# Introduction of passive reference

Kengo Nakahara

(knakahara@n.o / k-nakahara@iij.ad.jp)

Internet Initiative Japan Inc.

AsiaBSDCon 2016 ~~Net~~BSD BoF
March 11 2016

# Table of contents

- Overview
- Motivation
- Concept
- Design
- Operation overview
- Summary

# Overview

- passive reference (psref) is a synchronization mechanism like reference counting
  - using pserialize(9) (*)
    - pserialize(9) is one of lockless synchronization mechanisms like RCU of Linux
  - to scale better than reference counting
- psref is under development for NetBSD kernel
  - e.g. packet processing paths
- psref is
  - discussed by riastradh@n.o, rmind@n.o, and dyoung@n.o
  - reviewed by riz@n.o
  - being implemented by riastradh@n.o
    - http://mail-index.netbsd.org/tech-net/2016/01/24/msg005507.html
      - and update http://mail-index.netbsd.org/tech-net/2016/02/15/msg005621.html
  - Thanks!
- I am using psref for making gif(4) MP-ify

(*) see "Modernizing NetBSD Networking Facilities and Interrupt Handling" in AsiaBSDCon2015

# Motivation

- Network packet processing needs to share resources
  - route, tunnel configuration, and so on
- pserialize(9) can achieve good scalability
  - we verified it with bridge(4) (*)
  - contract: **sleep is prohibited** in reader critical section
- Packet processing **may sleep** even in fast paths
  - e.g. adaptive mutex, rwlock, and rtalloc1
- How to resolve with good scalability?
  - Changing all of  these processings not sleeping in that section is hard work because of complex interdependency
  - Reference count decrease scalability because of interprocessor synchronization

(*) see “Modernizing NetBSD Networking Facilities and Interrupt Handling” in AsiaBSDCon2015, too

# Concept

- Somehow hold a reference to shared resource without interprocessor synchronization
  - like OpenBSD’s SRP(9) (I think. I don’t know detail)
- If sleepable processing doesn’t migrate between CPUs, interprocessor synchronization is not needed
  - Except for destruction, discuss later
- softint(9) and CPU-bound kthread satisfy this assumption
  - If not satisfied, we have to prevent it somehow during using psref

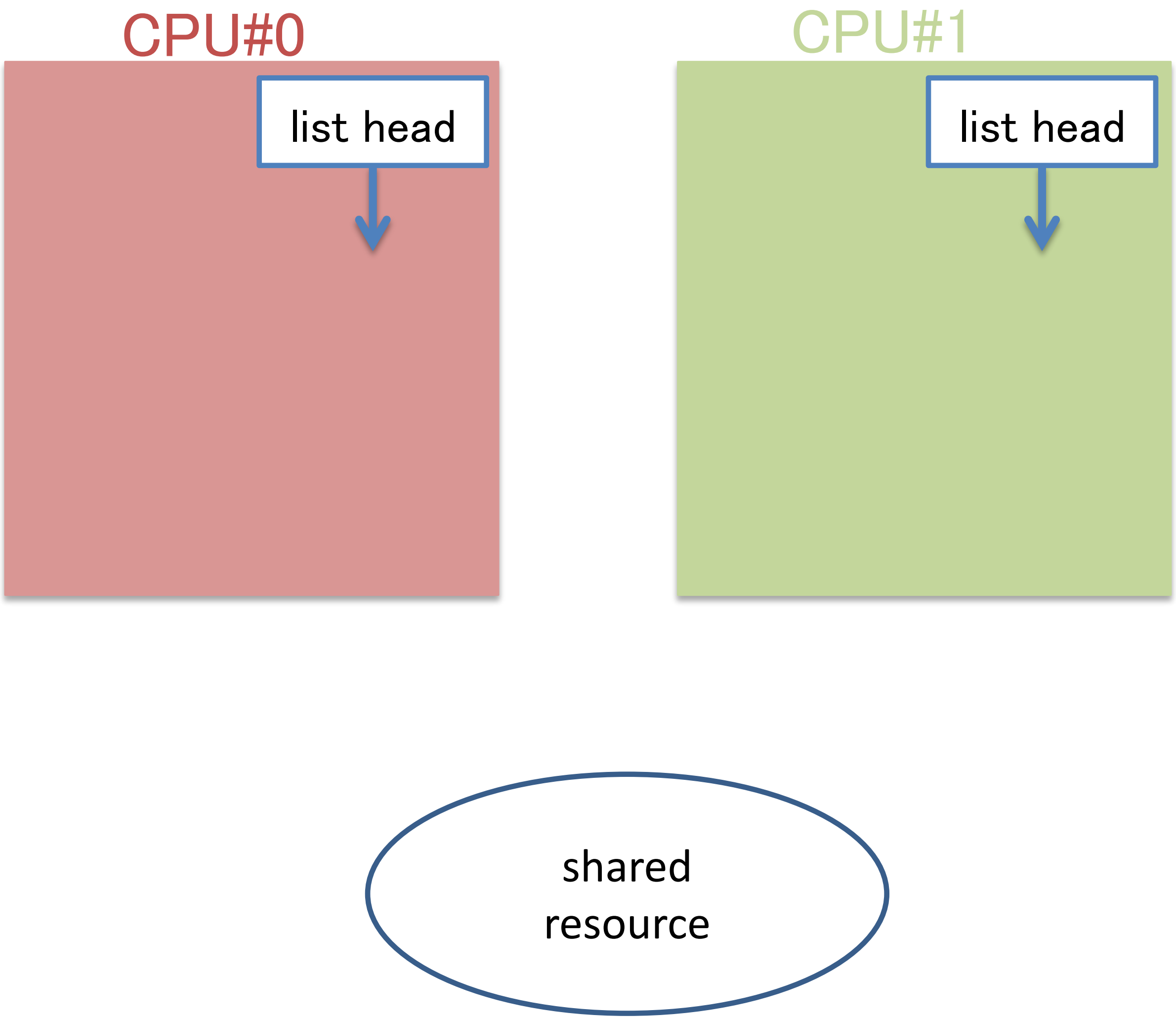
# Design

- Add a CPU-local list to each CPU to manage references
- Read side (fast path)
  - Acquiring a reference is represented as adding an entry to the list of the current CPU
    - pserialize(9) guarantees the entry isn't destroyed during the operation
  - Releasing a reference is represented as removing the entry from the list
- Write side (slow path)
  - Before destroying a shared resource, wait for **ALL** CPUs to release their references to it
    - i.e. IPI (*) broadcast is needed

(*) Inter-Processor Interrupt, also called "cross call", "xcall"

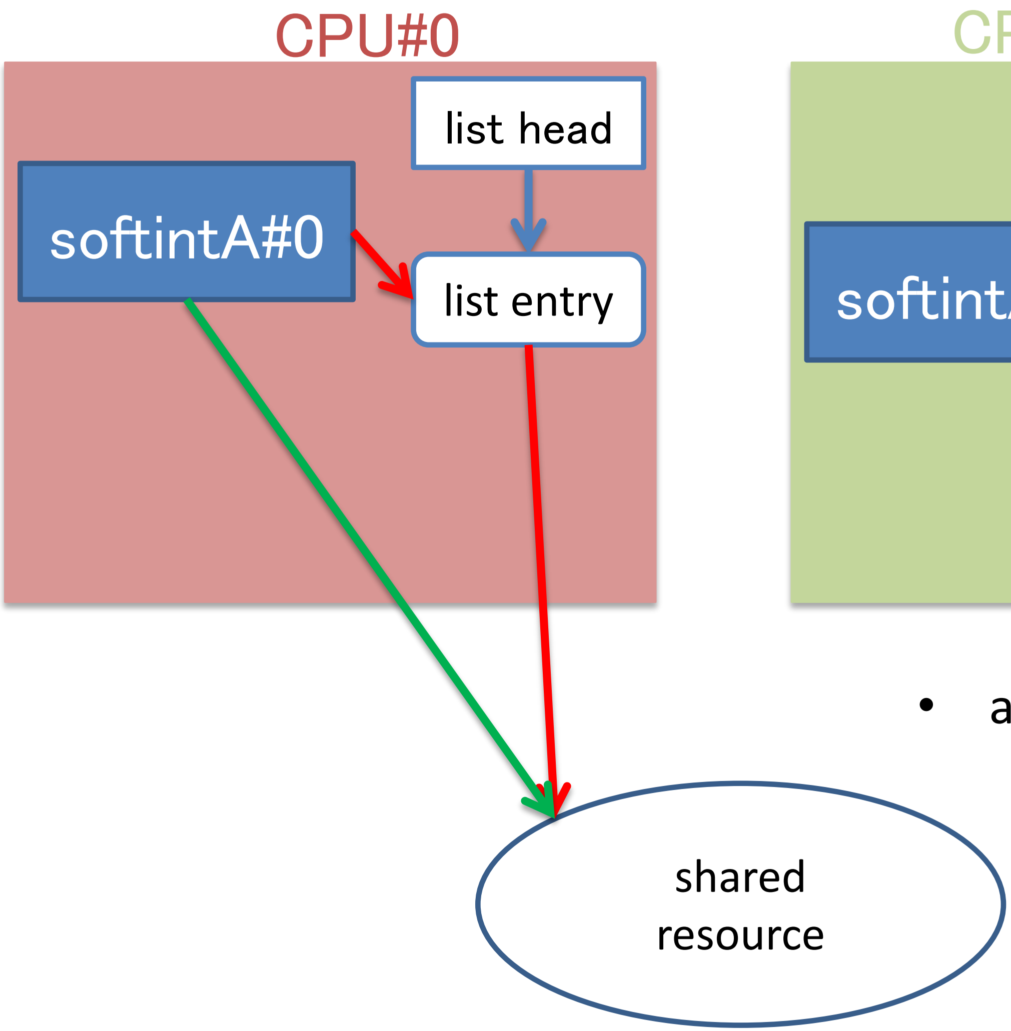
# Operation overview (1/7)

initial state



# Operation overview (2/7)

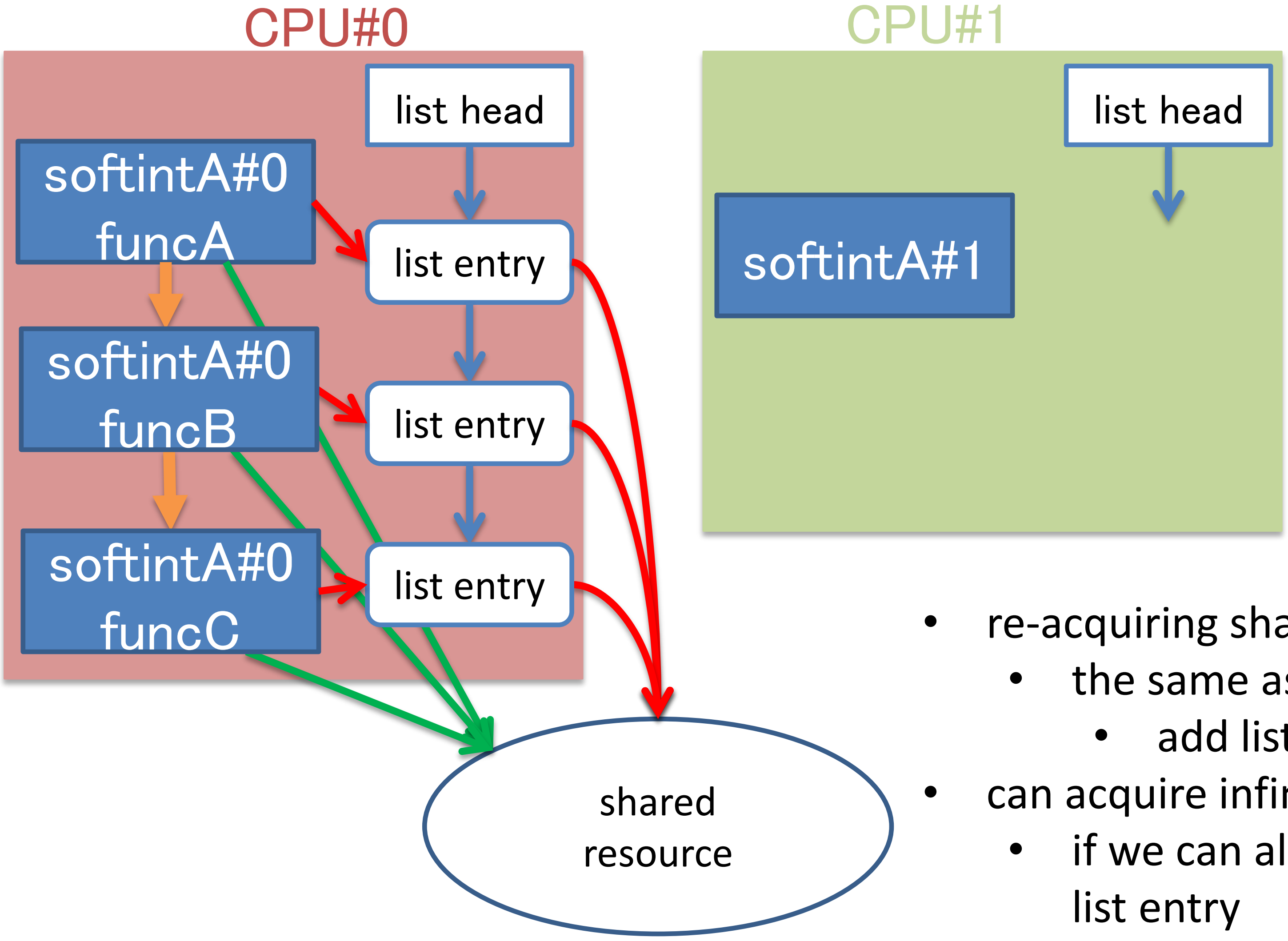
acquiring reference by CPU#0



- acquiring reference to shared resource
  - add new entry to CPU local list
    - list entry refer to shared resource
  - refer list entry from call stack
  - use shared resource

# Operation overview (2-b/7)

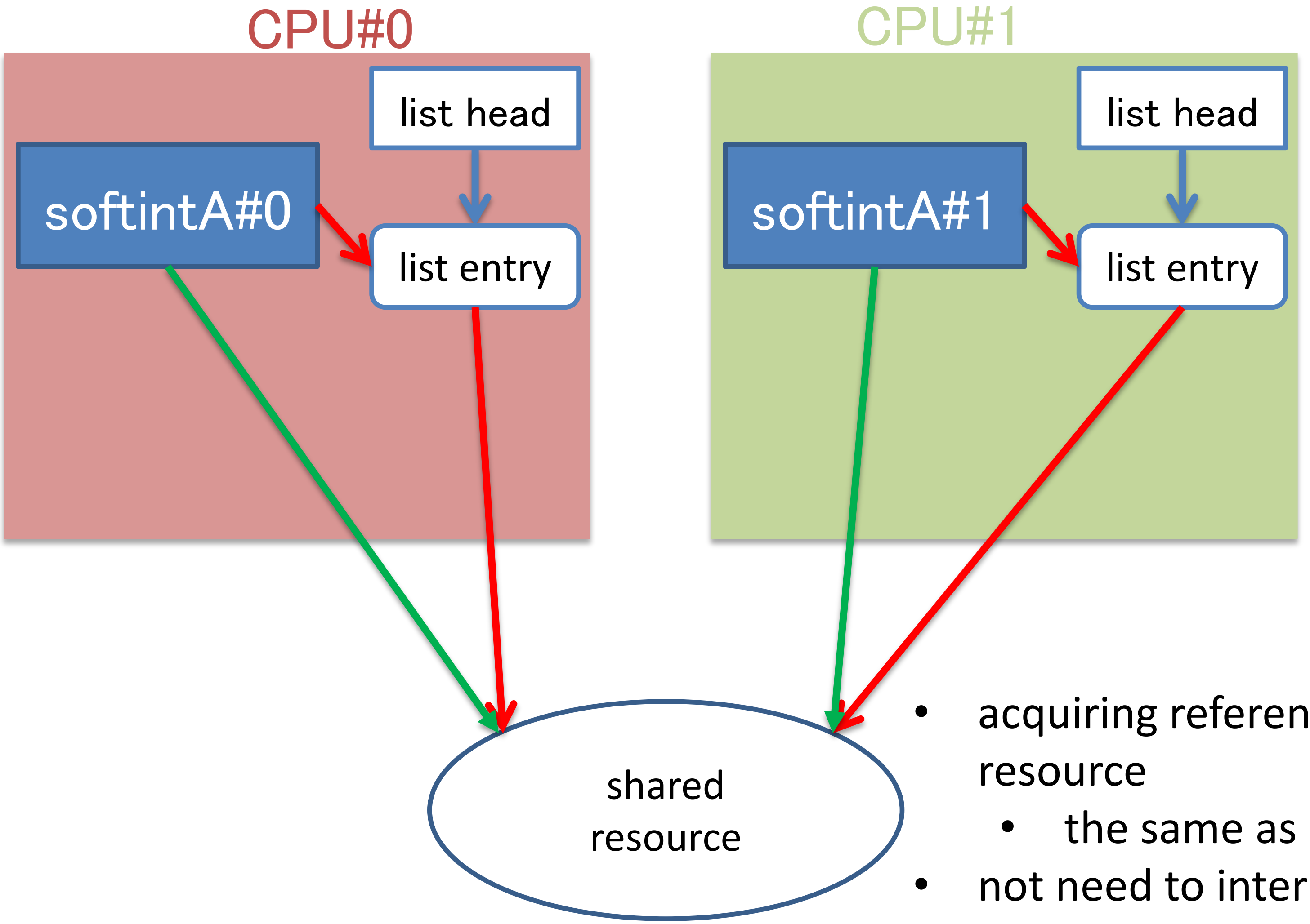
re-acquiring reference by CPU#0



- re-acquiring shared resource
  - the same as fist time
    - add list entry, and...
- can acquire infinitely
  - if we can allocate memory for list entry

# Operation overview (3/7)

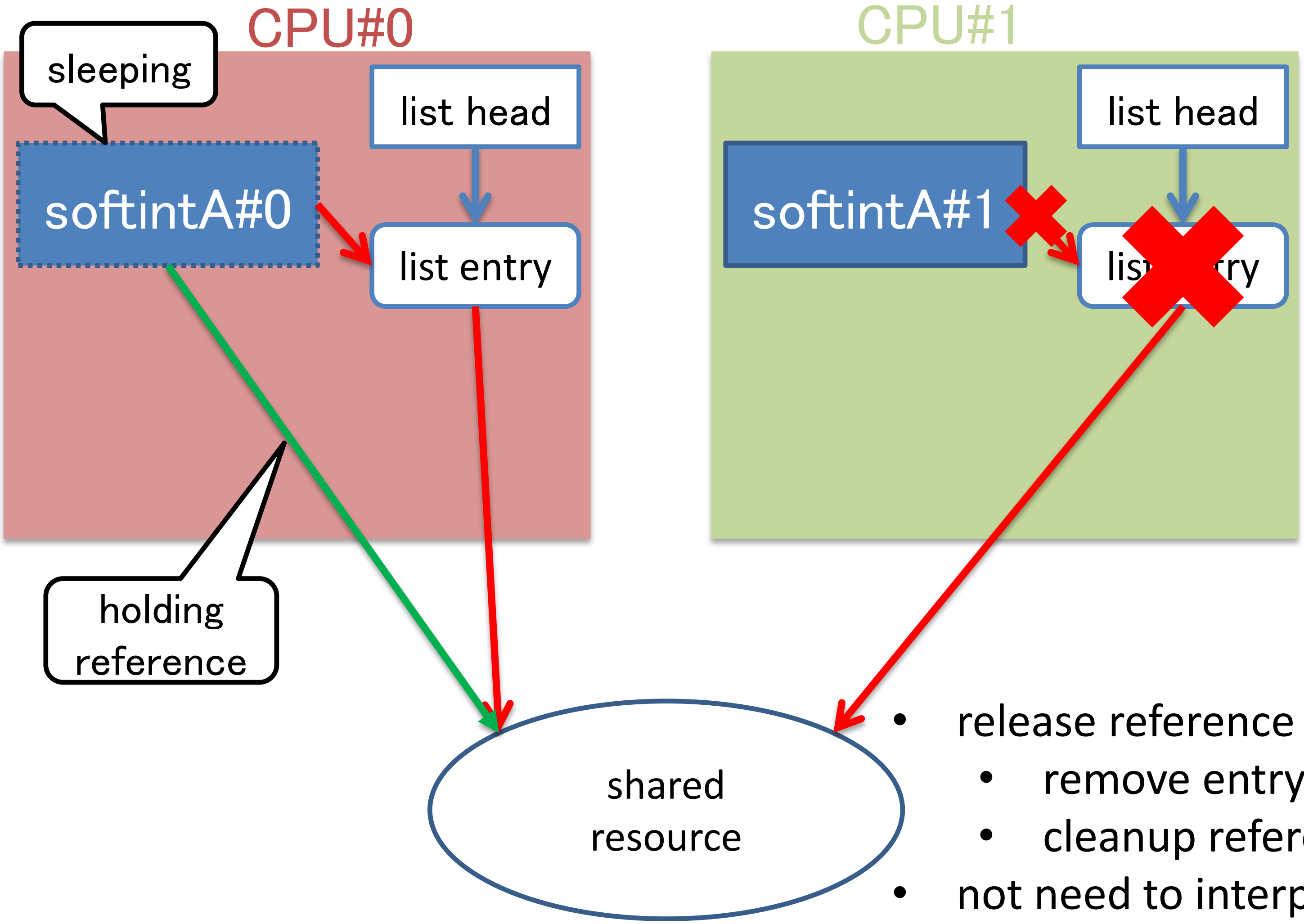
acquiring reference by CPU#1



- acquiring reference to shared resource
  - the same as CPU#0
- not need to interprocessor sync

# Operation overview (4/7)

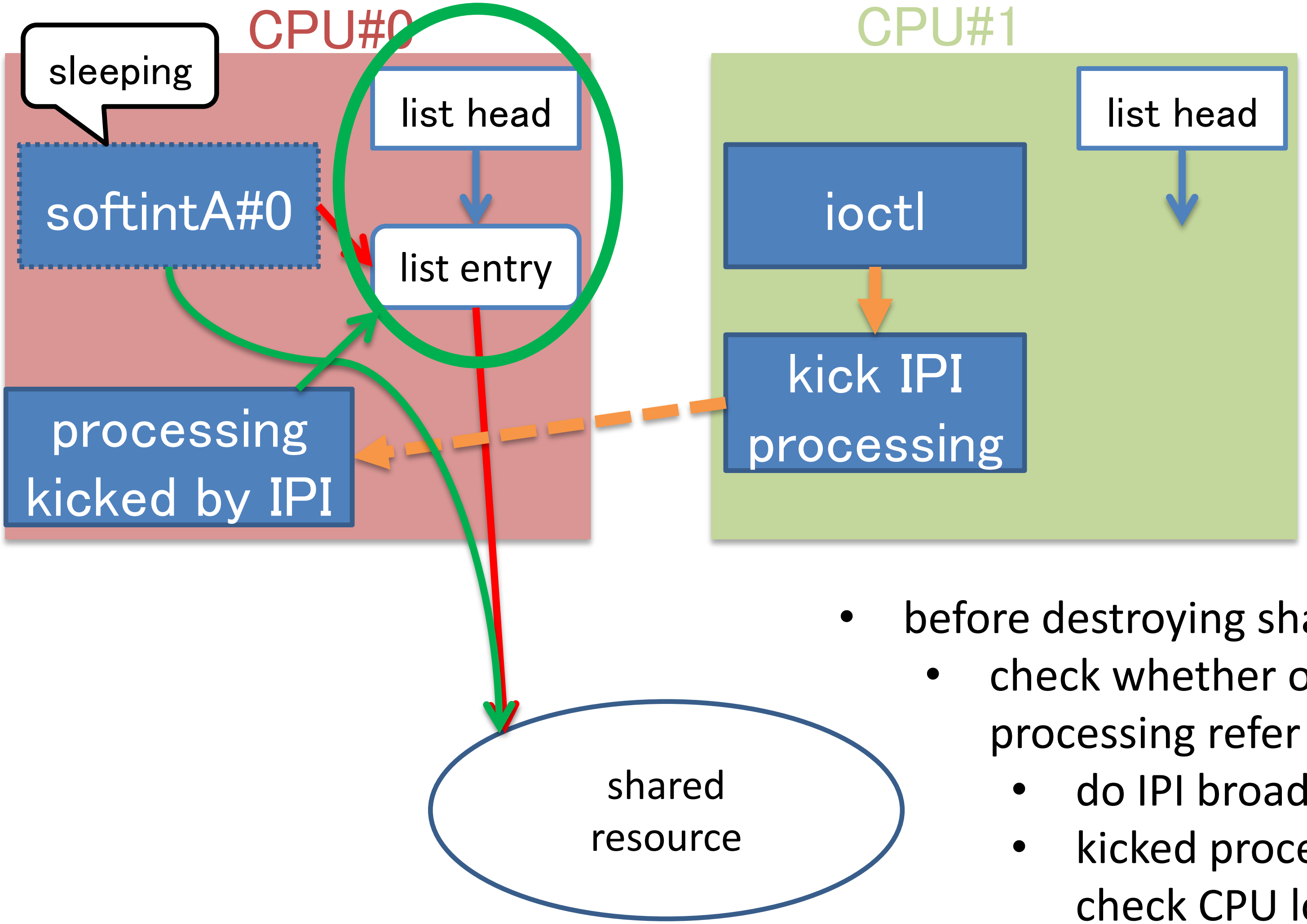
release reference by CPU#1



- release reference to shared resource
  - remove entry from CPU local list
  - cleanup reference from stack
- not need to interprocessor sync also

# Operation overview (5/7)

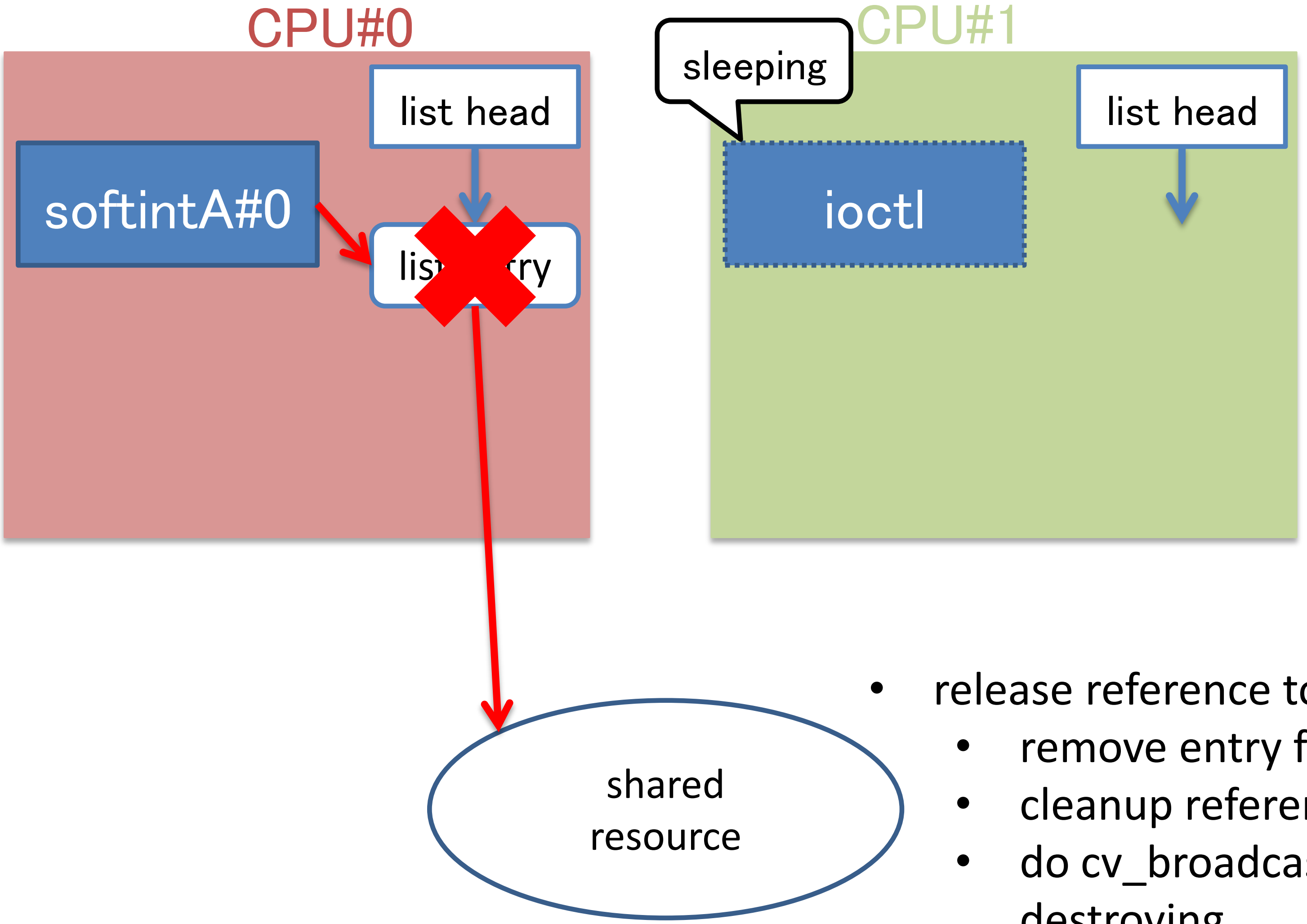
try to destroy resource by CPU#1



- before destroying shared resource
  - check whether other CPUs processing refer shared resource
    - do IPI broadcast and wait it
    - kicked processing just has to check CPU local list

# Operation overview (6/7)

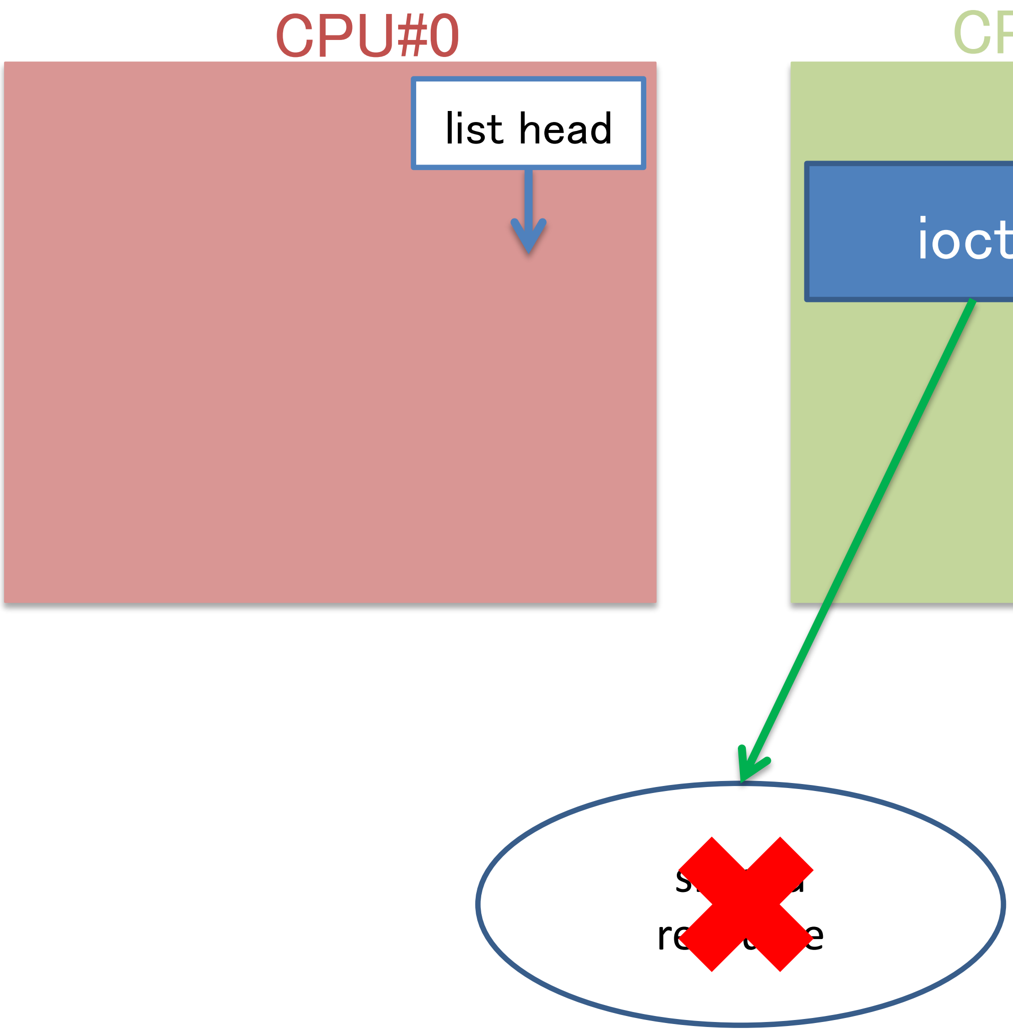
release reference by CPU#0



- release reference to shared resource
  - remove entry from CPU local list
  - cleanup reference from stack
  - do cv_broadcast if someone is destroying

# Operation overview (7/7)

do destroy resource by CPU#1



- wakeup by cv_broadcast
- resume to destroy shared resource

# APIs

```
struct psref_class *psref_class_create(const char *name, int ipl);
void    psref_class_destroy(struct psref_class *class);

void    psref_target_init(struct psref_target *target, struct psref_class *class);
void    psref_target_destroy(struct psref_target *target,
                             struct psref_class *class);

void    psref_acquire(struct psref *psref, struct psref_target *target,
                      struct psref_class *class);
void    psref_release(struct psref *psref, struct psref_target *target,
                      struct psref_class *class);
void    psref_copy(struct psref *pto, const struct psref *pfrom,
                   struct psref_class *class);

bool    psref_held(struct psref_target *target, struct psref_class *class);
```

# Pseudo code (read side)

```
lookup_elem_and_sleepable_processing() {
    struct record *elem;
    struct psref psref;

    s = pserialize_read_enter();                    // protect the list itself.
    LIST_FOREACH(elem, head, field) {
        if (elem->key == key) {
            psref_acquire(&psref, &elem->target);   // protect the element.
            break;
        }
    }
    pserialize_read_exit(s);                        // unprotect the list, but
                                                    // the element has been protected.

    if (elem) {
        some_processing_that_sleeps(elem);          // may sleep, so this cannot do
                                                    // before pserialize_read_exit().
        psref_release(&psref, &elem->target);       // unprotect the element.
    }
}
                                                    // to keep the reference across
                                                    // function, pass psref as argument.
```

pserialize read critical section

psref holding reference section

# Pseudo code (write side)

```
remove_elem() {

    mutex_enter(lock);                                  // protect against other write
                                                        // side processing.
    LIST_FOREACH(elem, head, field) {
        if (elem->key == key) {
            LIST_REMOVE(elem);
            pserialize_perform(psz);                    // wait for reader lookups to
                                                        // finish.
            break;
        }
    }
    mutex_exit(lock);

    if (elem) {
        psref_target_destroy(&elem->psref_target);  // wait for readers to drain.
        kmem_free(elem);                             // destroy itself.
    }
}
```

# Summary

- Introduce psref
- psref enables us to work on parallelizing packet processing incrementally without making the significant changes
  - The significant changes are needed as pserialize(9) read side would require to avoid sleeping
- psref will be merged to NetBSD-current
  - soon?
- Welcome to feedback to use pserialize(9) and psref
- If you have questions, please ask riastradh@n.o ☺