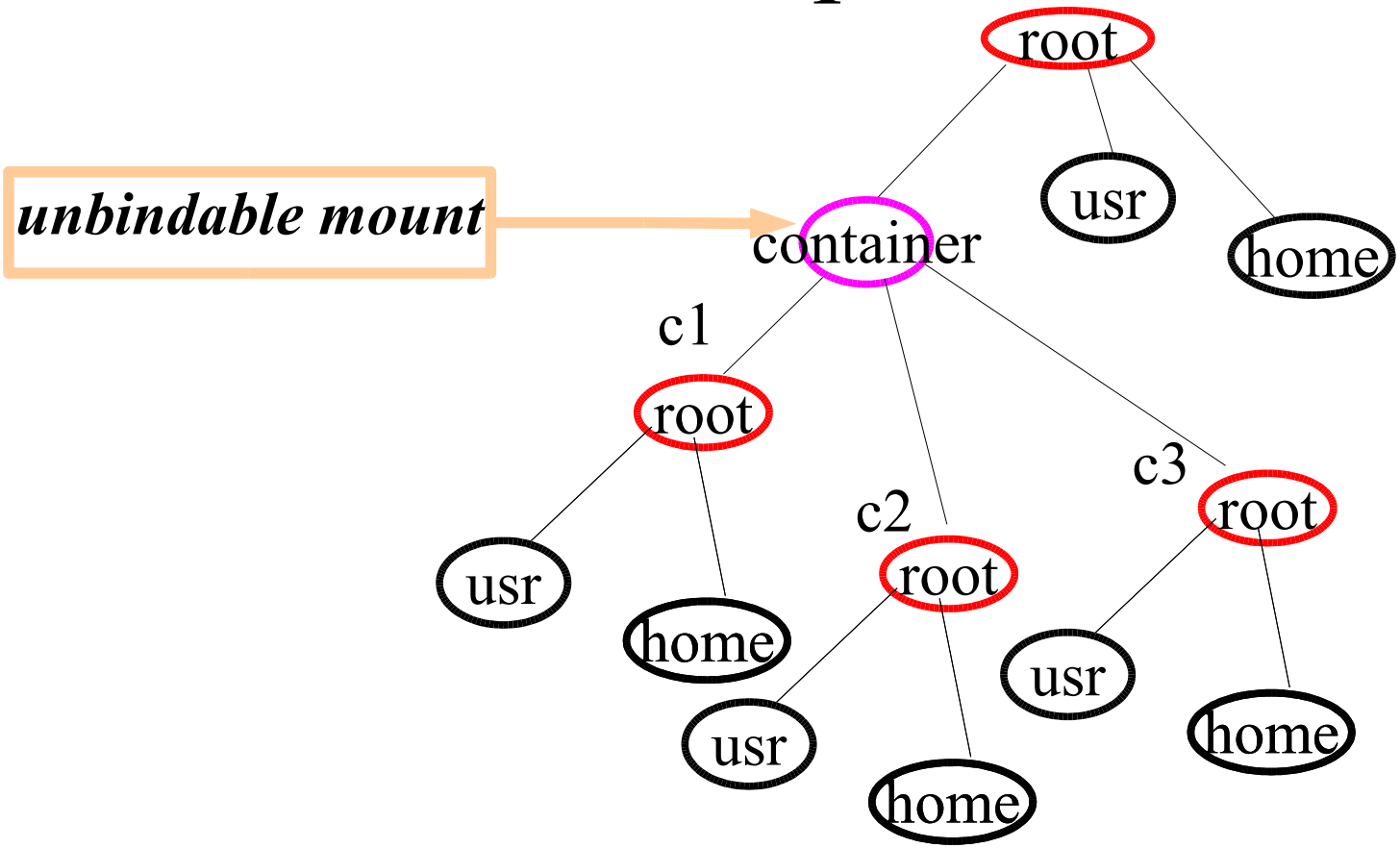
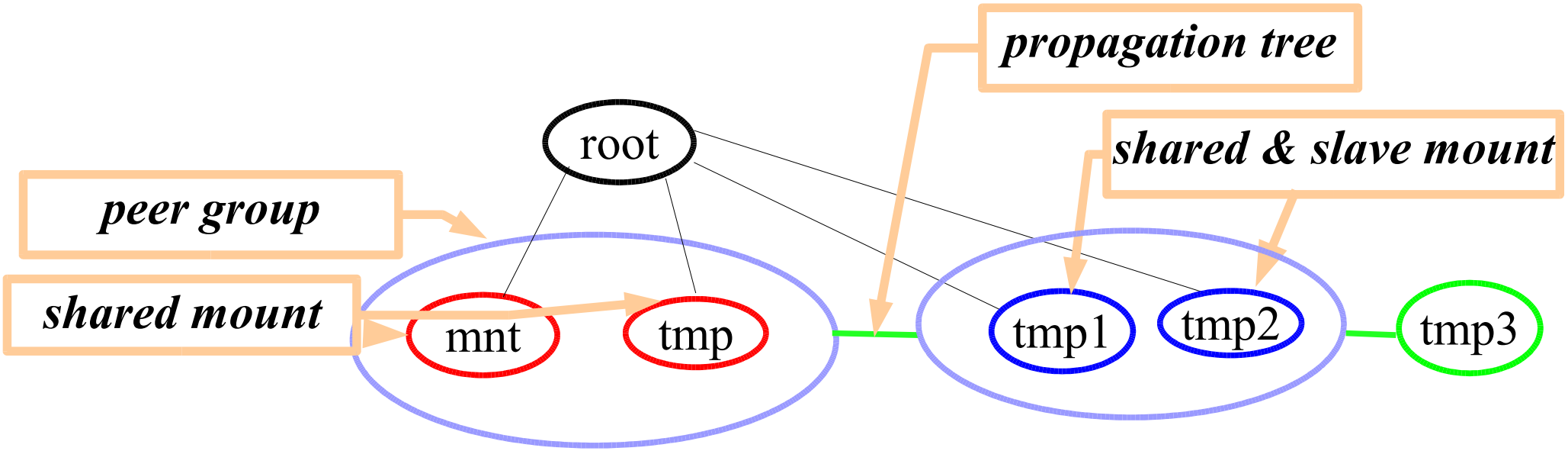


Shared and Slave mount

- shared and slave mount
  - mount,unmount events propagate towards it from master and it propagates them to its slaves



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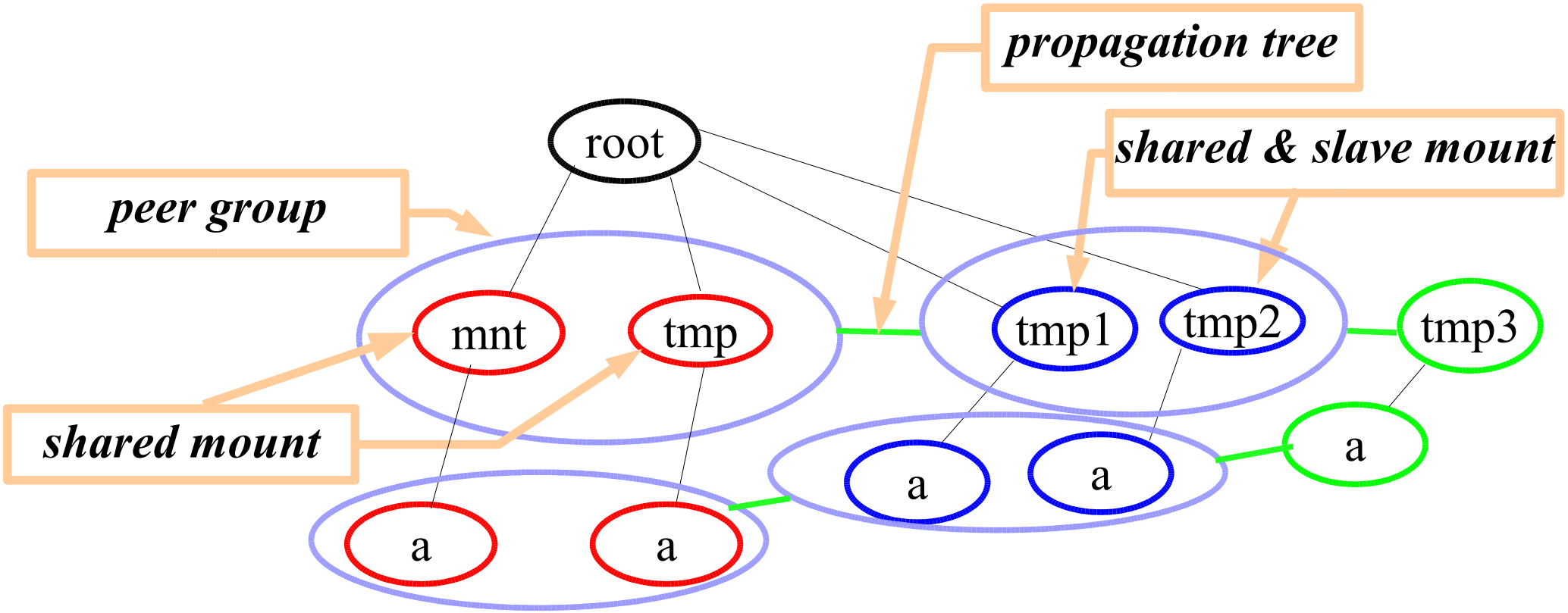

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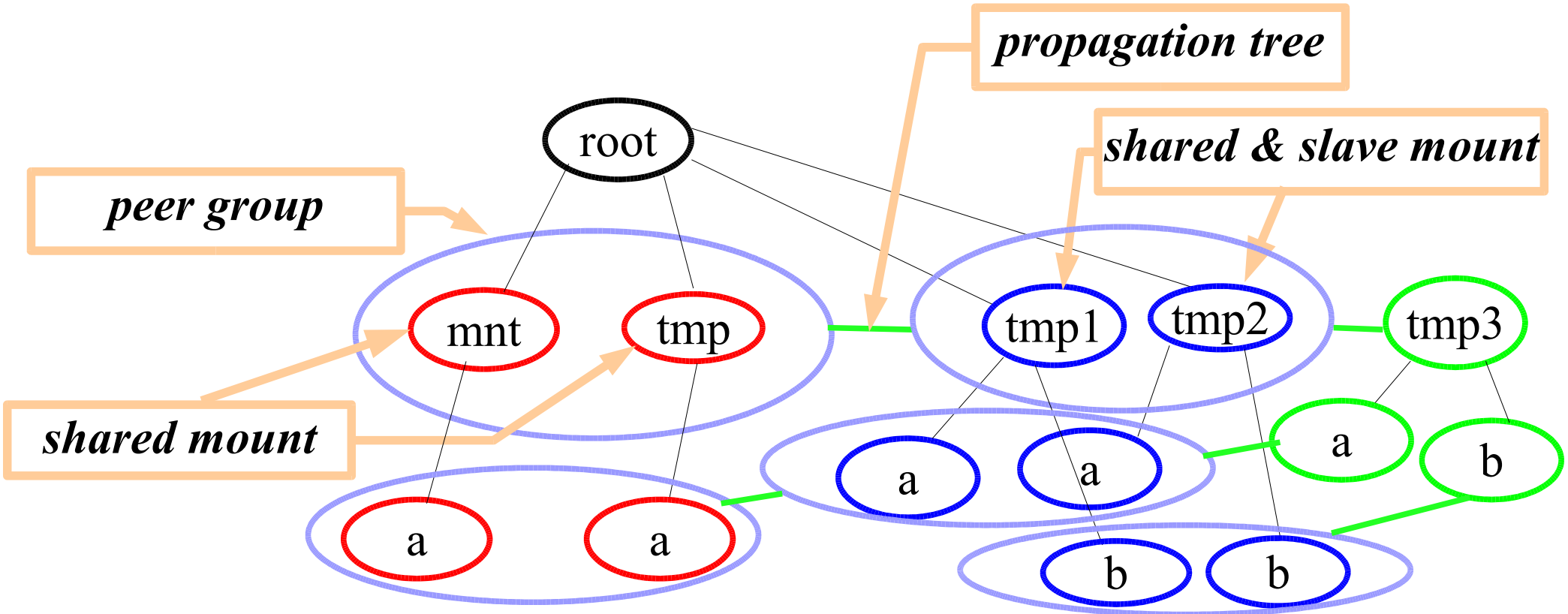
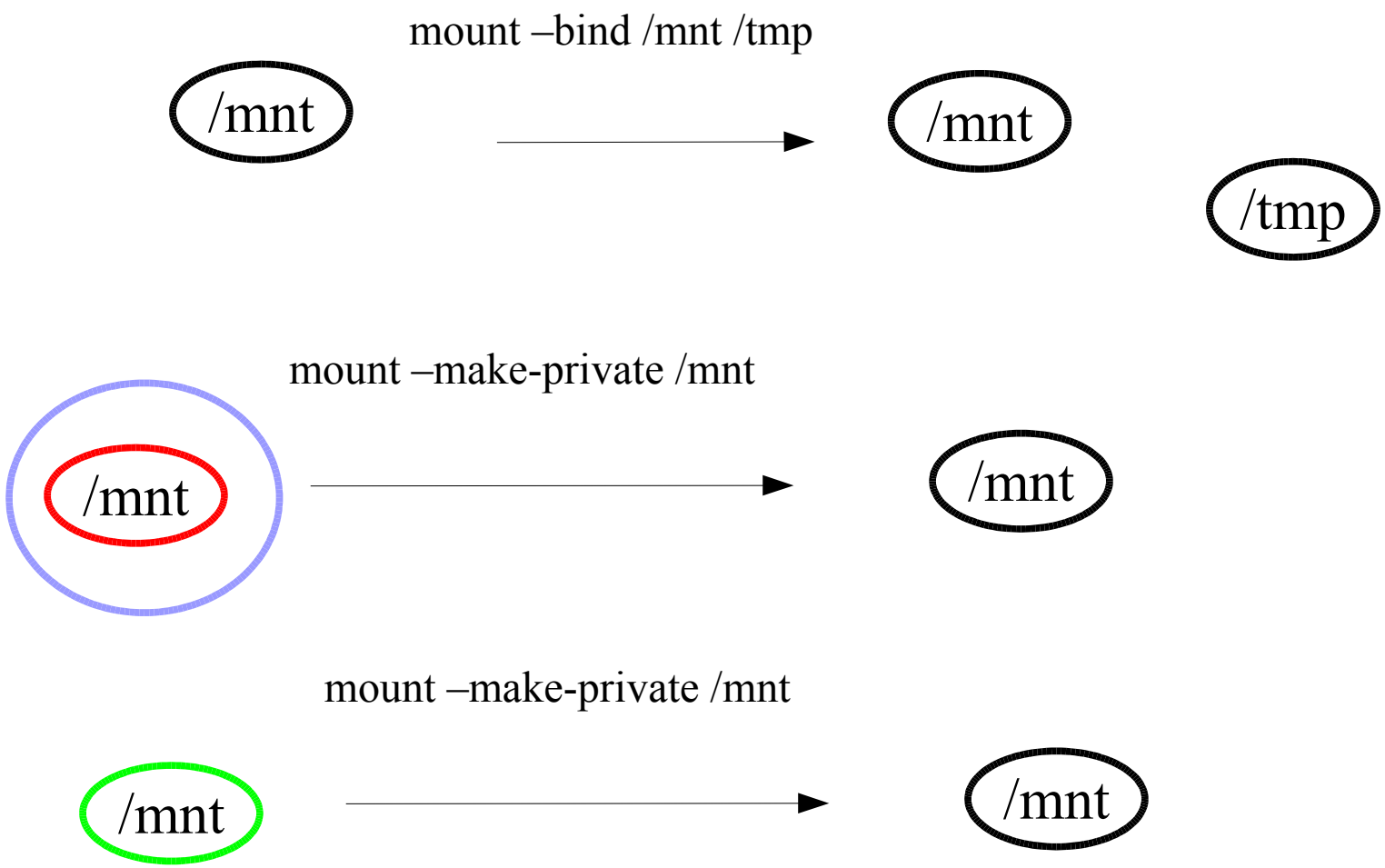


Private mount



Private mount

- private mounts.
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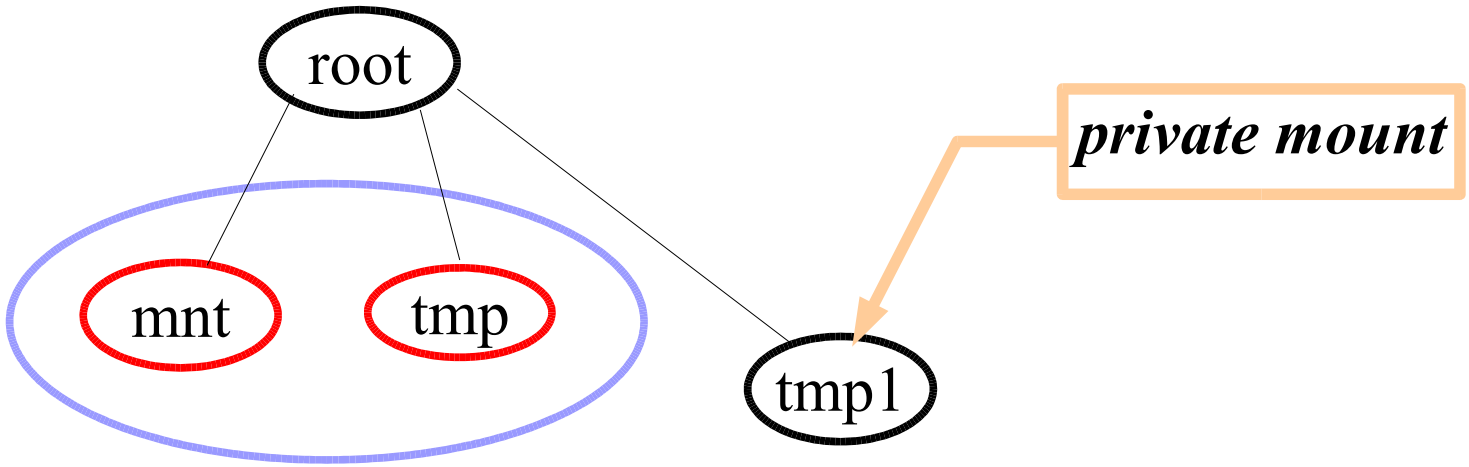

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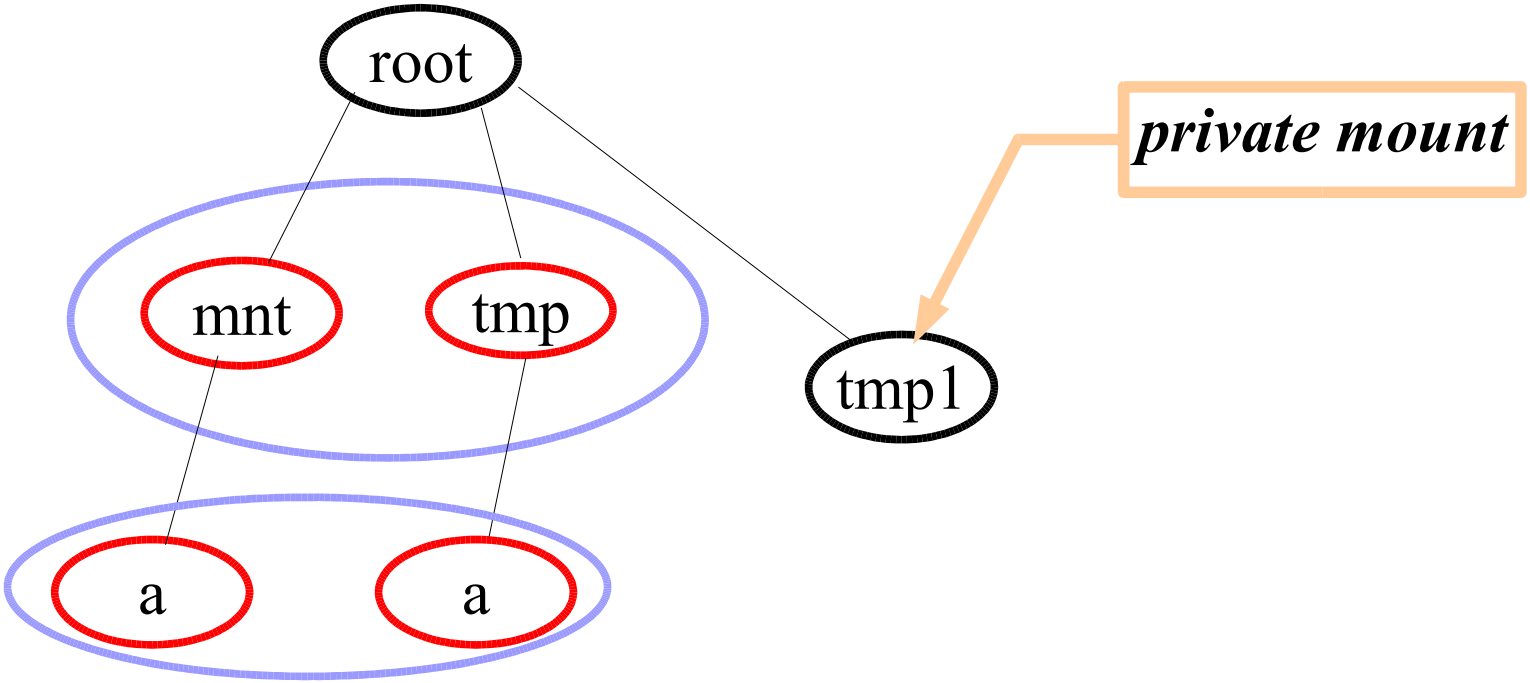
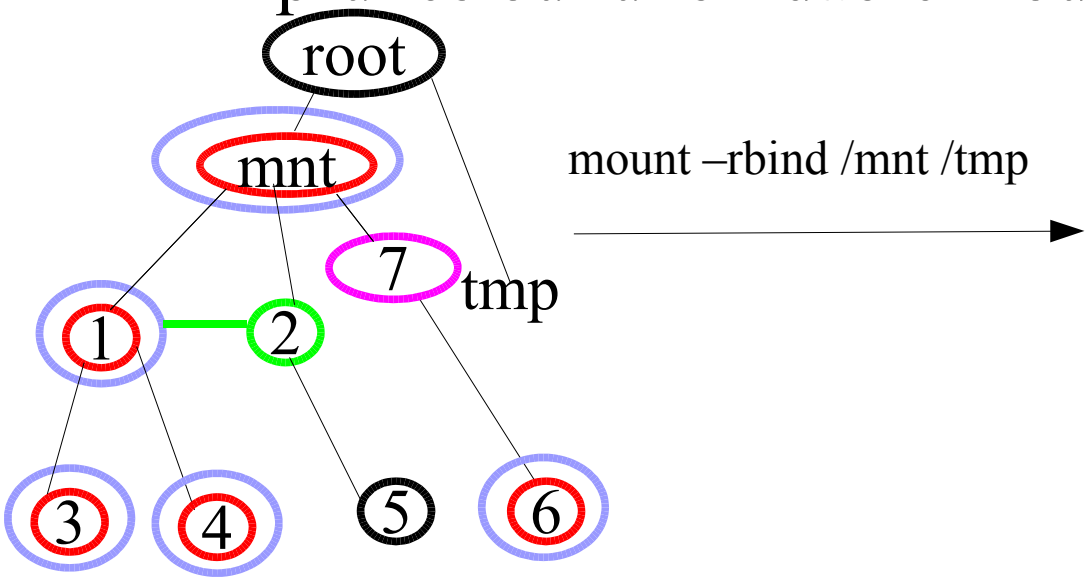


Rbind

- rbind
  - applies the bind-mount rules for each mount in the mount-tree
  - prunes out unbindable mounts



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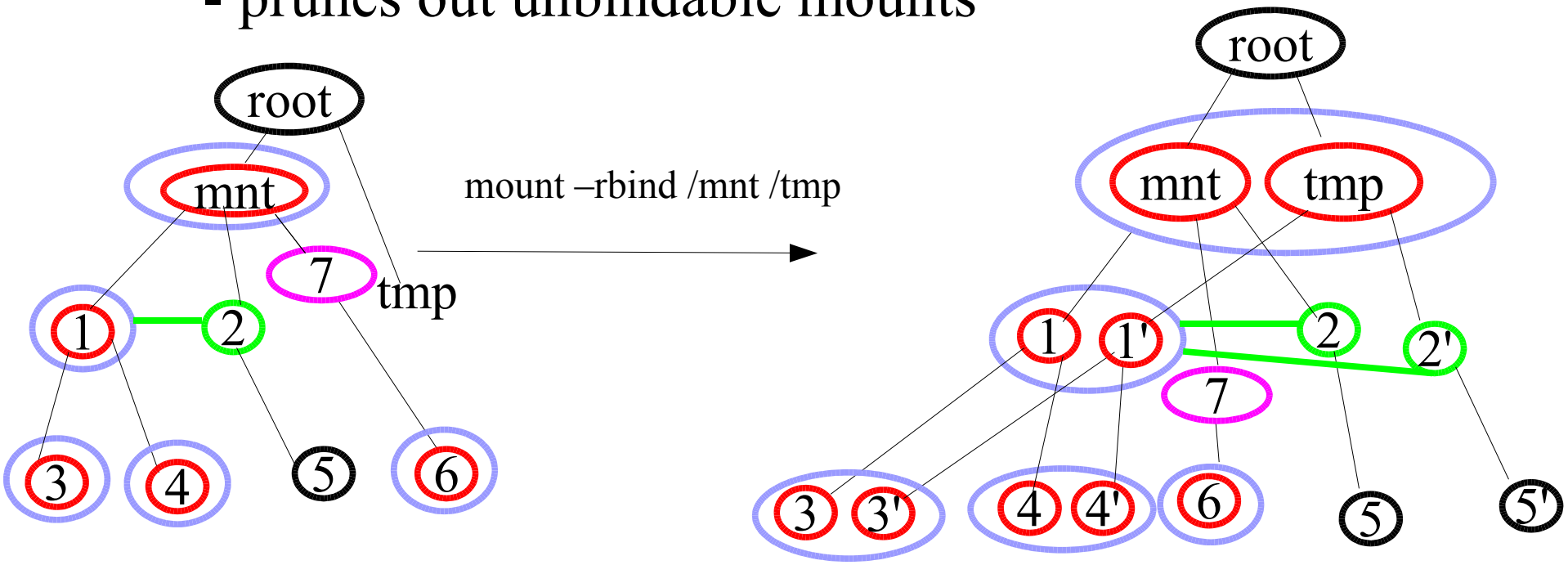
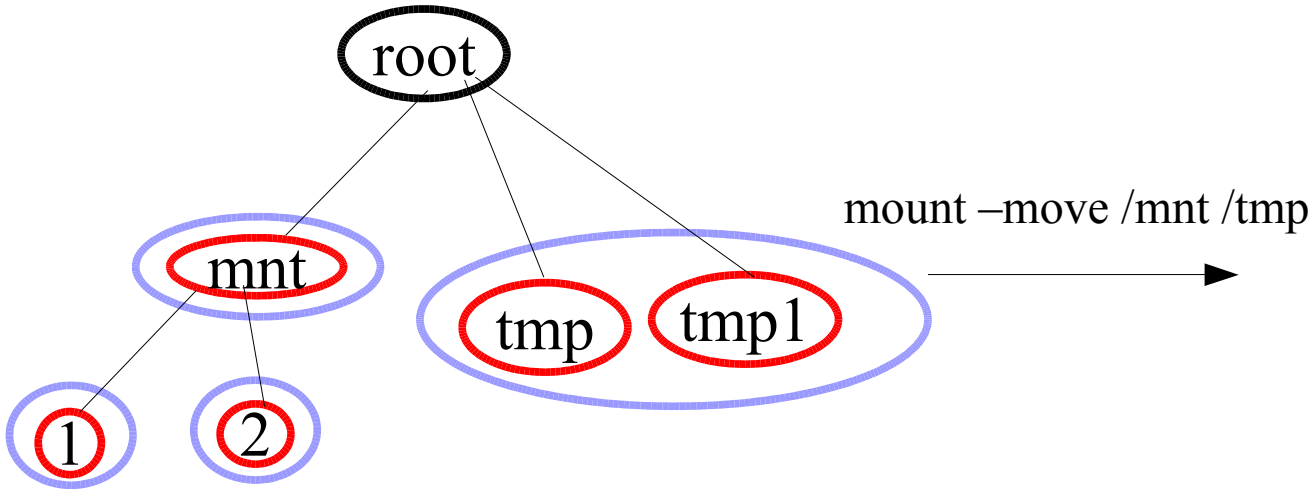


Move

- move
  - invalid if parent is a shared mount.
  - invalid if the tree contains unbindable mount and moved under a shared mount*



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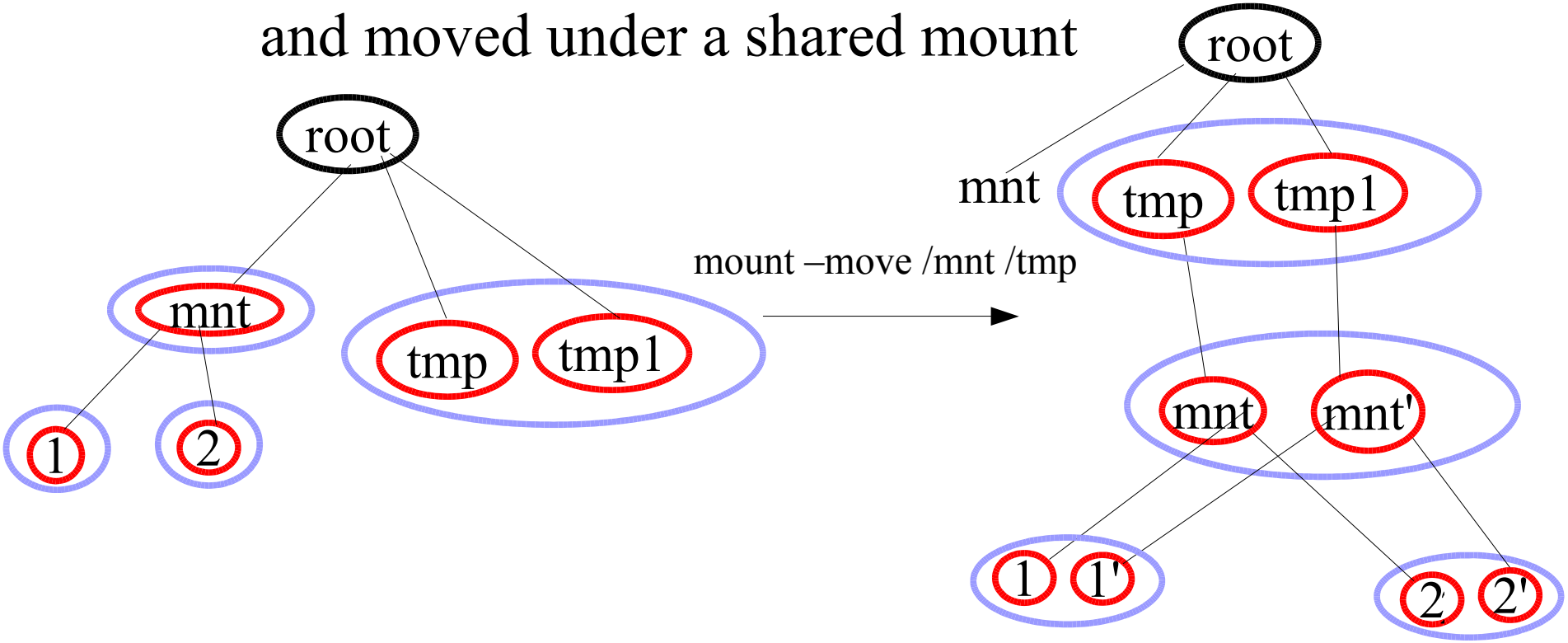
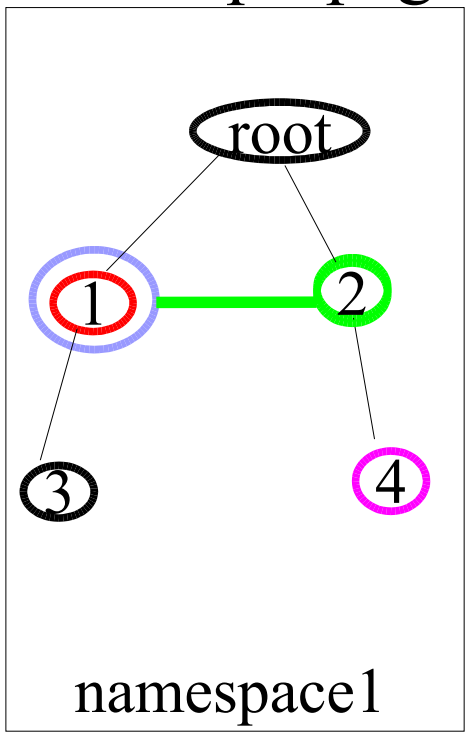


Clone namespace

- clone namespace
  - Clones all the mounts including unbindable mounts
  - adds the new shared and slave mounts in their respective propagation trees



sysclone(...,CLONE_NS);

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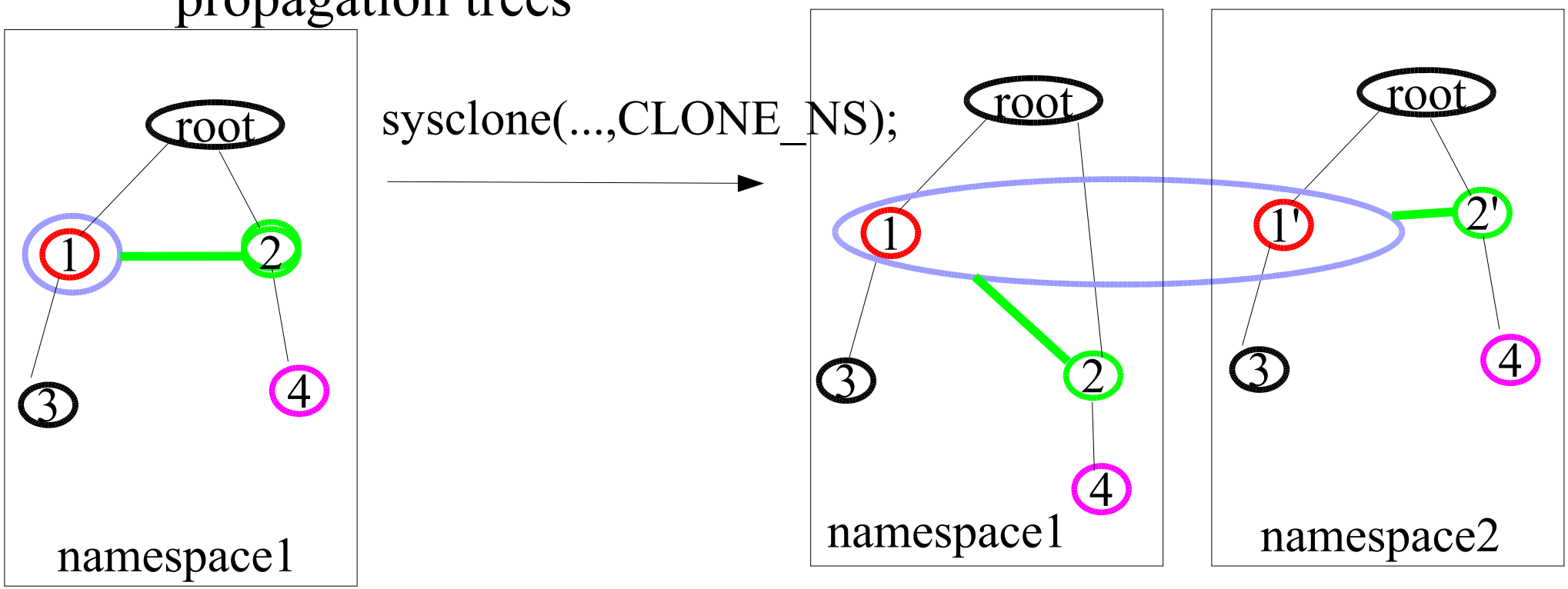
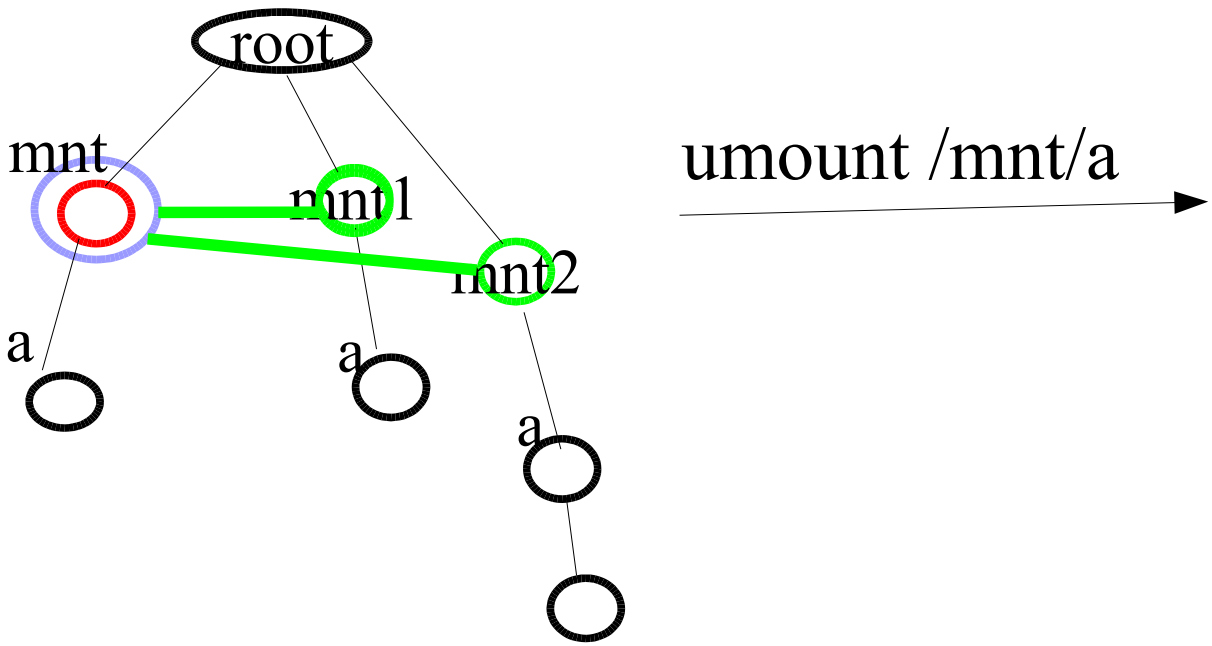
  - Clones all the mounts including unbindable mounts
  - adds the new shared and slave mounts in their respective propagation trees



Umount

- umount
  - fail if the mount has submounts
  - unmount all child mounts on the mounts belonging to the parent's propagation tree (only if the child mounts do not have children mounts)



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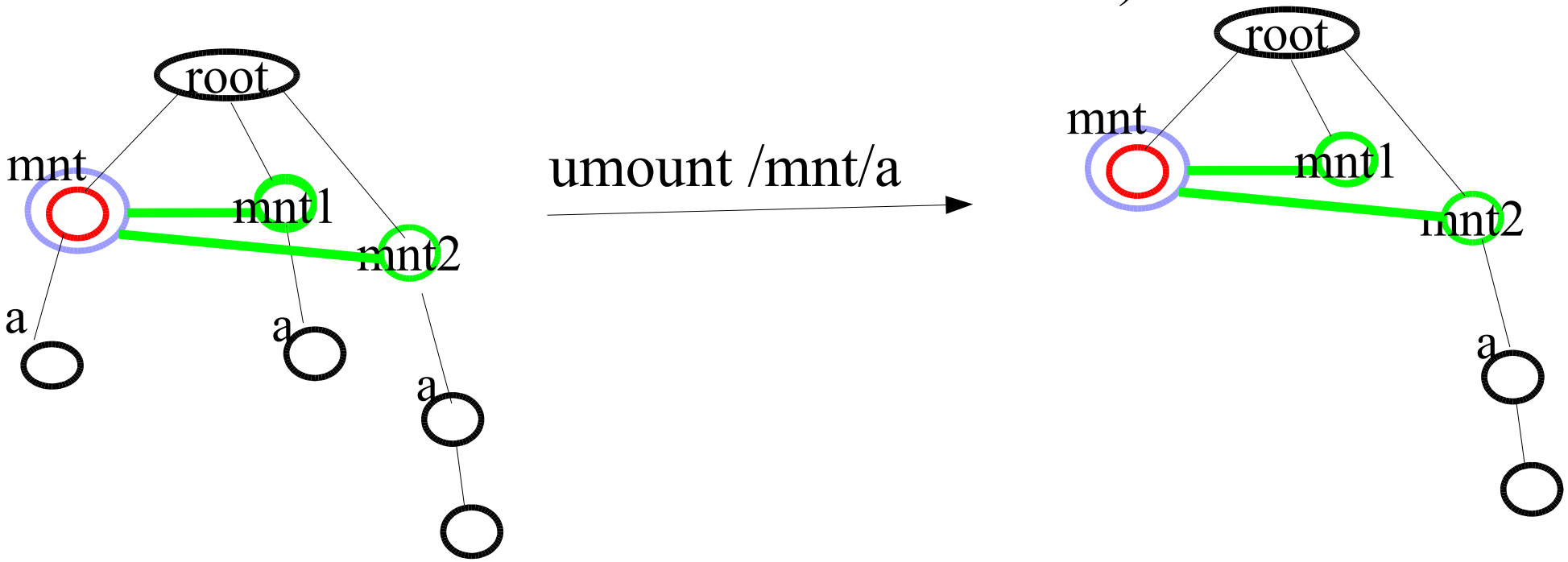
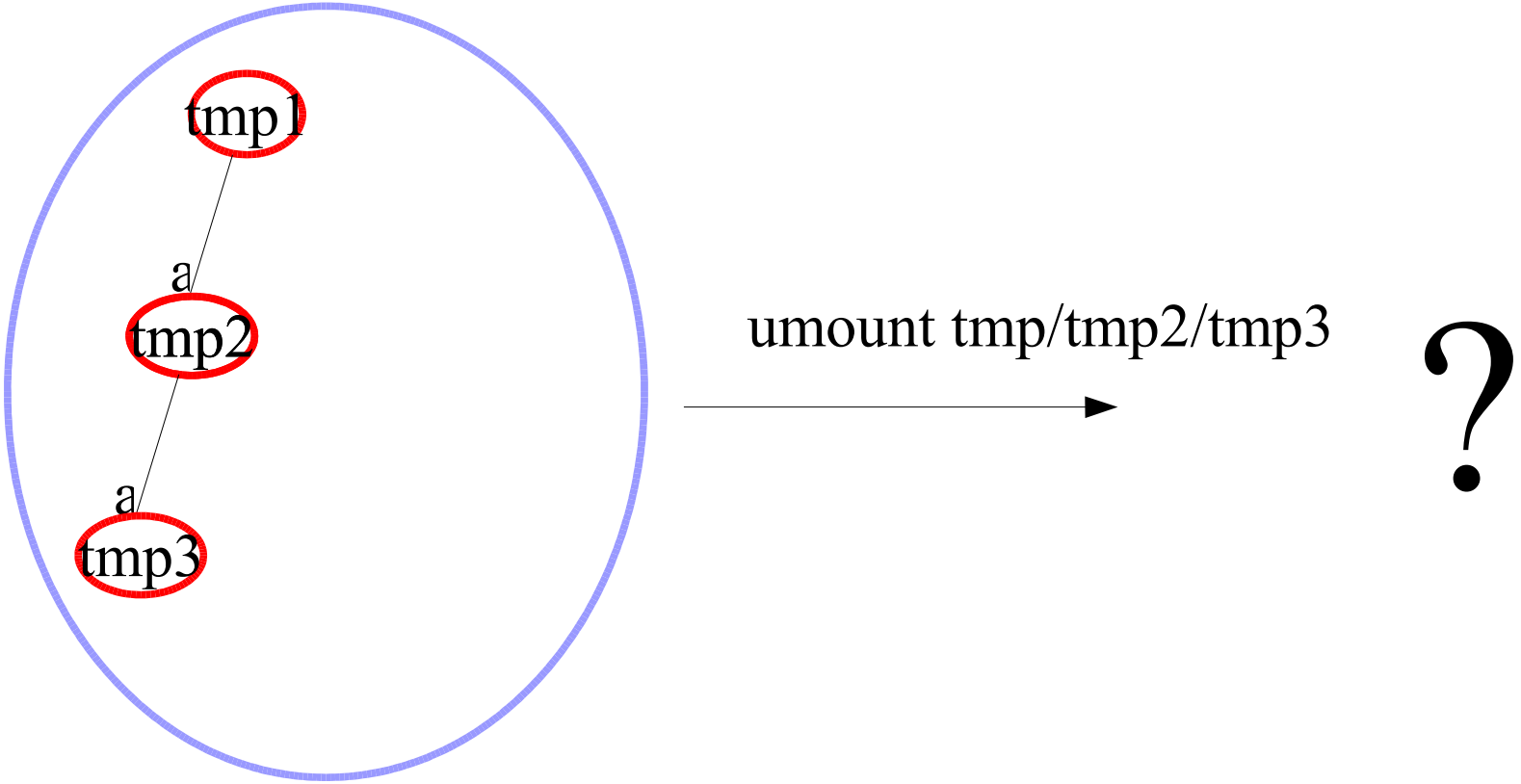
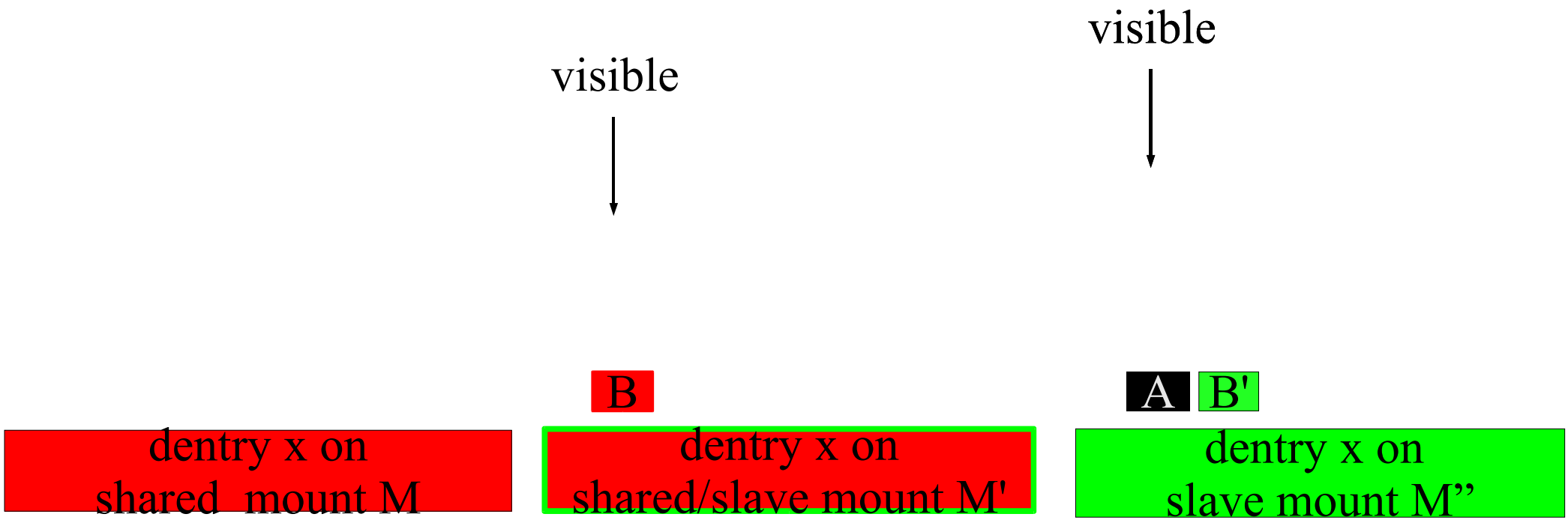



tmp1
a
tmp2
a
tmp3
umount tmp/tmp2/tmp3
?

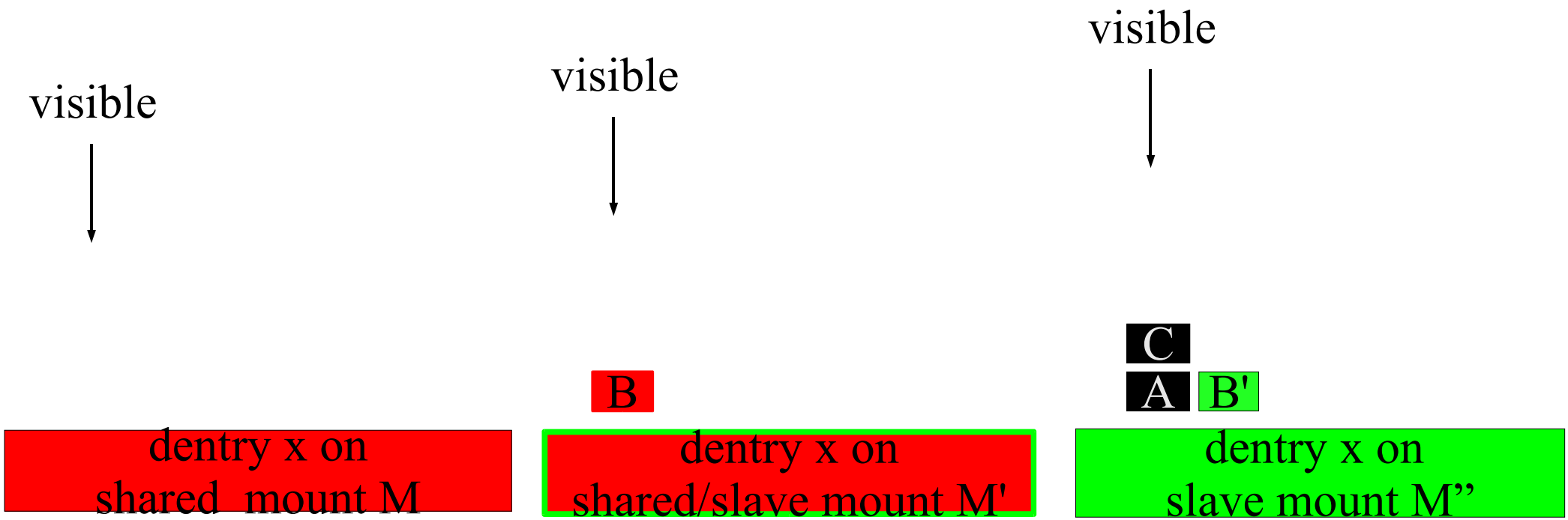
Side-mounts/Over-mounts

Side-mounts/Over-mounts



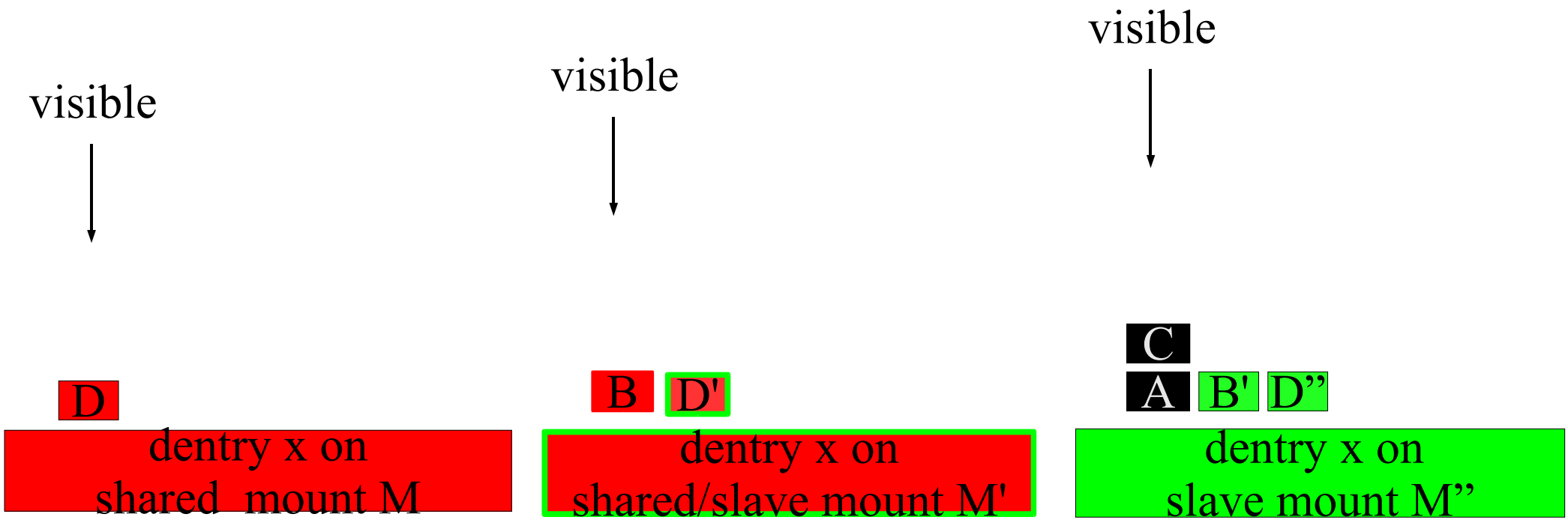
- Side-mount: vfsmounts on the same dentry of a vfsmount. (eg. A and B')
- Least recent side-mount always visible. (A is visible)

Side-mounts/Over-mounts



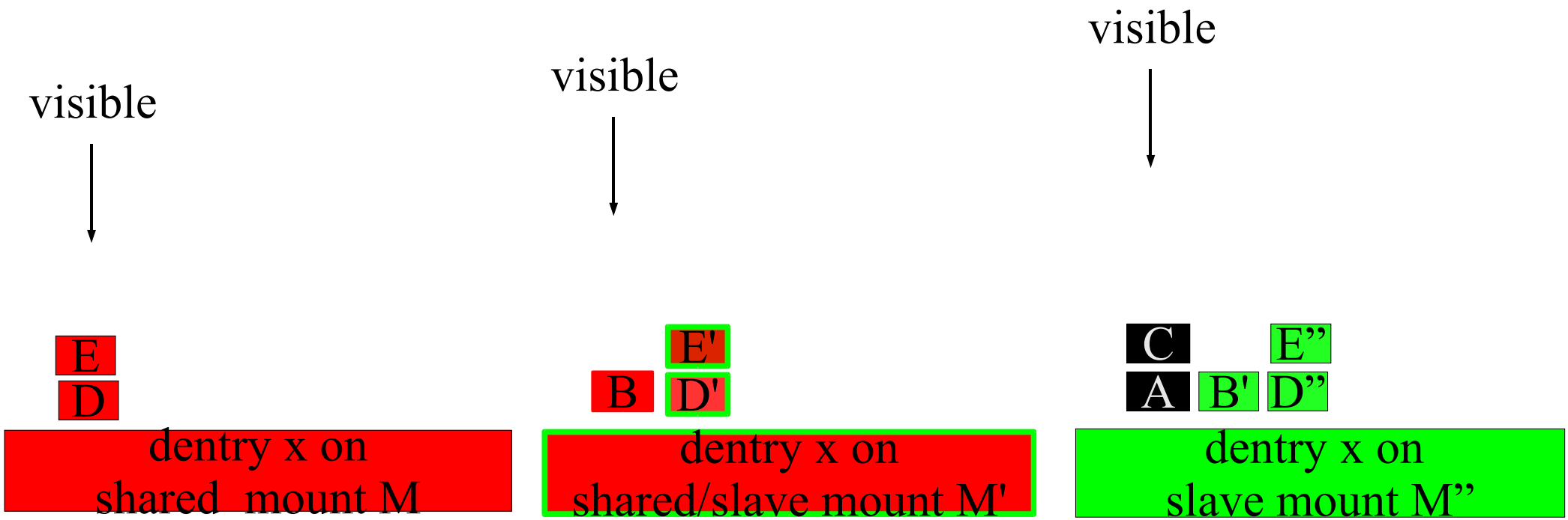
- Side-mount: vfsmount mounted on the same dentry. (eg A and B')
- Over-mount: vfsmount on top of another vfsmount. (eg C over-mount on A)
- Least recent side-mount always visible.(provided there is no over-mount).

Side-mounts/Over-mounts



- Side-mount: vfsmount mounted on the same dentry. (eg A, B' and D”)
- Over-mount: vfsmount on top of another vfsmount. (eg C over-mount on A)
- Least recent side-mount always visible.(provided there is no over-mount).

Side-mounts/Over-mounts



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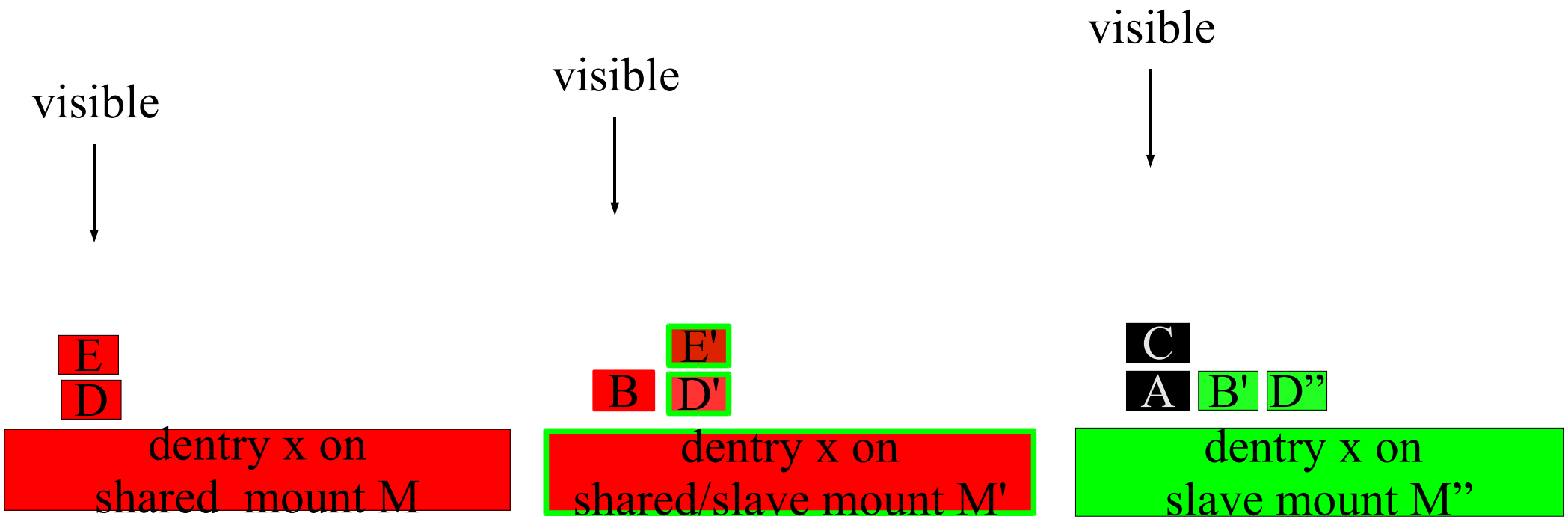
- Least recent side-mount always visible.(provided there is no over-mount).
- Over-mount on a side-mount is obscured too. (E' is obscured by B)

Side-mounts/Over-mounts



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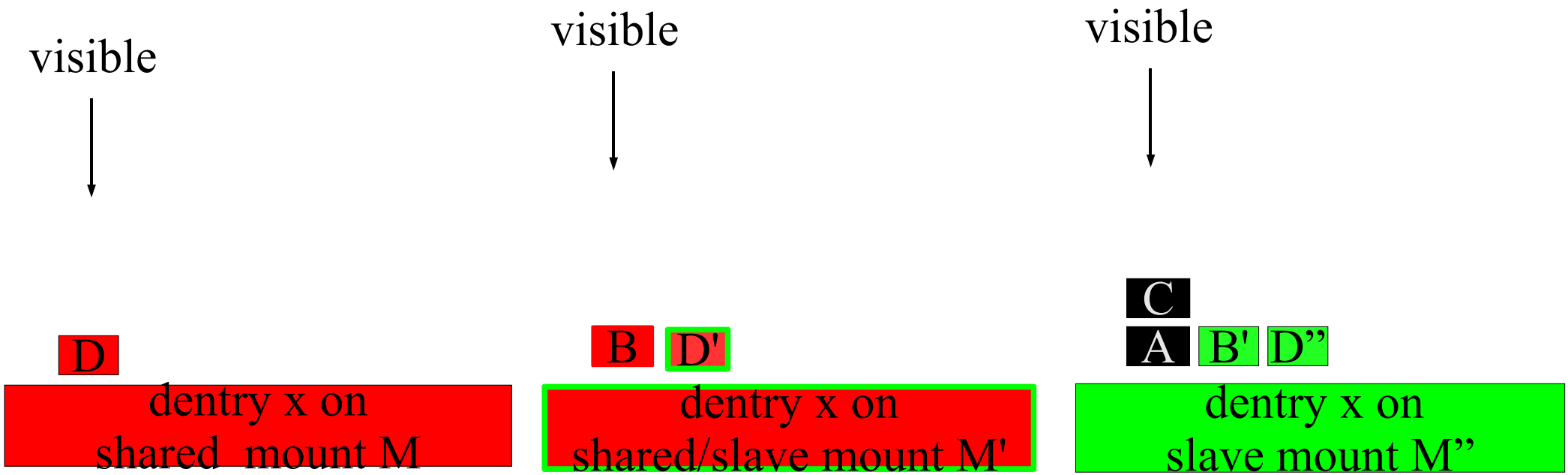
- Explicit-unmount unmounts the specified mount and propagates it. (eg E”).

Side-mounts/Over-mounts



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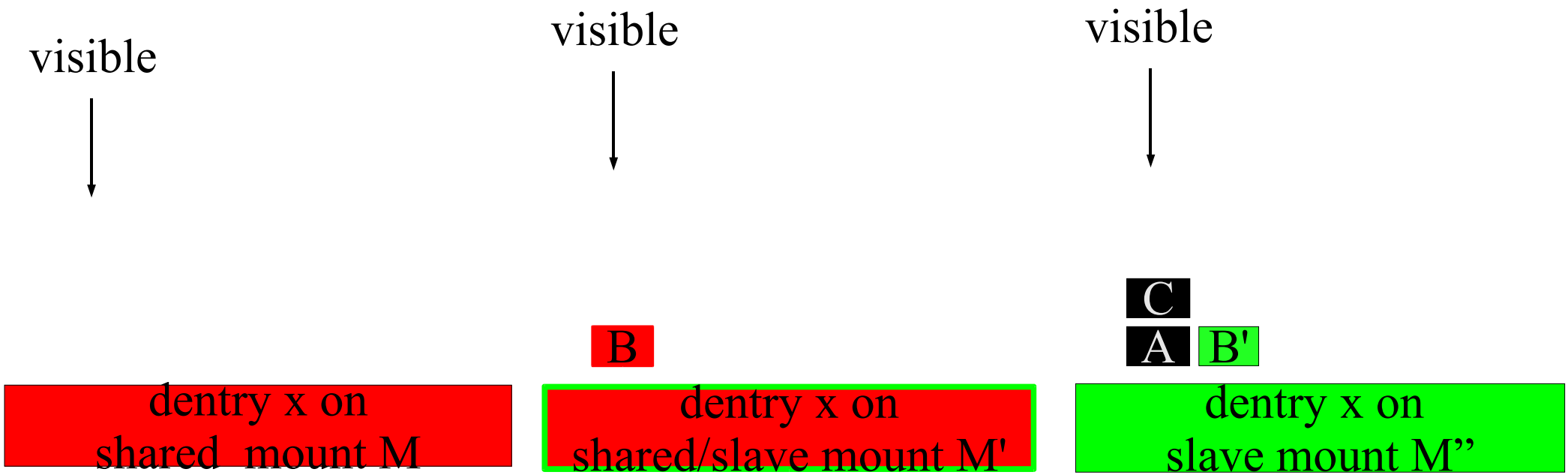
Side-mounts/Over-mounts



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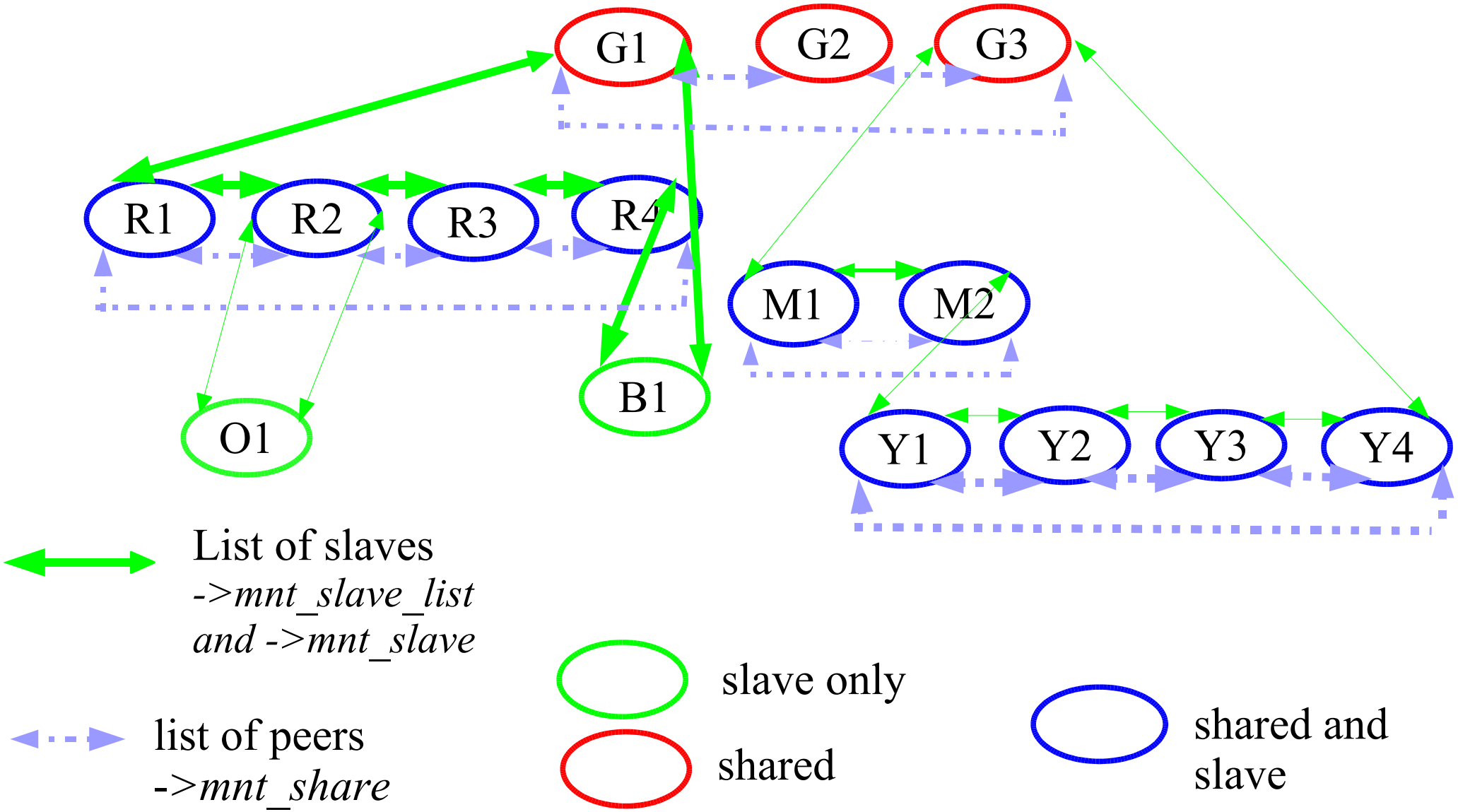
- Propagated unmount always unmounts the most recent side-mount.

Implementation detail

additions to vfsmount structure

- *->mnt_share* circular list of peer mounts
- *->mnt_master* if slave, points to master mount
- *->mnt_slave_list* list of slave mounts
- *->mnt_slave* slave list entry
- additional flags in *->mnt_flags*
  - *MNT_SHARED*
  - *MNT_UNBINDABLE*

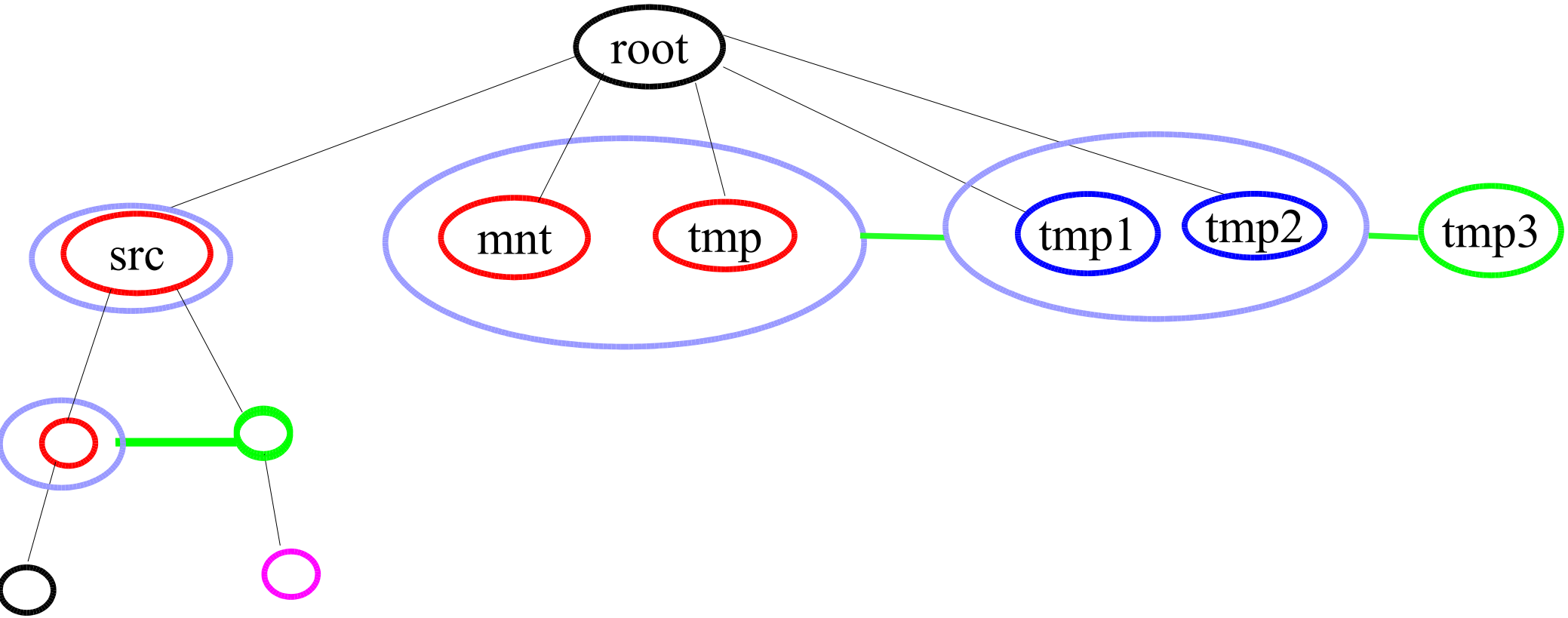
Propagation tree representation

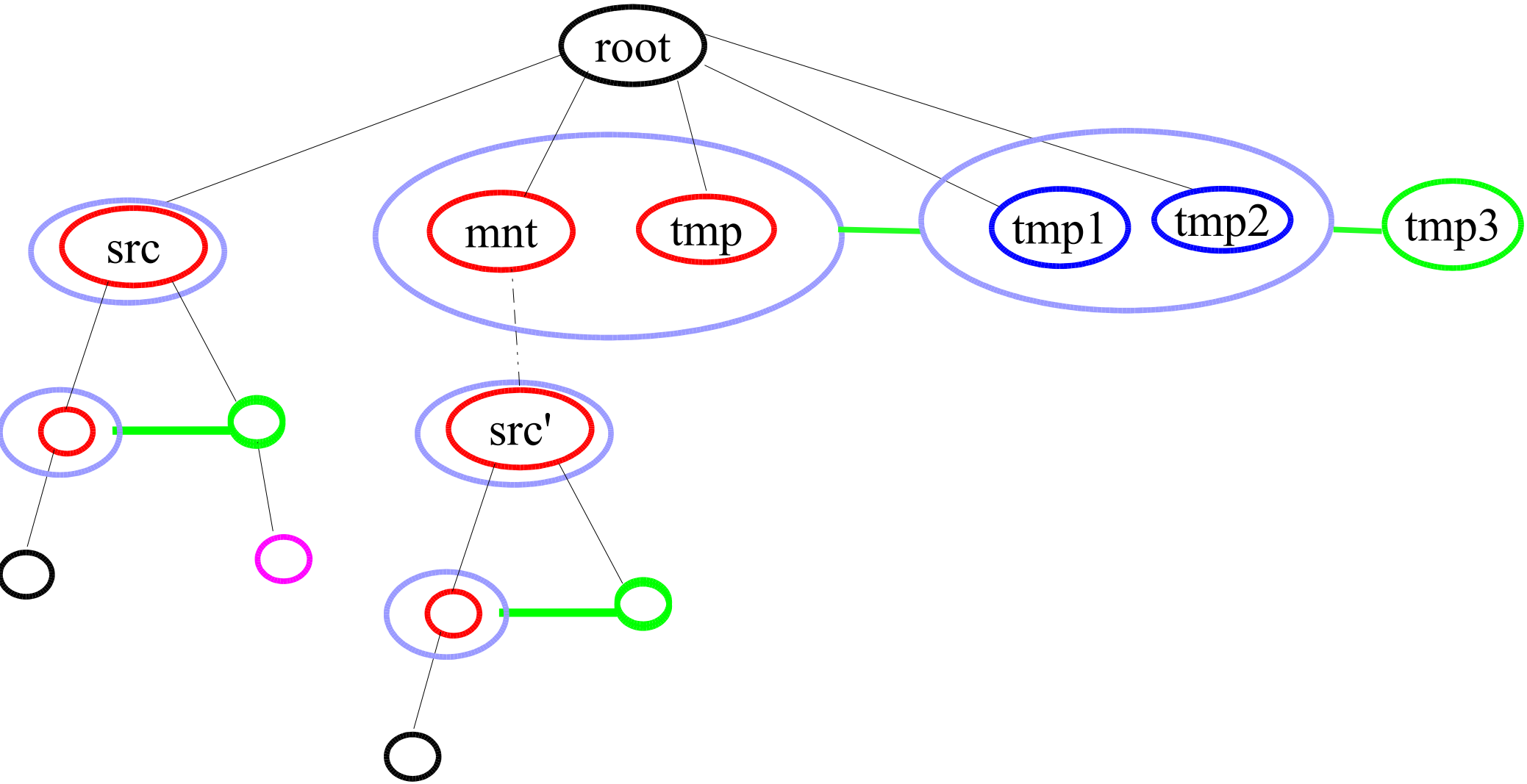


Implementation (continued)

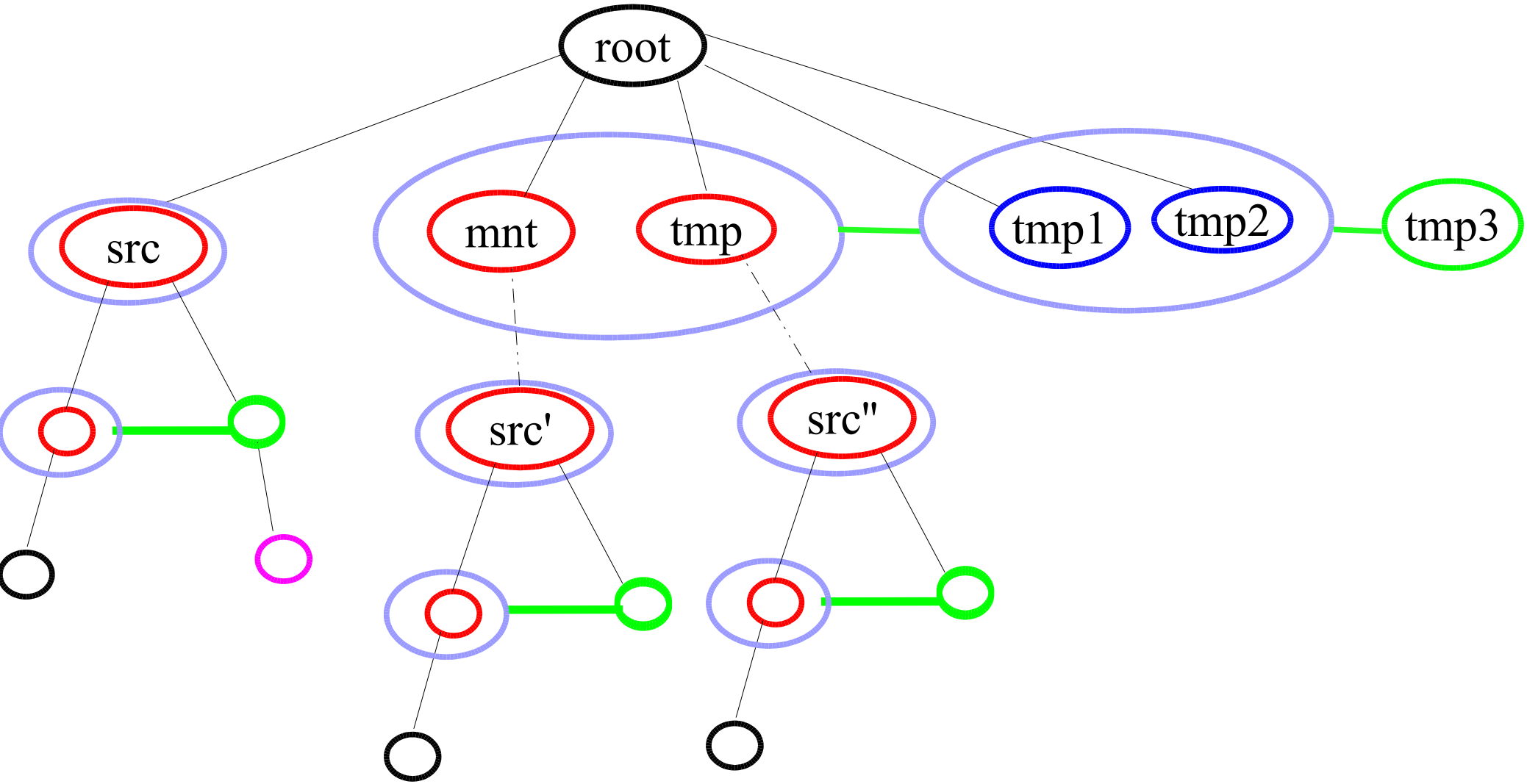
crux of the bind/move operation in

- *attach_recursive_mnt()*
  - clone a copy of the source mount tree for each mount that receives propagation from the destination (*propagate_mnt()/copy_tree()*)
  - build-up the propagation tree for each of the child mount (*clone_mnt()*)
  - if successful, attach the trees to their parents and place them in the hash list. (*commit_tree()*)
  - if allocation fails, release all the newly allocated mount trees (*propagate_mnt()*/*umount_tree()*)

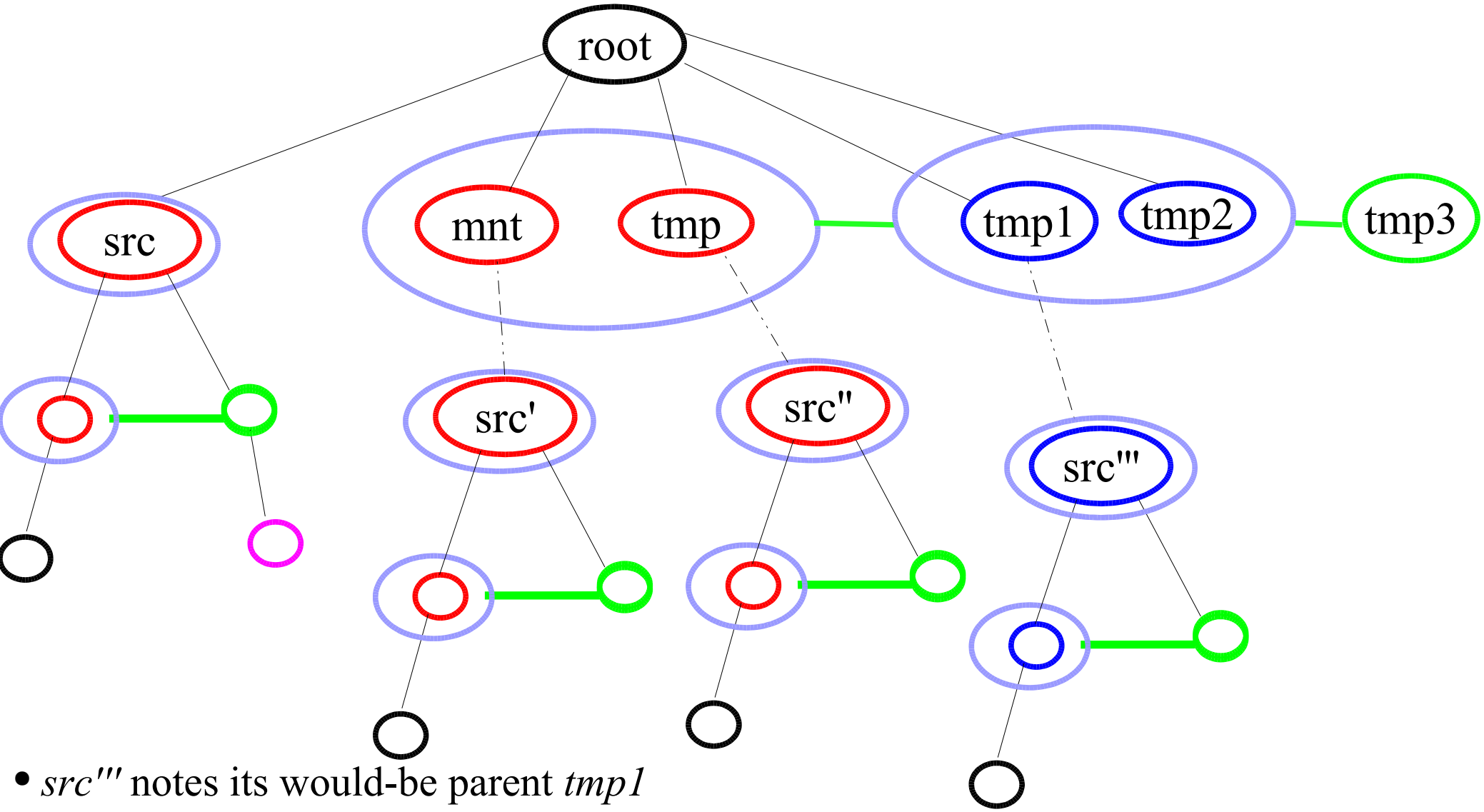

root
src
mnt
tmp
tmp1
tmp2
tmp3



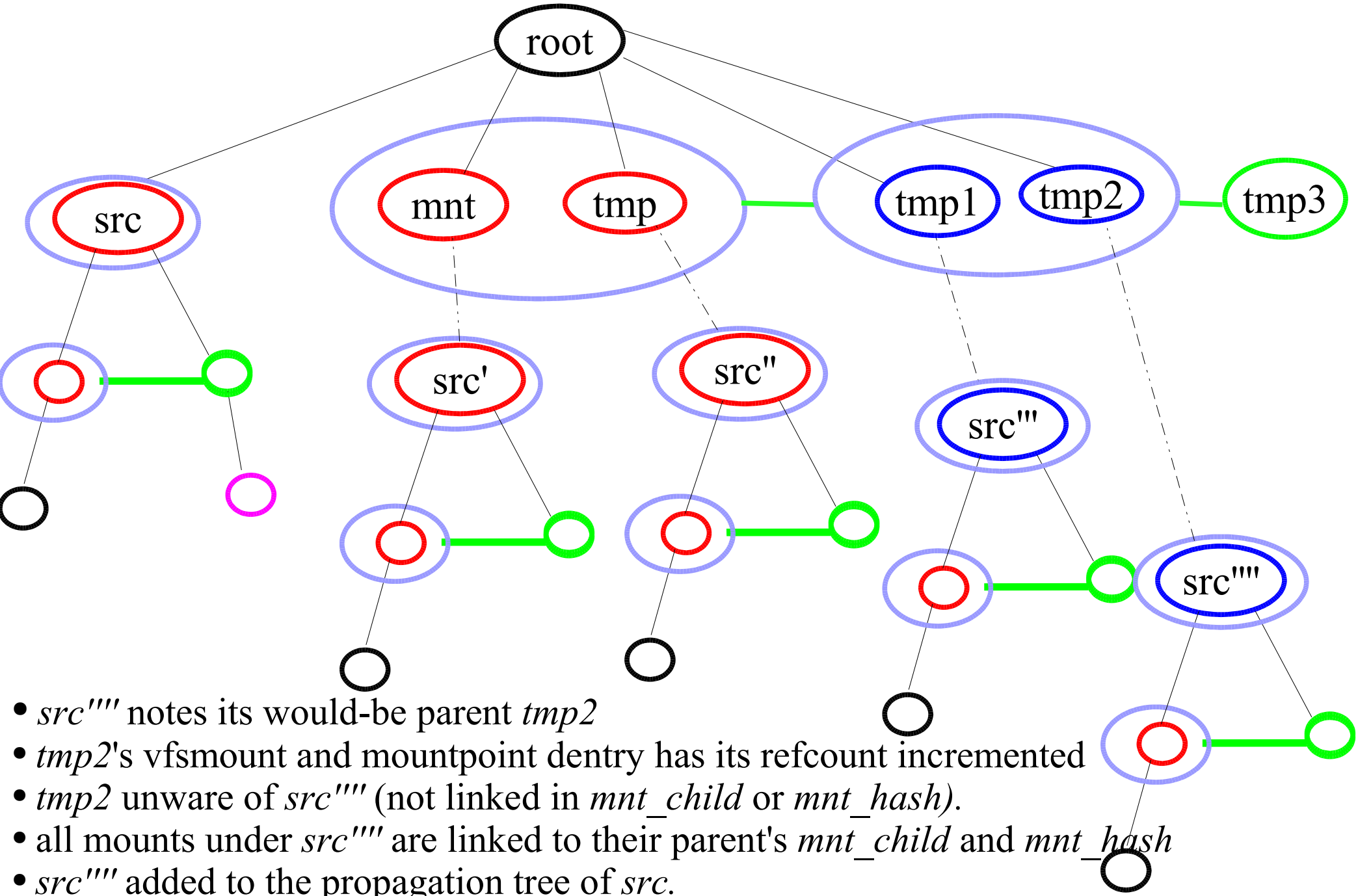
- *src'* notes its would-be parent *mnt*
- *mnt*'s vfsmount and mountpoint dentry has its refcount incremented
- *mnt* unware of *src'* (not linked in *mnt_child* or *mnt_hash).*
- all mounts under *src'* are linked to their parent's *mnt_child* and *mnt_hash*
- *src'* added to the propagation tree of *src.*



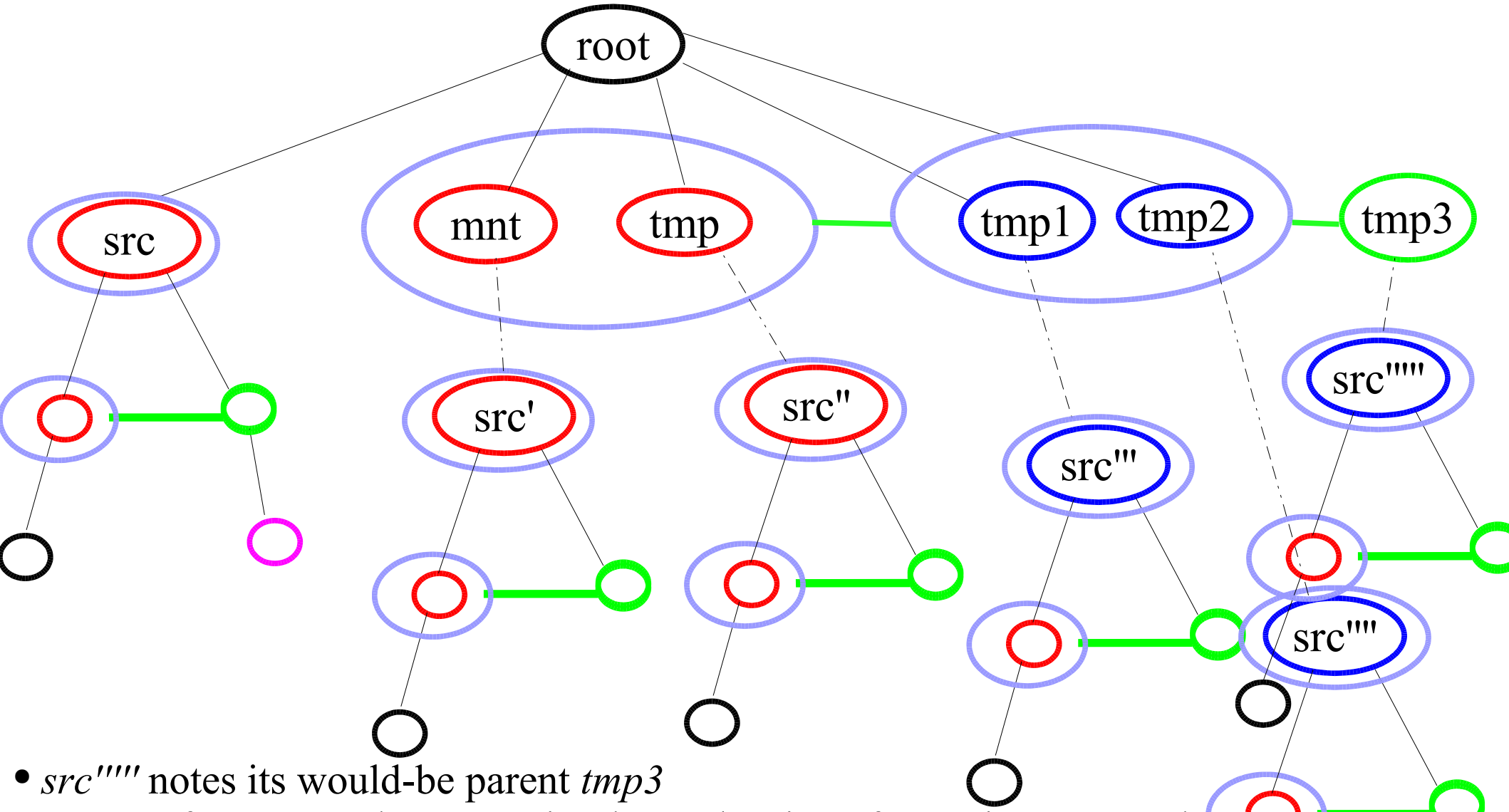
- *src"* notes its would-be parent *tmp*
- *tmp*'s vfsmount and mountpoint dentry has its refcount incremented
- *tmp* unware of *src"* (not linked in *mnt_child* or *mnt_hash).*
- all mounts under *src"* are linked to their parent's *mnt_child* and *mnt_hash*
- *src"* added to the propagation tree of *src*.



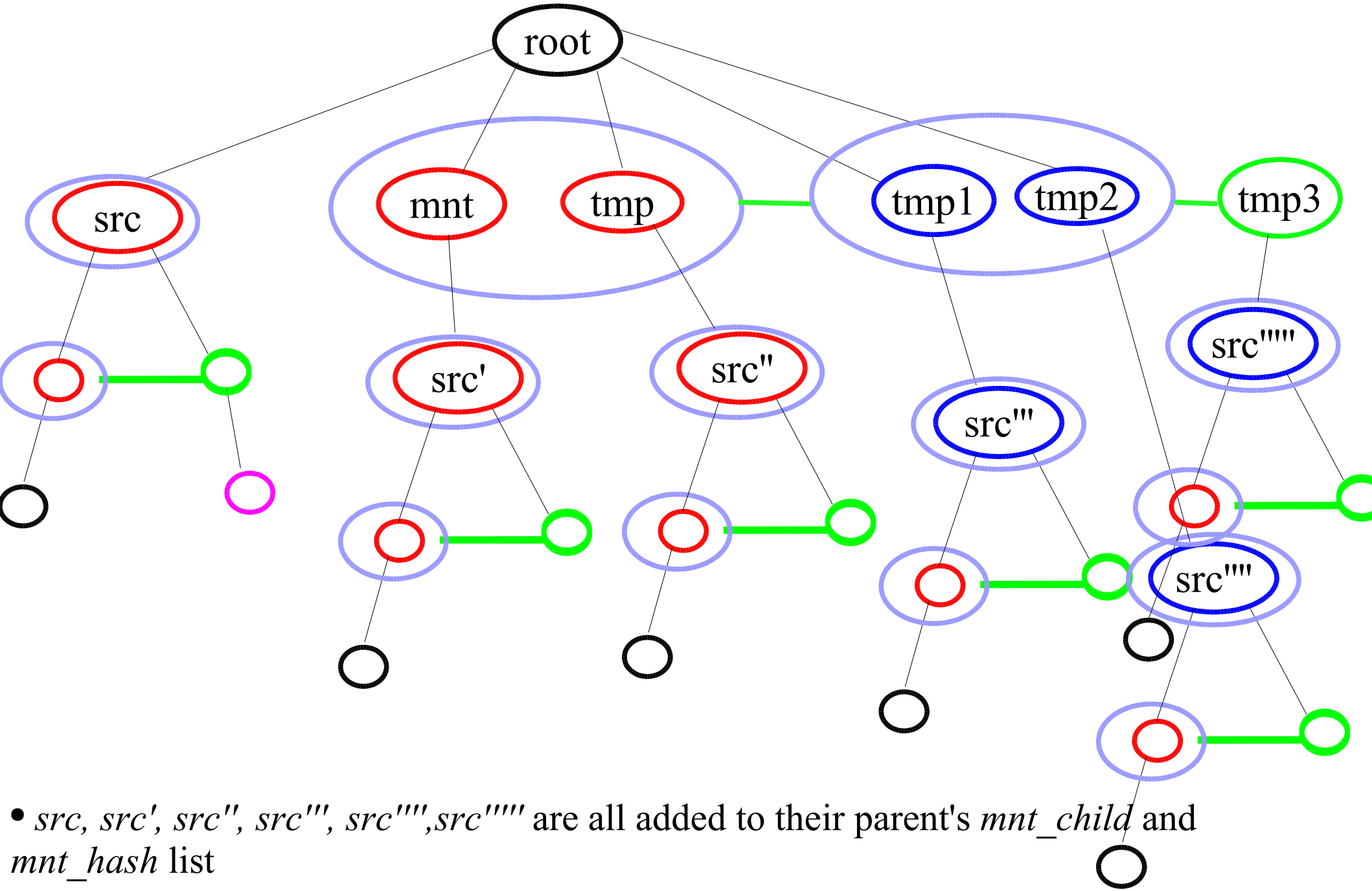
- *src'''* notes its would-be parent *tmp1*
- *tmp1*'s vfsmount and mountpoint dentry has its refcount incremented
- *tmp1* unware of *src'''* (not linked in *mnt_child* or *mnt_hash).*
- all mounts under *src'''* are linked to their parent's *mnt_child* and *mnt_hash*
- *src'''* added to the propagation tree of *src*.



- *src''''* notes its would-be parent *tmp2*
- *tmp2*'s vfsmount and mountpoint dentry has its refcount incremented
- *tmp2* unware of *src''''* (not linked in *mnt_child* or *mnt_hash).*
- all mounts under *src''''* are linked to their parent's *mnt_child* and *mnt_hash*
- *src''''* added to the propagation tree of *src*.



- *src'''''* notes its would-be parent *tmp3*
- *tmp3*'s vfsmount and mountpoint dentry has its refcount incremented
- *tmp3* unware of *src'''''* (not linked in *mnt_child* or *mnt_hash).*
- all mounts under *src'''''* are linked to their parent's *mnt_child* and *mnt_hash*
- *src'''''* added to the propagation tree of *src*.



- *src, src', src'', src''', src'''',src'''''* are all added to their parent's *mnt_child* and *mnt_hash* list

Implementation (continued)

crux of the umount operation in

- umount_tree*()*
  - collect all the mount trees that can be unmounted (*propagate_umount()*)
  - unhash the mounts. No longer available through *lookup_mnt().*
  - detach them from their propagation trees. (*change_mnt_propagation()*)
  - detach each mount from their mount trees. (*release_mounts()*)

Pointers to documentation

Al Viro's RFC:
http://lwn.net/Articles/119232/

Ram Pai's implementation history:
https://www.sudhaa.com/~ram/sharedsubtree

Extensive Documentation:
http://lwn.net/Articles/159077/

This paper (updated):
https://www.sudhaa.com/~ram/sharedsubtree/paper/sharedsubtree.pdf

per-user namespace

A user-space solution

- maintain /share as a shared mount in original namespace.
- maintain a mount for each user in /share.
- when user logs in, sshd clones-off a new namespace.
- rbind /share/$USER /home/$USER
- mount –make-private /share
- umount -l /share

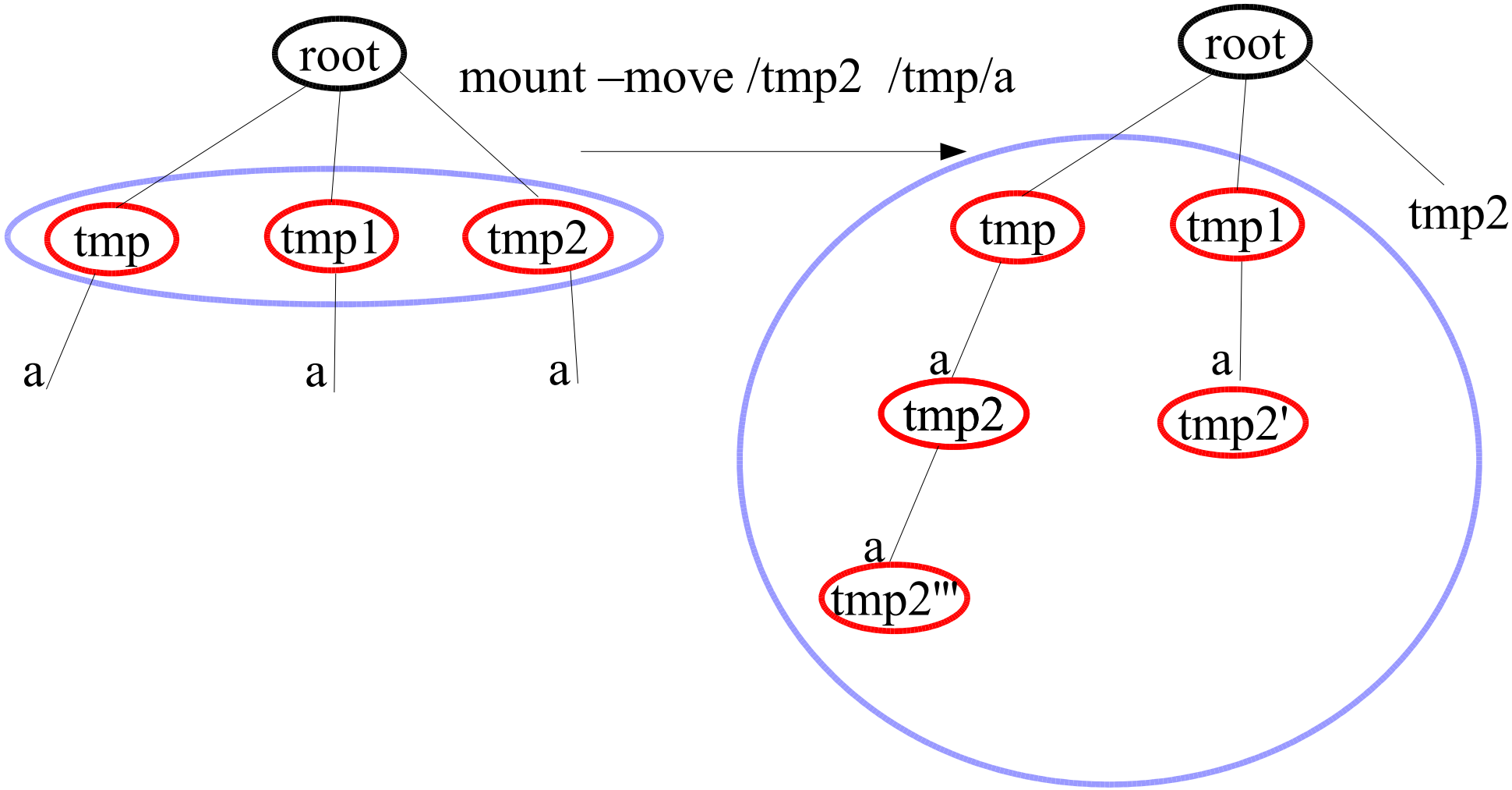
Future work

- /proc interface to view the propagation tree.
- /proc/mount confusion fix.
- mount command using the new interfaces.
  - may need revamp of /proc/mount interface or something similar
- user-mount accounting.
- Ability to lazy unmount a tree without dismantling it.
- union-mount semantics definition and implementation.

Summary

- Ability to share mount tree.
  - fixes namespace isolation
  - makes bind/rbind dynamic
- provides building blocks for
  - per-user-namespace.
  - versioned filesystem.
  - containers.

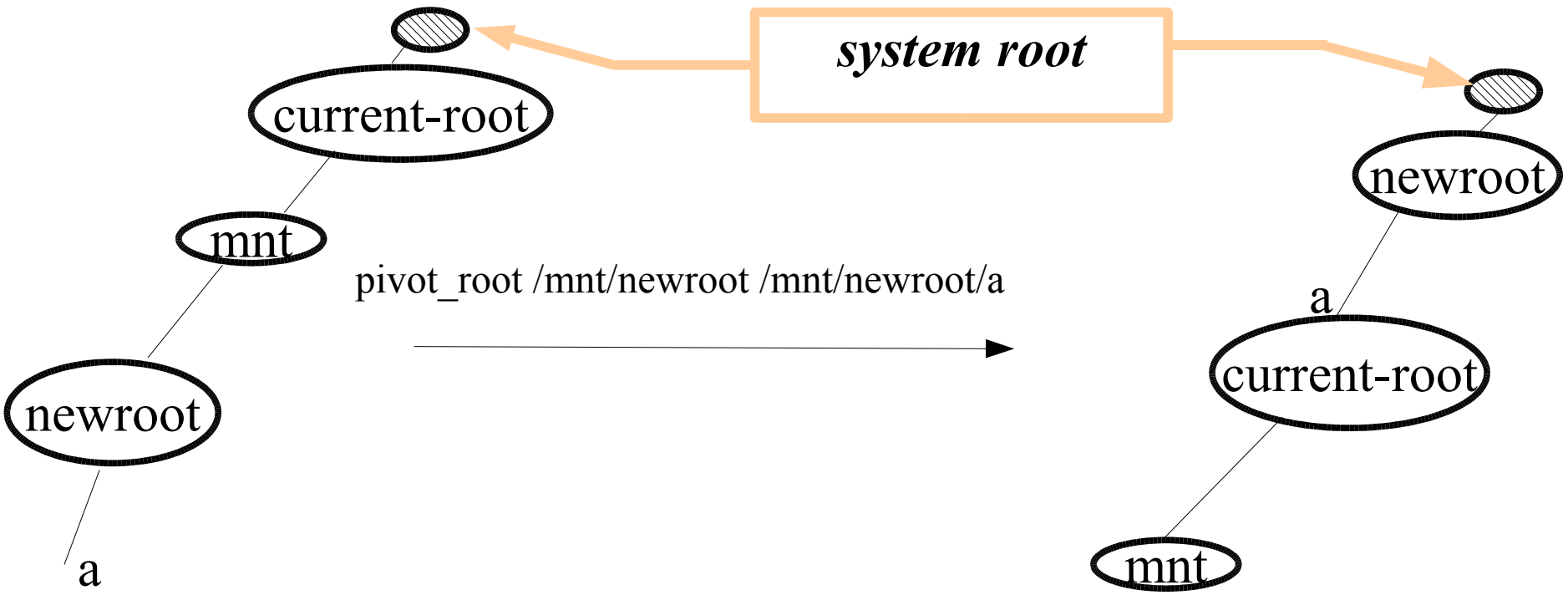
Legal Statement


root
mount –move /tmp2 /tmp/a
tmp
tmp1
tmp2
a
a
a
root
tmp
tmp1
tmp2
a
a
tmp2
tmp2'
a
tmp2'''

Pivot root

- pivot_root

- parent of current-root cannot be shared
- parent of new-root cannot be shared
- new-root cannot be shared



Requirement

- Ability to maintain multiple identical mount trees, each tree associated with some entity.
  - containers (associate a system mount tree per container)
  - MVFS (associate a mount tree per view)
- Ability to make private changes to part of a tree.
  - FUSE (private mount that is not visible to anybody else).
  - SeLinux LSPP (private mounts not visible to anybody else).
- How?
  - Filesystem Namespace (per-process namespace)?
  - Rbind?