为Linux引入技术

Or: Introducing your technology Into Linux will require introducing a ***lot of Linux into your technology!!!***

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IBM Linux 技术中心

25周年: 1983年五月至今

概览

- 获得RCU技术更多资料
- Linux 内核中RCU 的使用
- Linux 如何改变RCU
- 经验总结

哪里可以获取更多的RCU资料？

哪里可以获取更多的RCU资料？

- 在极端要求读的性能、可测量性和决定论的时候，**RCU** 可以被看作读写锁的替代技术
- **RCU**的更多信息请参考:
  - Linux 每周新闻 “真实的 RCU 是什么?” 系列
    - RCU基本概念?
      - http://lwn.net/Articles/262464/
    - RCU是什么? 第二部分：使用
      - http://lwn.net/Articles/263130/
    - RCU 第三部分: RCU API (包括附说明的资料目录)
      - http://lwn.net/Articles/264090/
  - Paul McKenney 的 RCU 网址
    - http://www.rdrop.com/users/paulmck/RCU/

RCU性能问题出现的原因

4-CPU 1.8GHz AMD Opteron 844 system

RCU 读取器

Operation	Cost (ns)	Ratio
Clock period	0.6	
Best-case CAS	37.9	63.2
Best-case lock	65.6	109.3
Single cache miss	139.5	232.5
CAS cache miss	306.0	510.0

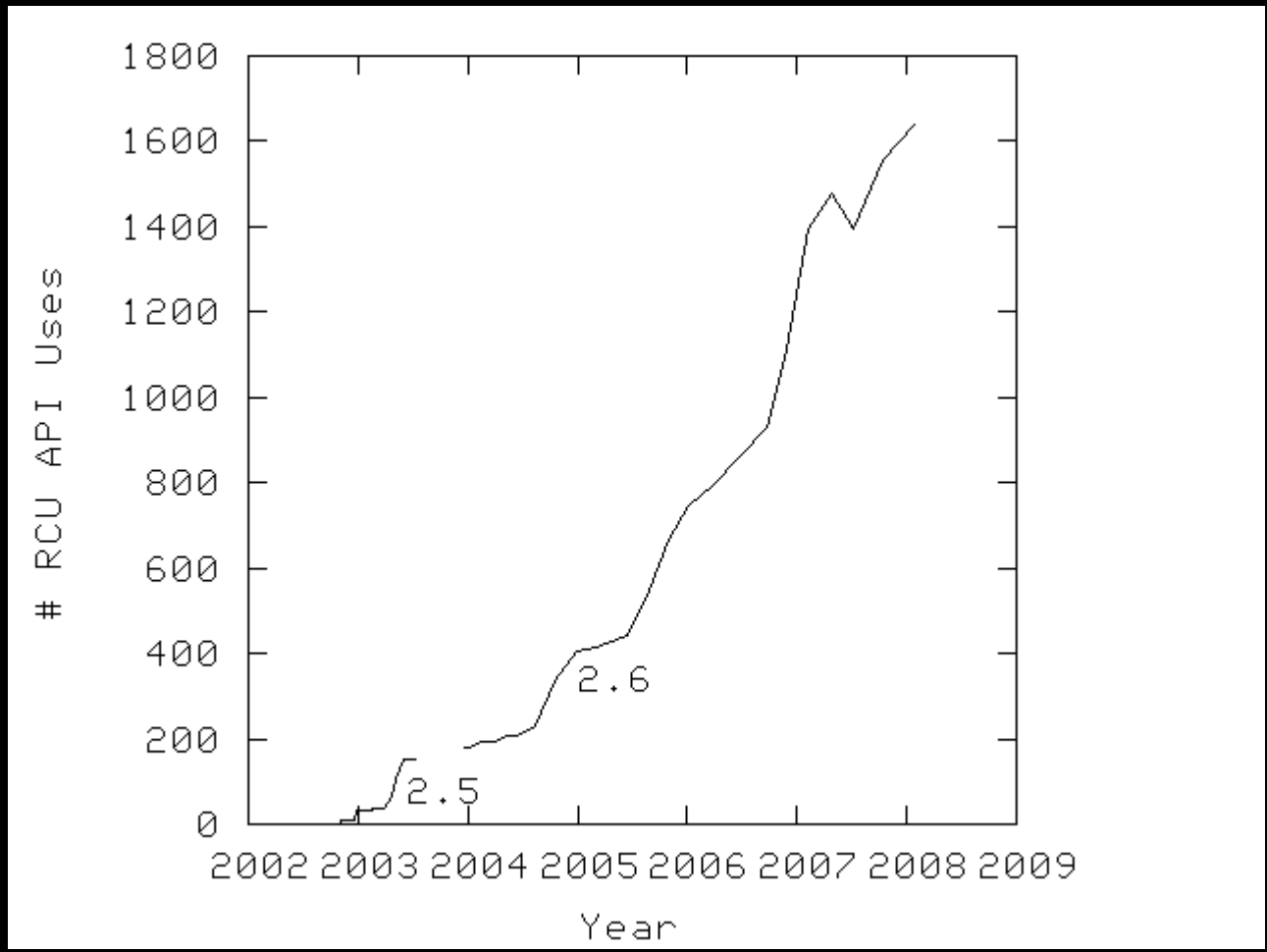
读写器的读取功能可能能高优化 (但是写入器功能不行...)

典型同步机制

RCU 读取器使用低成本指令, 而其他方法使用高成本指令.

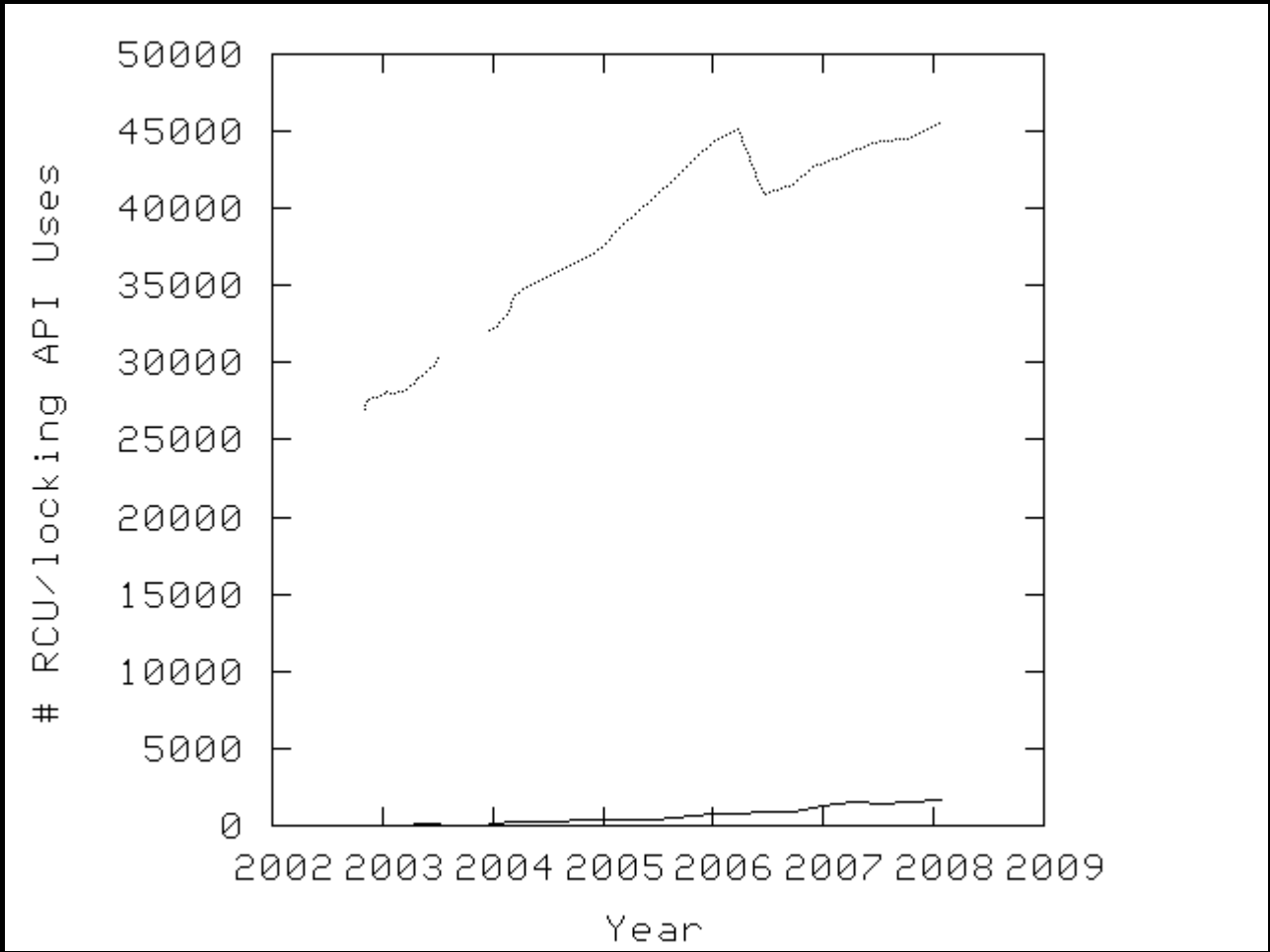
Linux 内核中RCU 的使用

Linux 内核中RCU 的使用(2.6.24)

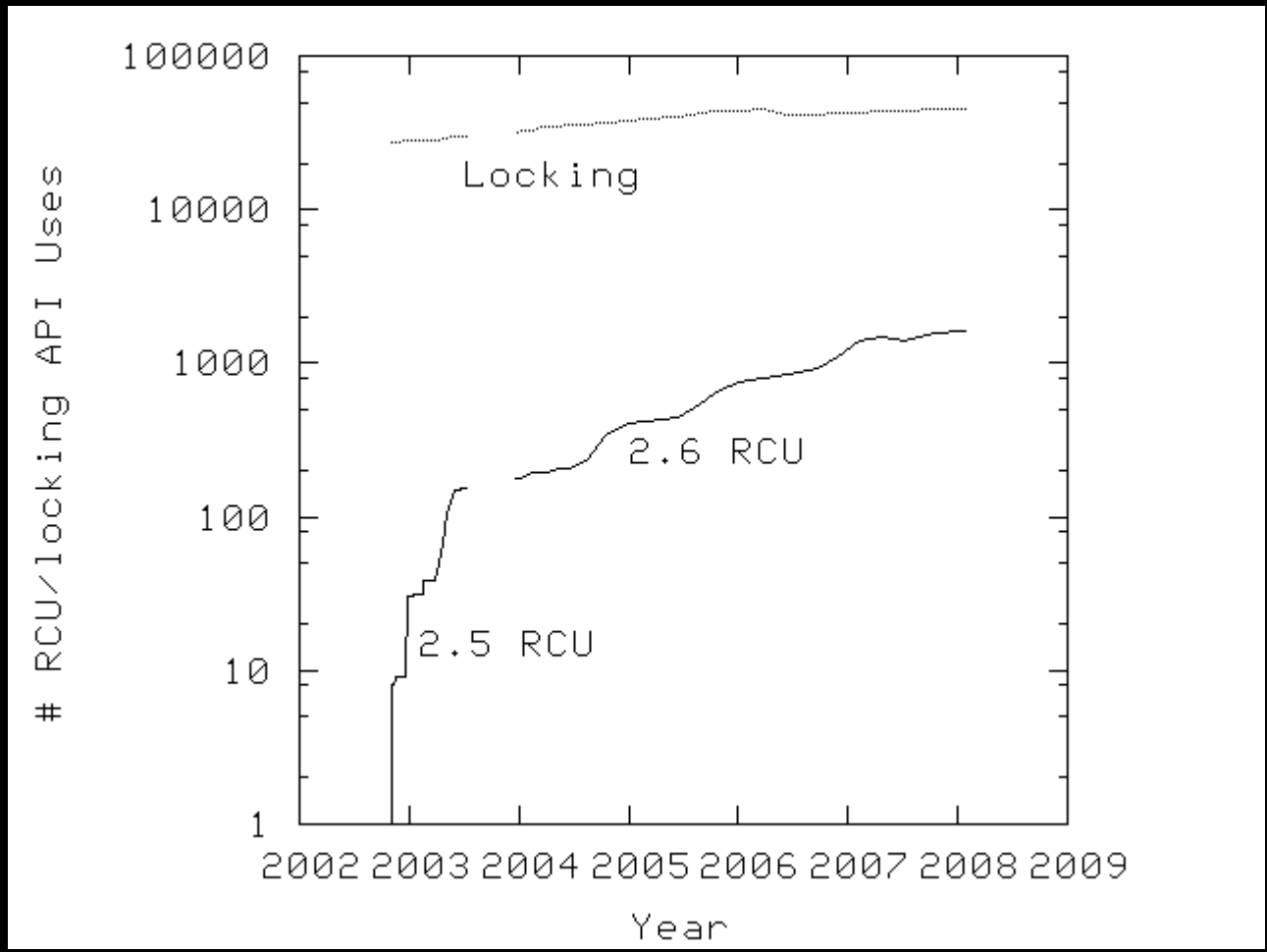


In case there was any doubt, the Linux community ***can*** handle RCU.

Linux 内核中RCU 的使用与锁的比较



Linux 内核中RCU 的使用与锁的比较



Linux 内核中RCU 的使用与锁的比较

RCU技术被成功适当地应用到了Linux内核中

RCU如何做到的?

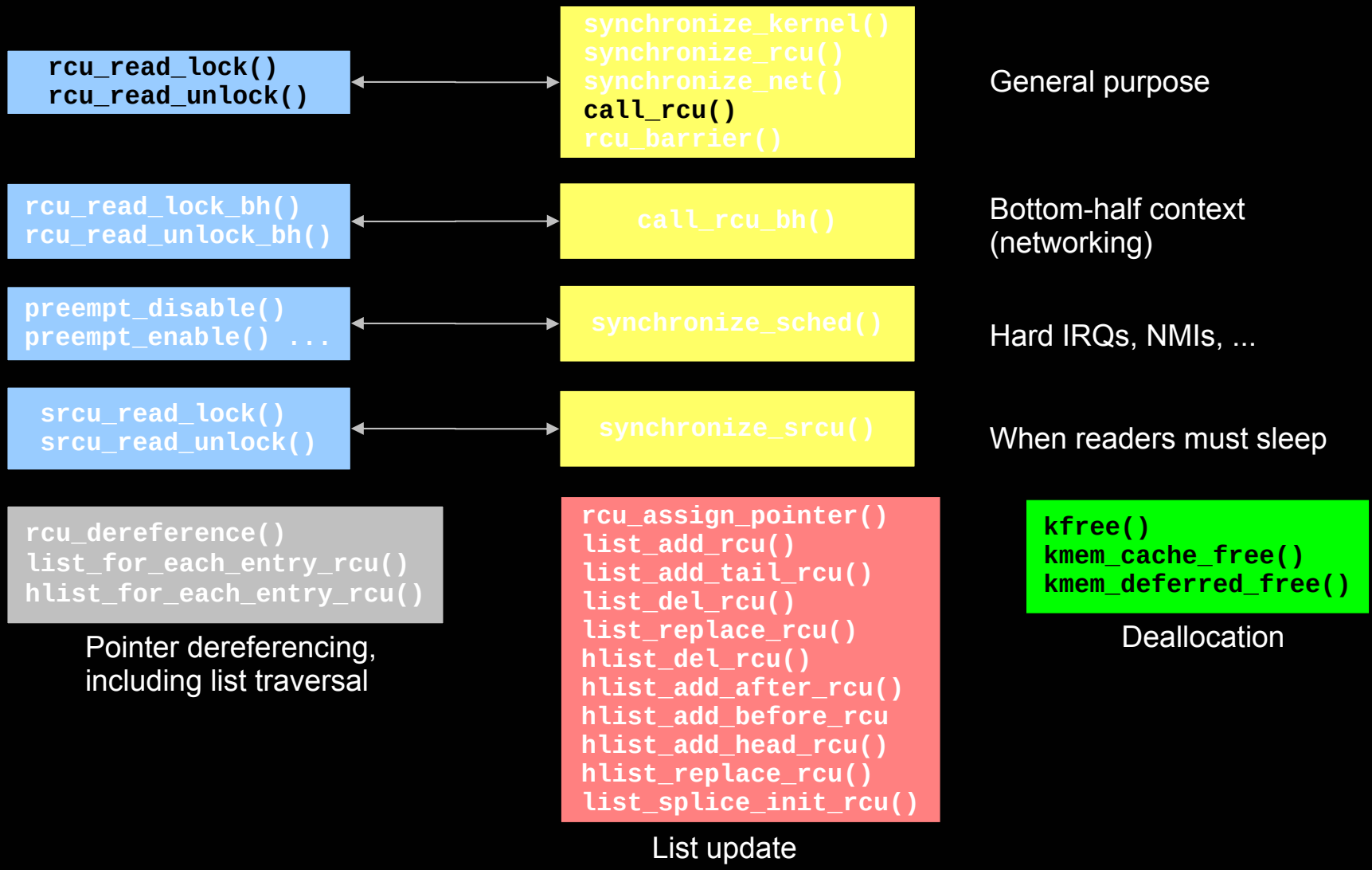
它戏剧性地被Linux系统改变了!!!

Linux 如何改变RCU

RCU的已有Linux经验

- 企业系统: 重要并行数据库服务器
  - 10 CPU, 10 GB 内存 (mid-90s 标准)
- 受护网络环境
  - 防火墙,客户端， 受限使用模式
- 不需实时应答的情形
  - 除非你注重 TPC/A 需求 即90% 事务在2个部分实现
- 内核开发者数目很少 (几十个)
- 为适应 Linux做的重大改动
  - 附细节信息和参考供回顾时使用
  - 目的在于给出更改的整体数量级

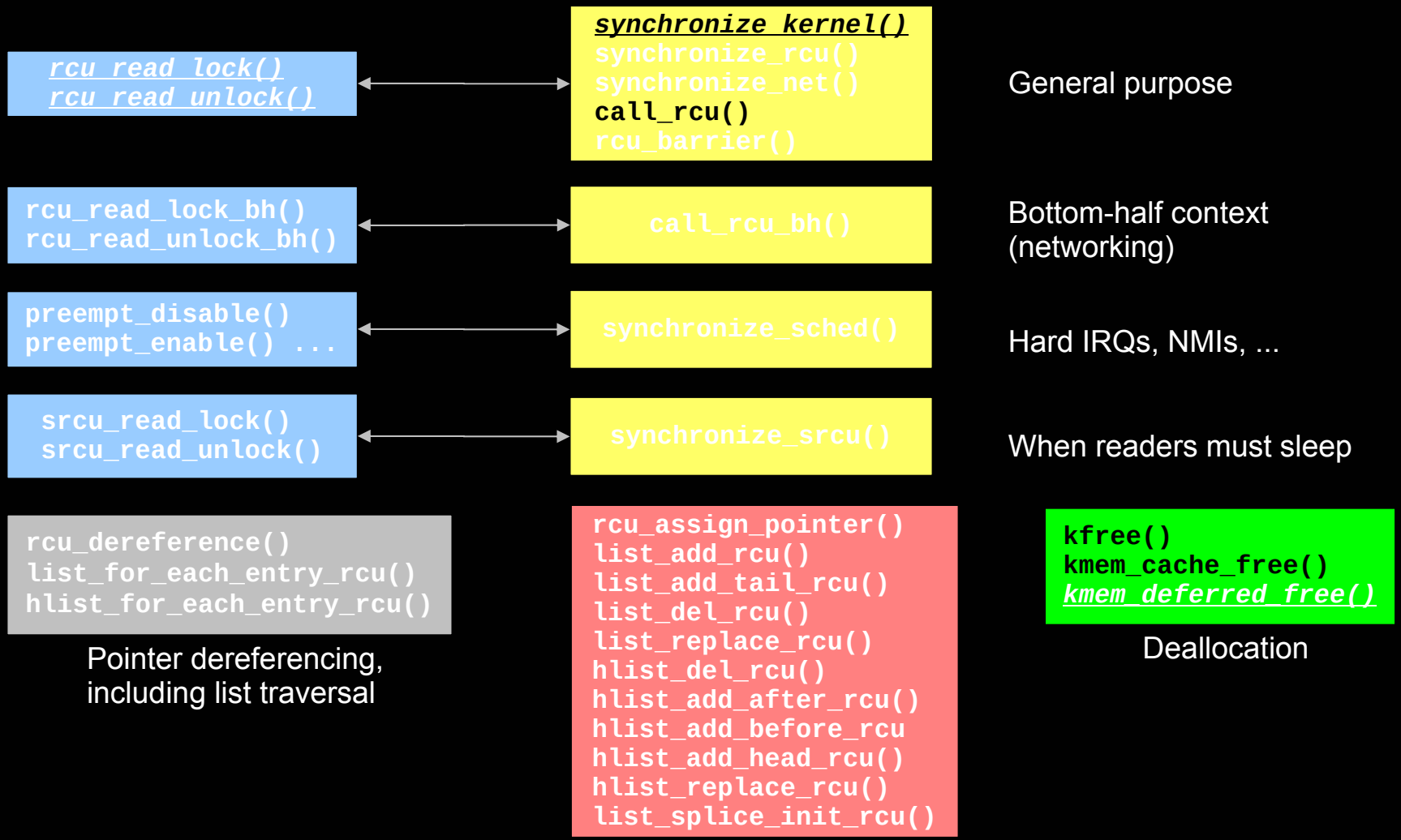
基于Linux经验构建RCU API



对Linux 内核开发者的价值—简易

- **Painful though it may be at times, this is a good thing**
- **In many cases, complexity is a symptom of lack of understanding**
  - If you know only one way to do something, the odds are against it being the best way!
  - Kudos to Andi Kleen, Rusty Russell, Andrea Arcangeli, and many others for generating alternative implementations
  - And to Dipankar Sarma for doing the implementation and incorporating the plethora of excellent ideas from the Linux community

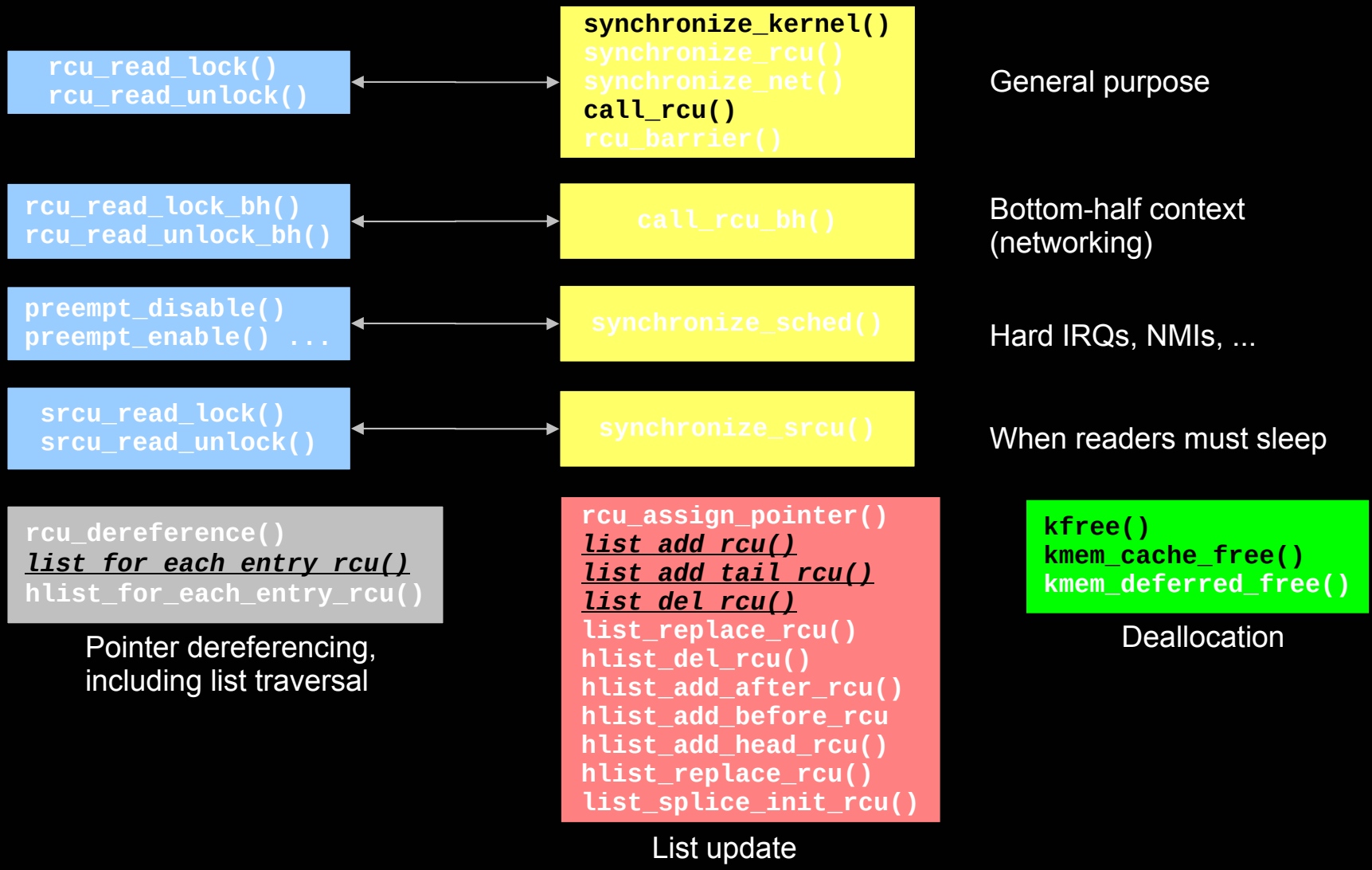
简化的Linux RCU API



内存栅不受欢迎

- **With good reason**
- **They are hard to understand and easy to get wrong**
- **Many maintainers had a blanket policy:**
  - “Reject any patch containing a memory barrier”
  - This has since been softened to require meaningful comments on memory barriers
- **It is far better to bury any needed memory barriers into a well-designed API**
  - Kudos to Manfred Spraul for suggesting the RCU list API!

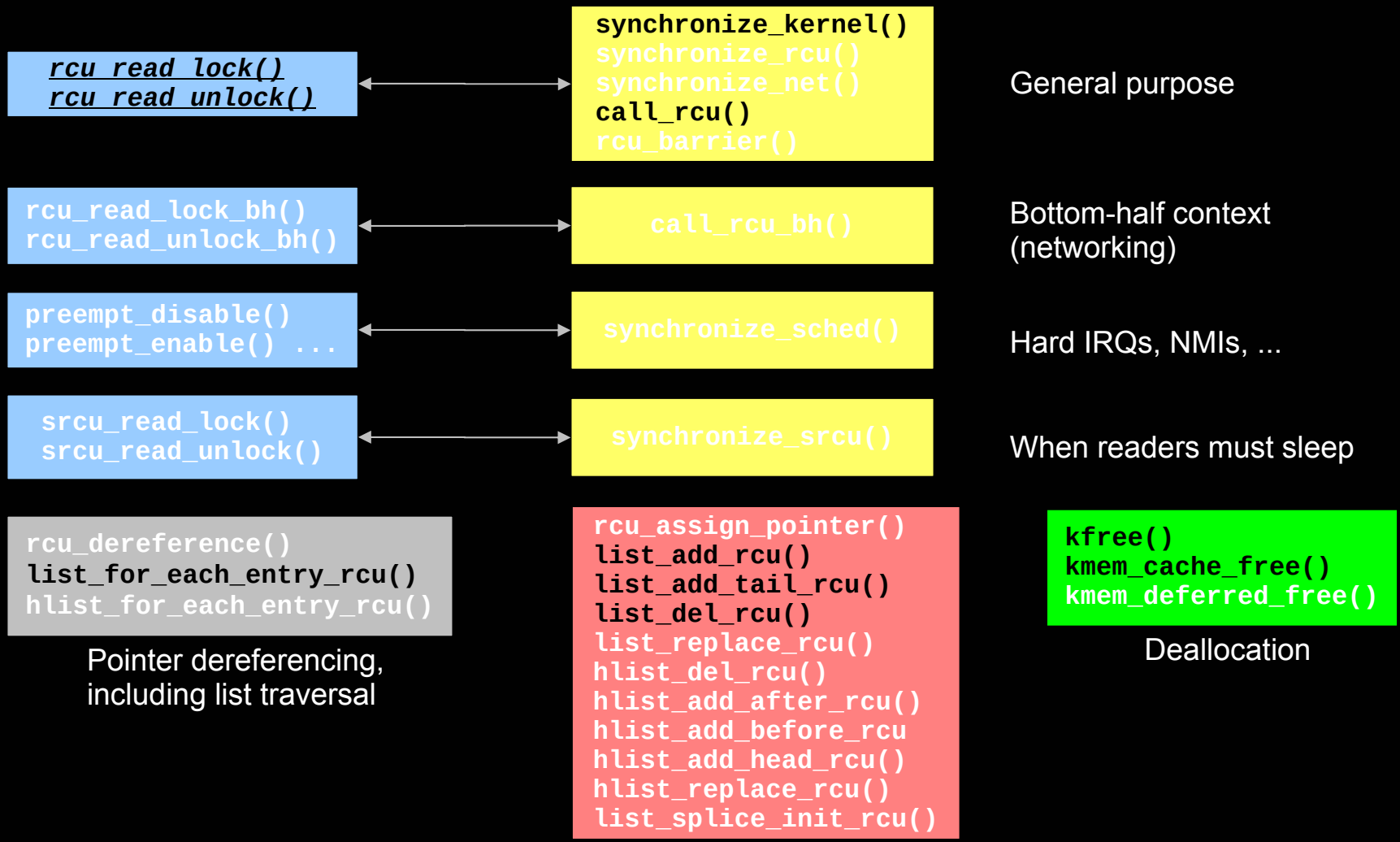
Linux内核内存栅不受欢迎（一）



Linux 内核实时操作系统（一）

- **The CONFIG_PREEMPT function enters the kernel**
- **The kernel becomes preemptable, invalidating key RCU assumption**
- **Easy fix requires bringing rcu_read_lock() and rcu_read_unlock() back into the Linux kernel**
  - Where they have been invaluable documentation aids

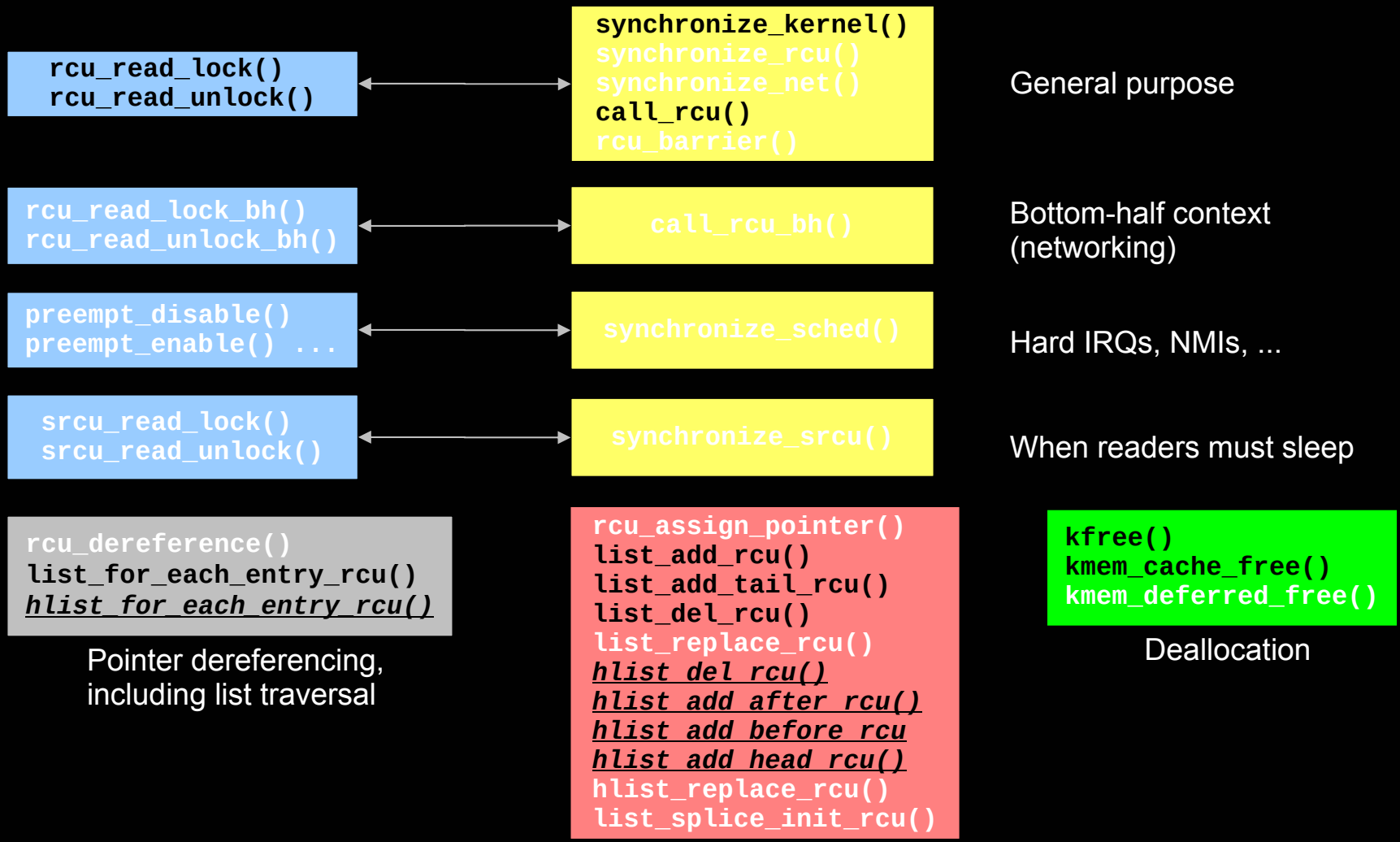
Linux 内核实时操作系统（一）



Linux 内核在小内存系统中运行

- **Linux does circular doubly linked lists**
  - Consumes two pointers per hash bucket
- **Problematic given large hash tables on small-memory machines**
- **Solution: hlist, a linear doubly-linked list**
  - Consumes only one pointer per hash bucket
  - But adds another group of RCU list APIs
  - Implemented by Andi Kleen

Linux 内核在小内存系统中运行

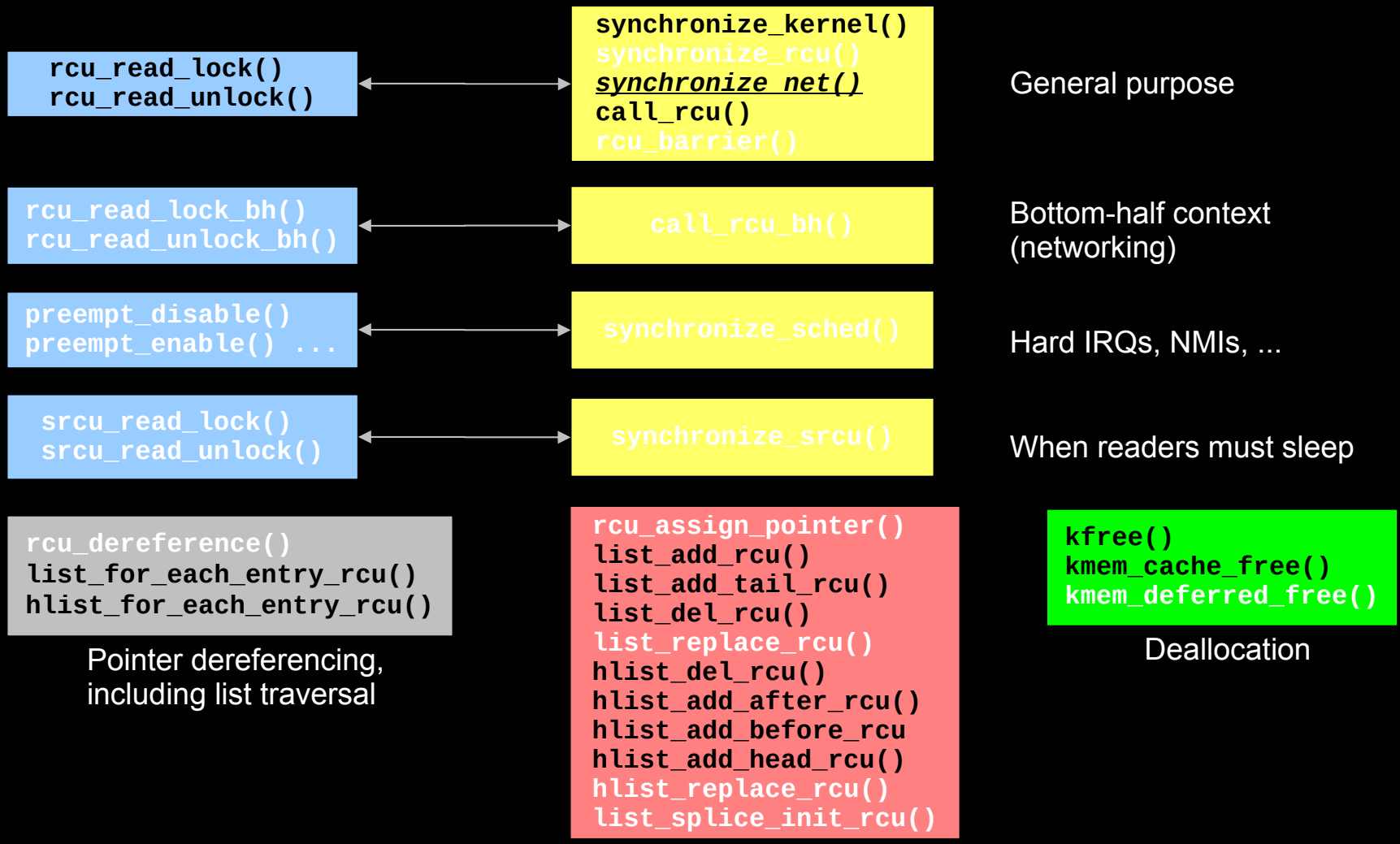


2.5.64

Linux 内核运行繁重网络工作负荷

- **Steve Hemminger converts networking code from brlock to RCU, introducing synchronize_net() to ease the transition**
  - And synchronize_net() continues to be a reasonably useful documentation aid

Linux 内核运行繁重网络工作负荷

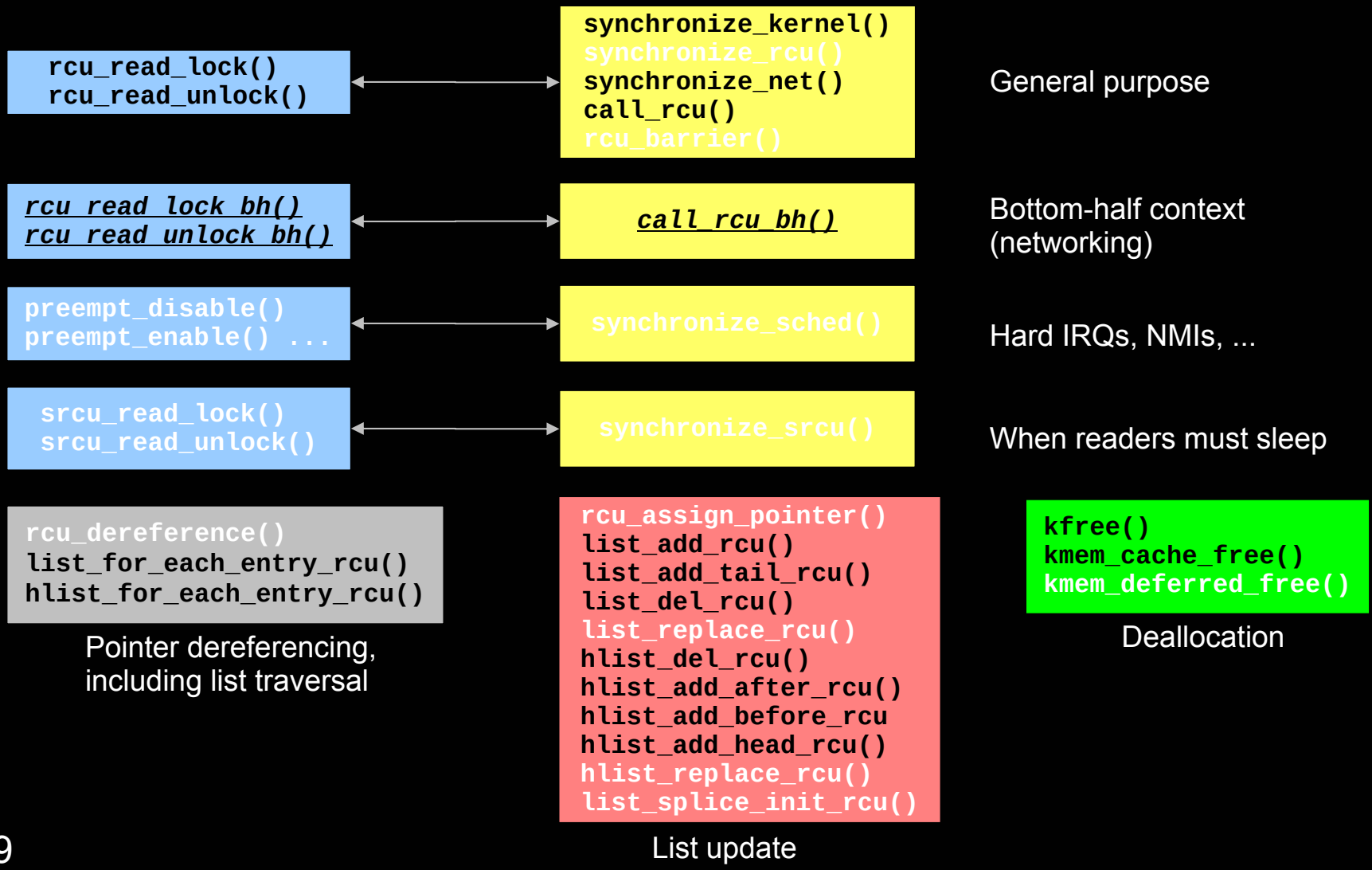


2.5.69

Linux 内核必须抵御网络 DoS 攻击

- **Extremely heavy networking loads from denial-of-service attacks prevent RCU from doing its work**
  - Indefinitely postpones grace periods
- **New _bh variant of RCU avoids this problem**
  - Implemented by Dipankar Sarma with Robert Olsson

Linux 内核必须抵御网络 DoS 攻击

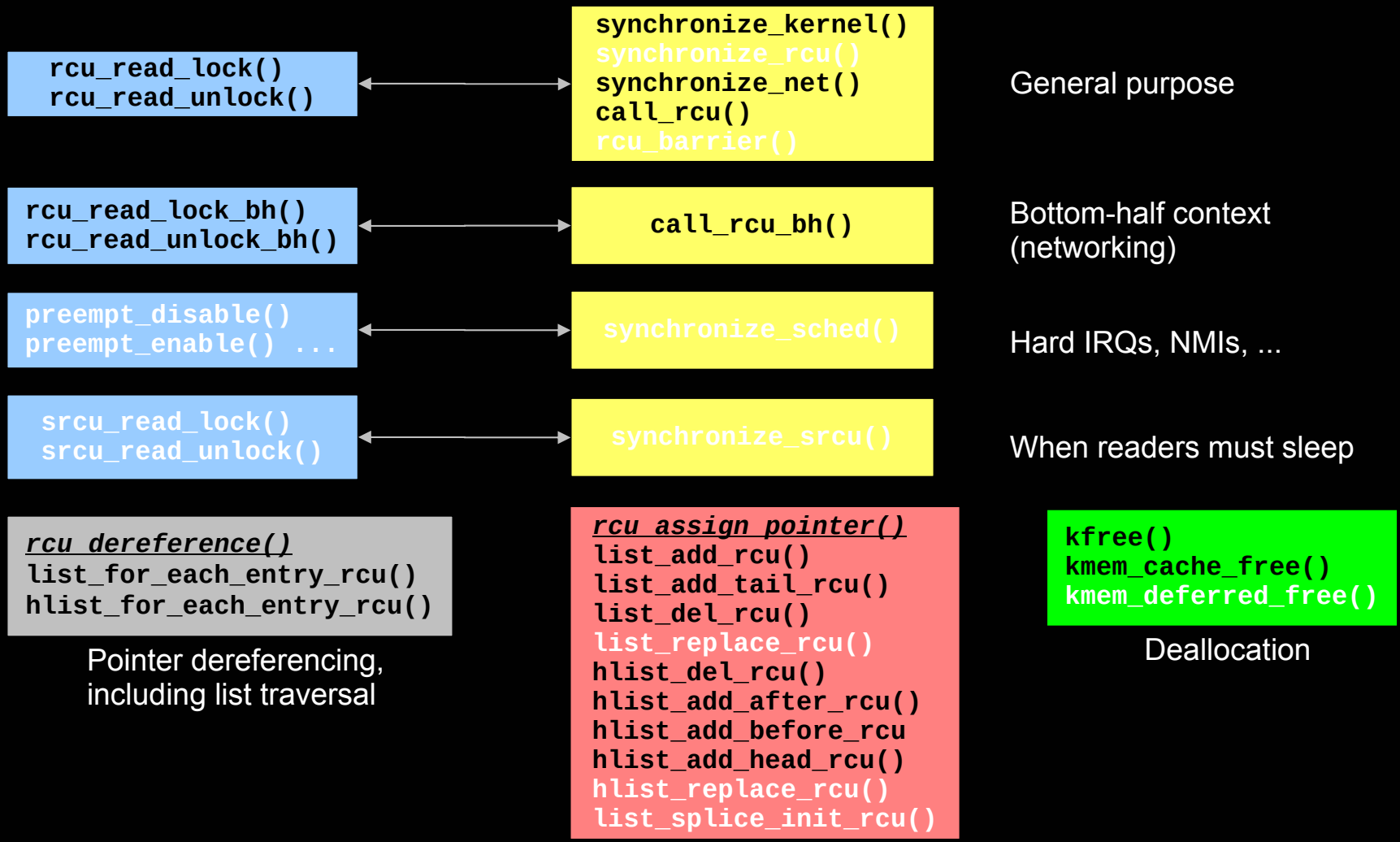


2.6.9

Linux内核内存栅不受欢迎（二）

- **Burying memory barriers in list primitives does not help when applying RCU to non-list data structures**
- **People start applying RCU to trees and the like**
- **Therefore, created primitives to handle this case**

Linux内核内存栅不受欢迎（二）

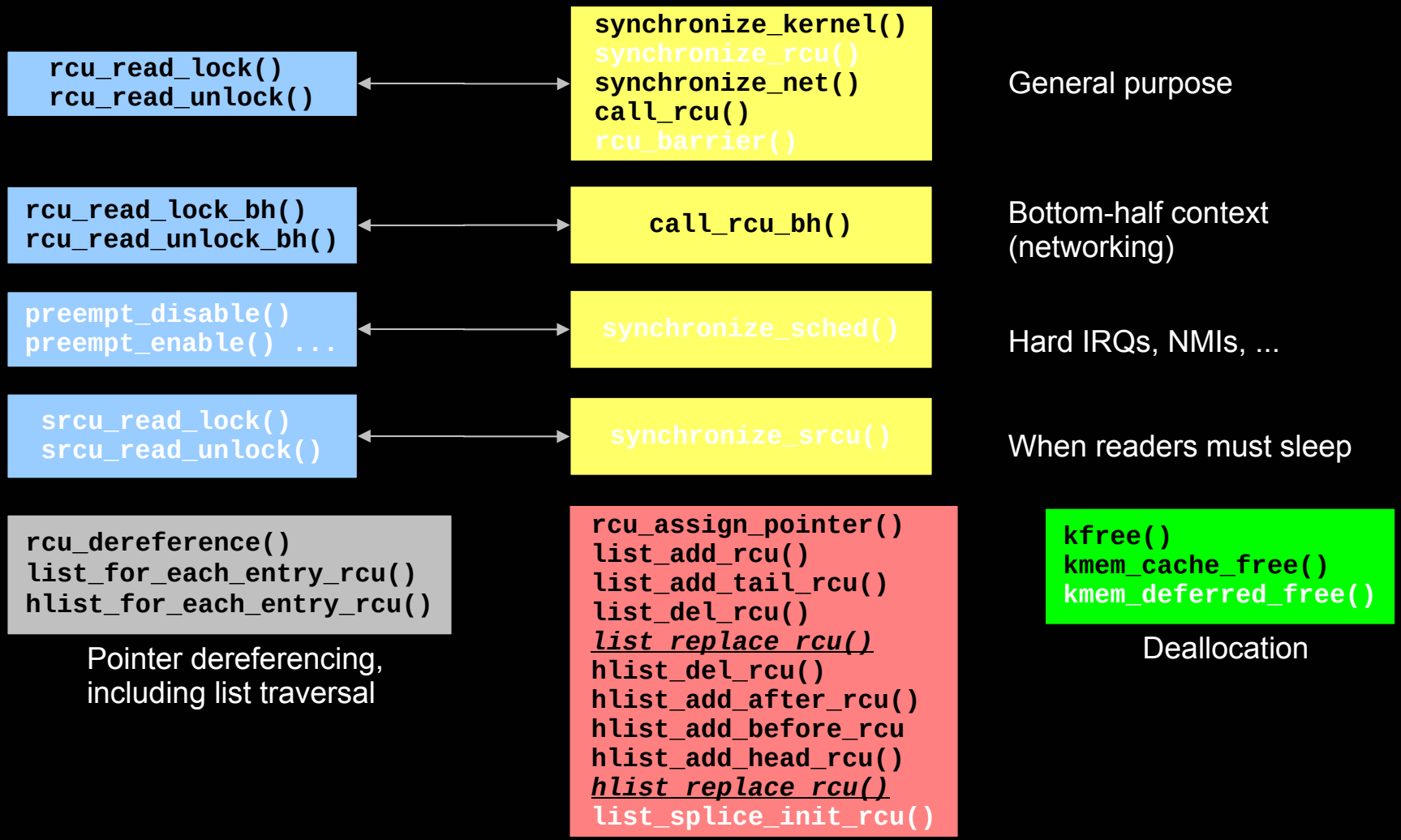


2.6.10

Linux RCU函数的最终名称和实现

- **“RCU” stands for “read-copy update”**
  - Readers access the data structure with copy-based updates
- **As Murphy would have it, this turned out to be an unusual use case**
- **But the Linux kernel eventually needed it**
  - Kaigai Kohei implements it for SELinux AVC work

Linux RCU函数的最终名称和实现

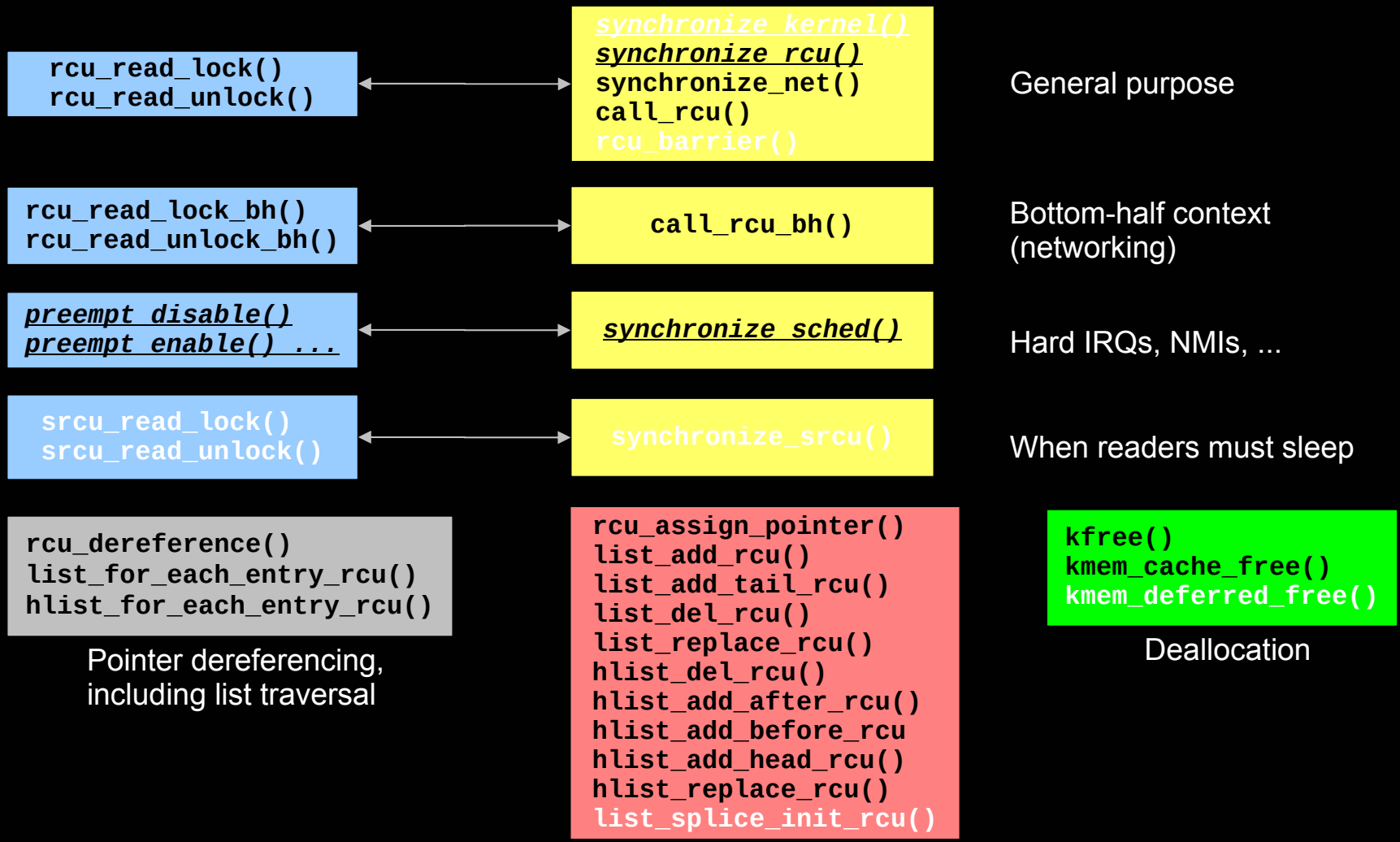


2.6.11

Linux 内核实时操作系统（二）

- **People use RCU for its side effects**
  - For example, waiting for interrupts and NMIs handlers to complete
- **This makes it hard to implement an aggressive realtime implementation of RCU**
  - So we create an alternative API specifically for waiting for interrupt handlers and NMIs
  - See http://lwn.net/Articles/134484/ for details

Linux 内核实时操作系统（二）

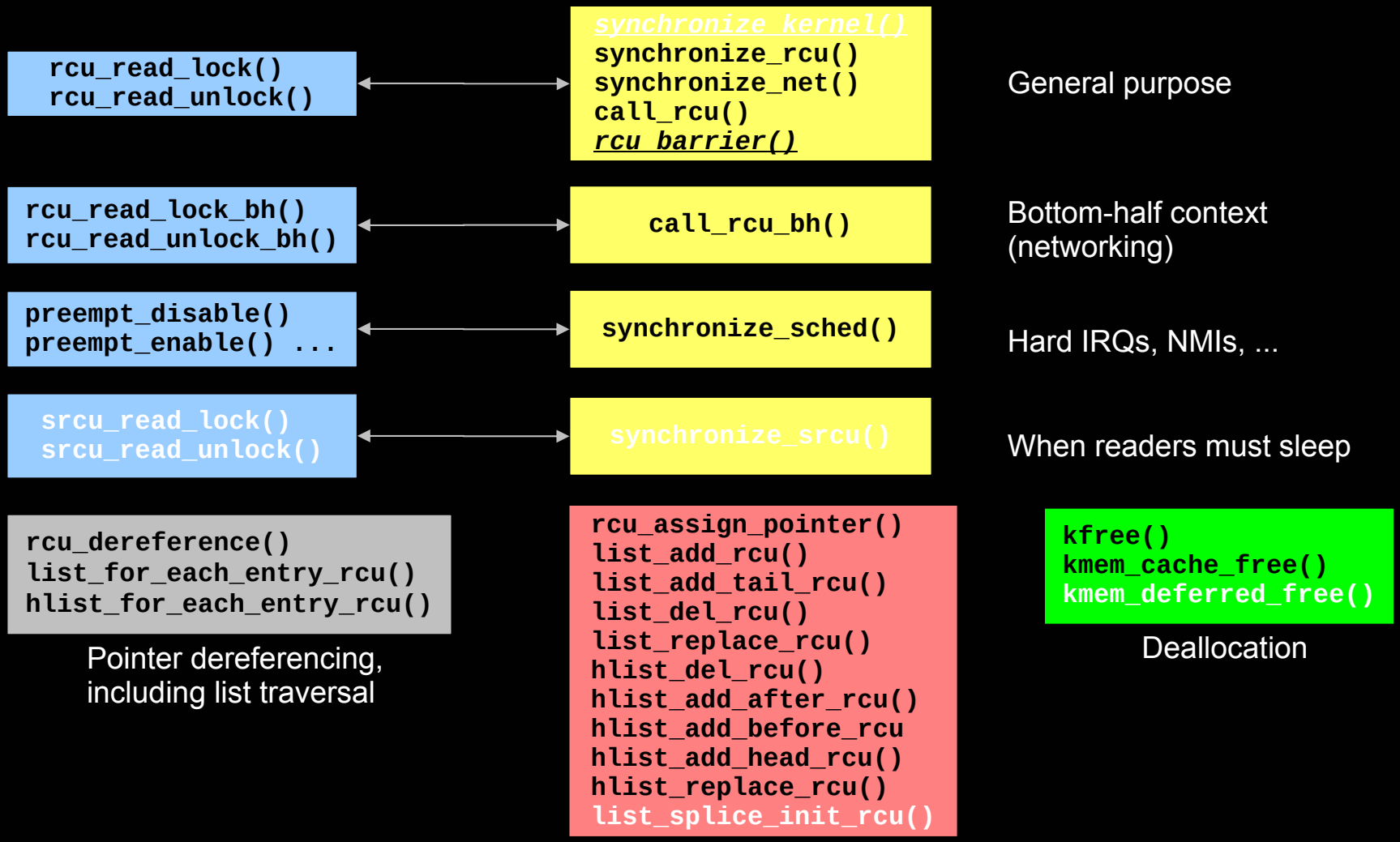


2.6.12

不可载入模块中Linux 内核对 RCU的使用

- **A given module's RCU callbacks can execute after a module is unloaded**
  - So that the affected callbacks cannot find their object code
  - See http://lwn.net/Articles/217484/ for details
- **Added Dipankar Sarma's rcu_barrier() primitive to allow a module to wait for all of its RCU callbacks to complete**

不可载入模块中Linux 内核对 RCU的使用

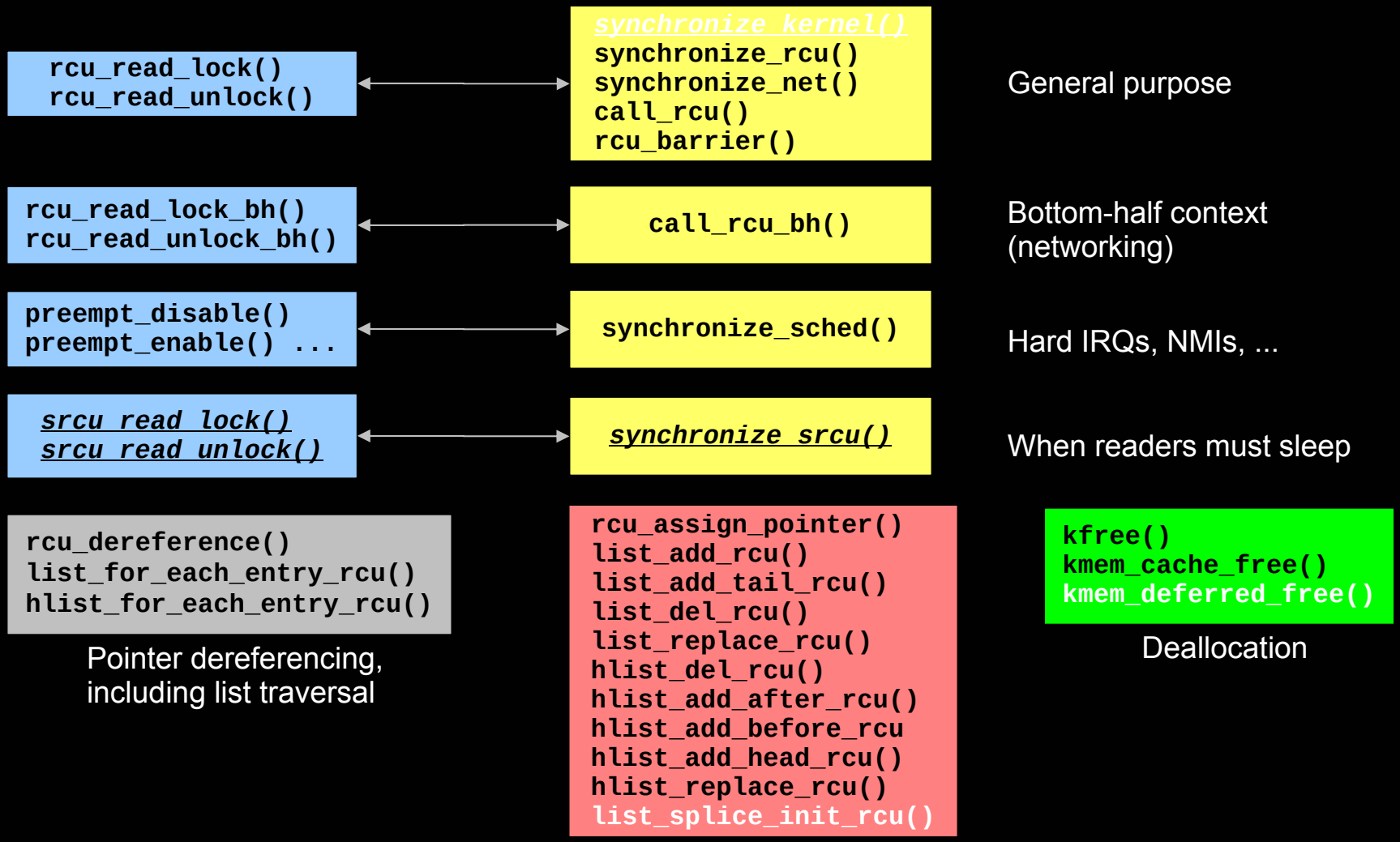


2.6.15

Linux 内核中RCU 读取器需要休眠

- **For more than a decade, “I need my RCU readers to be able to sleep” meant that the speaker didn't really understand RCU**
- **Until 2006, when I found someone who really did need RCU readers to sleep**
- **Hence SRCU...**
  - See http://lwn.net/Articles/202847/ for more details

Linux 内核中RCU 读取器需要休眠

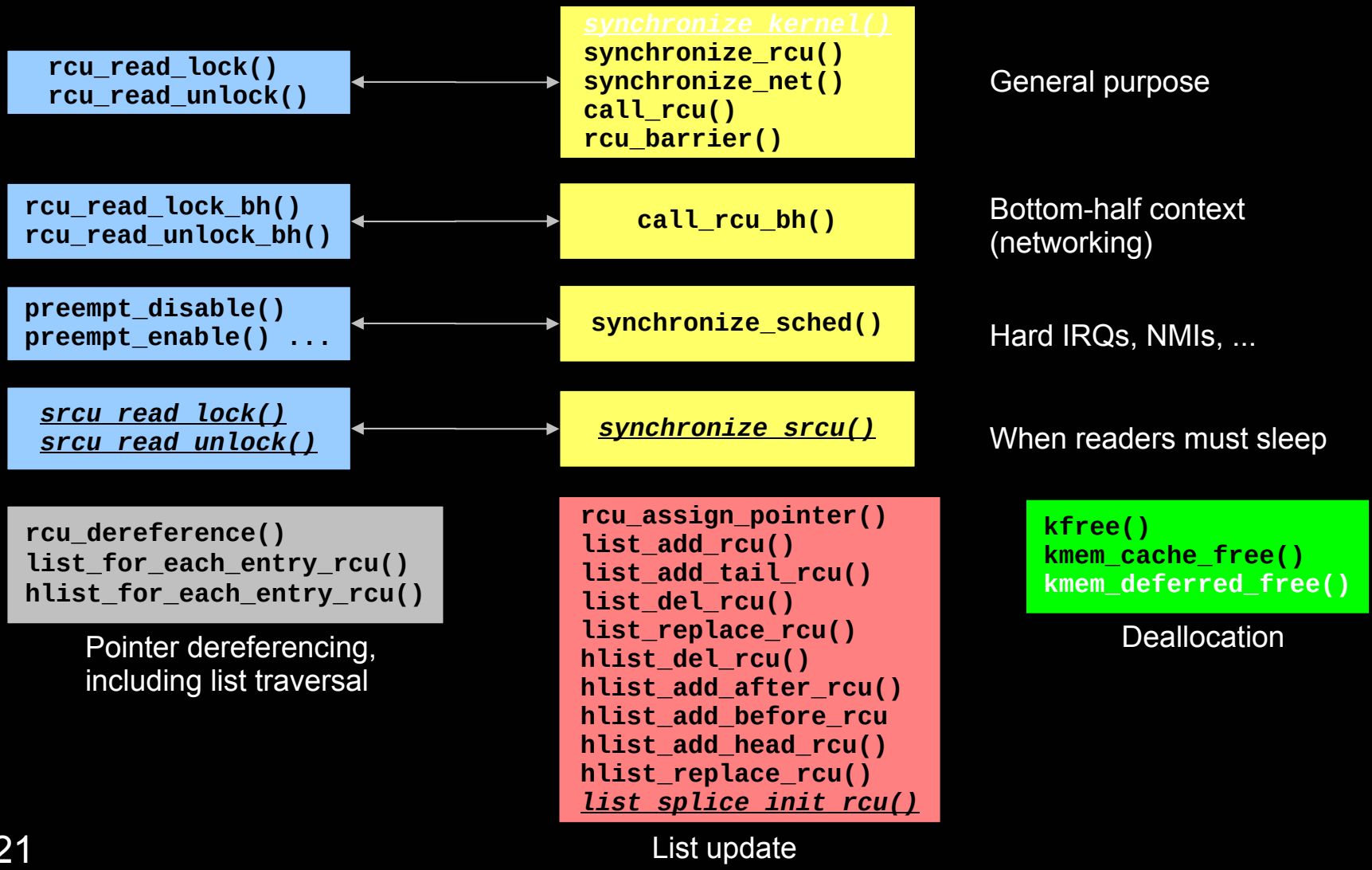


2.6.19

Linux 内核进行成熟的链表运算

- **Reap an entire list while being traversed by RCU readers**
- **We were going to open-code it, but Christoph Hellwig made us create a primitive for this situation**
  - Corey Minyard does the heavy lifting

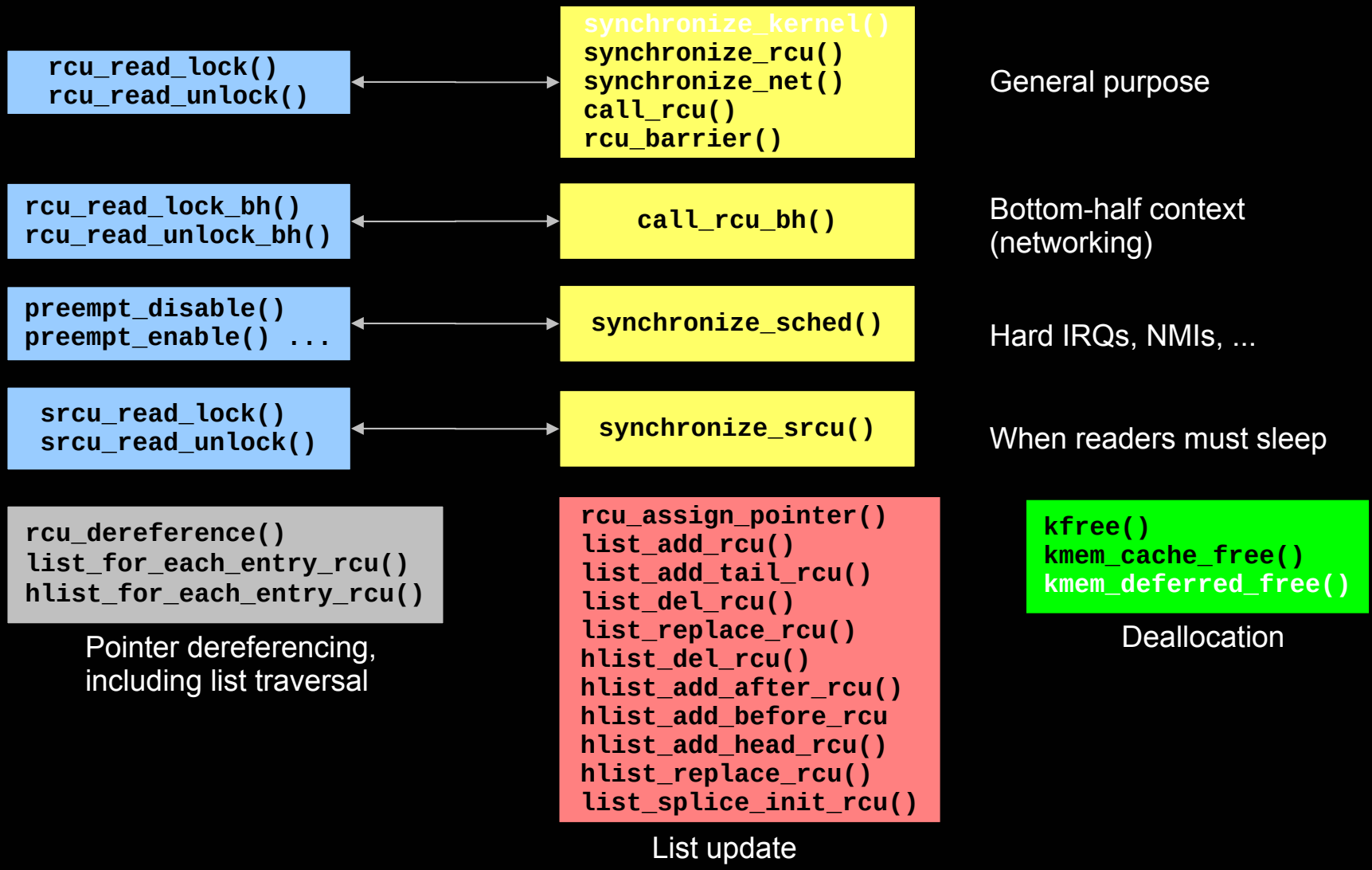
Linux Kernel 进行成熟的链表运算



2.6.21

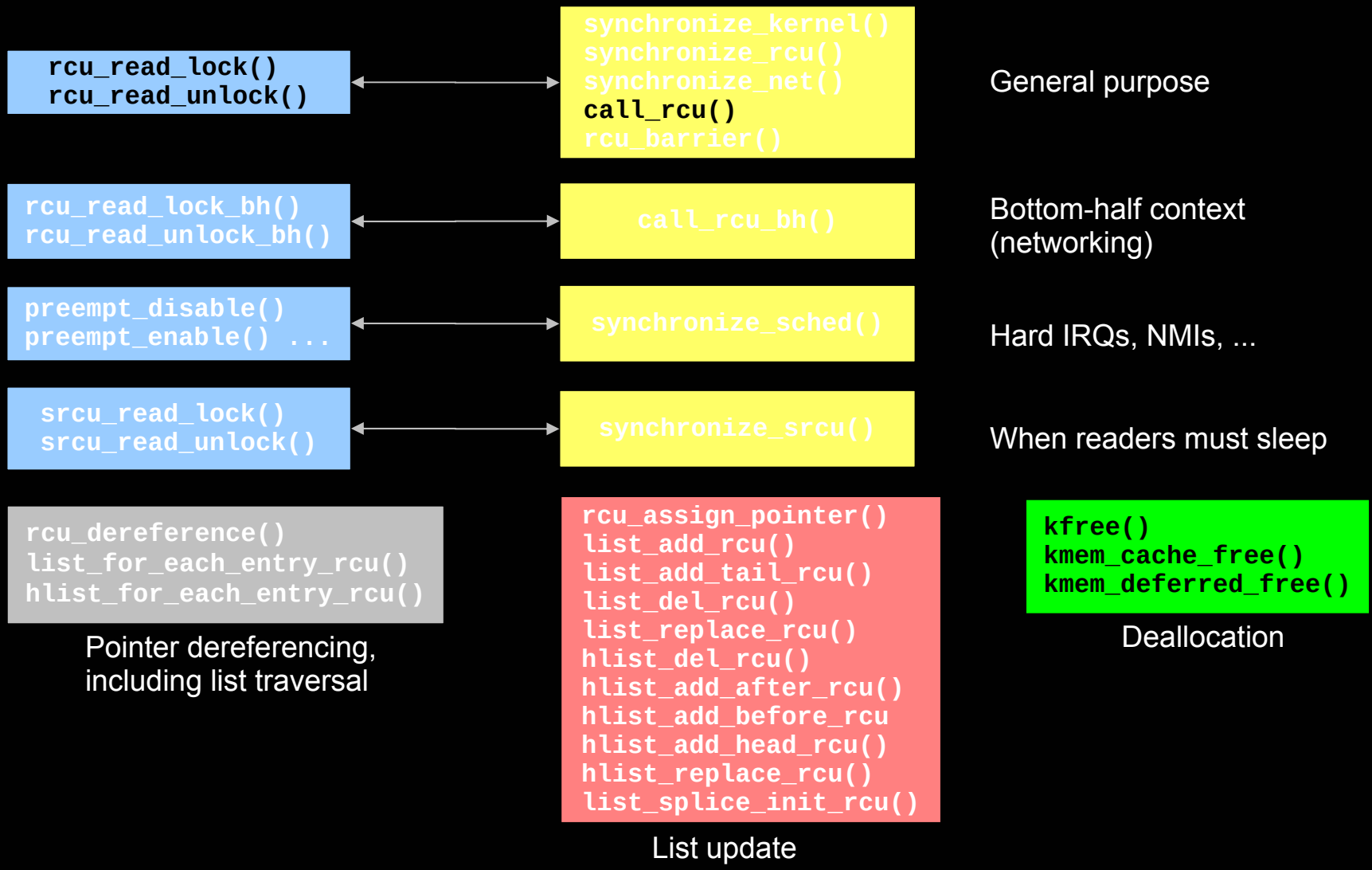
RCU 的现状?

Linux RCU API 2.6.24

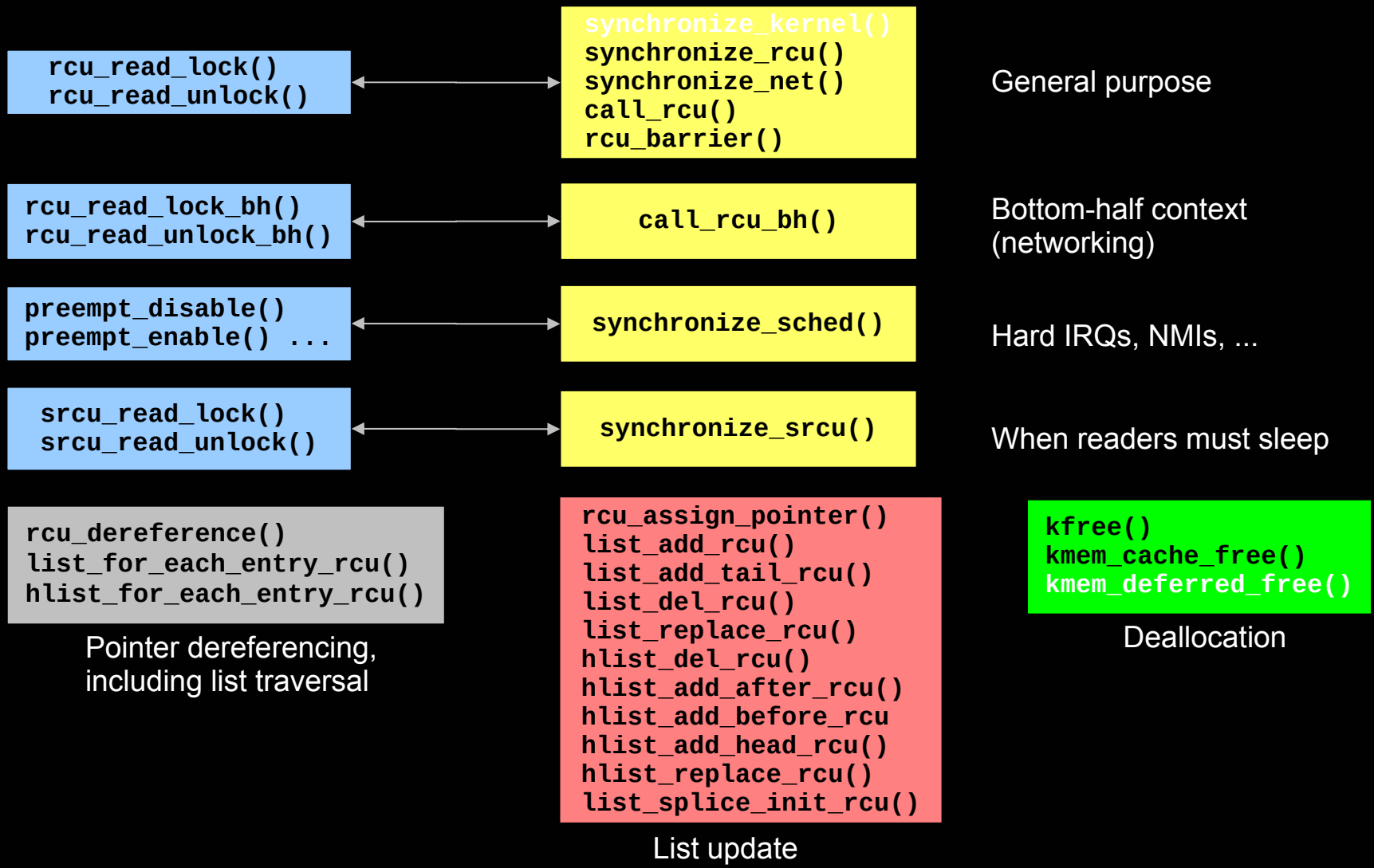


关于Linux 如何改变RCU的总结

这是你的技术



这是你的技术：6x API 增长



关于RCU 的经验总结

关于RCU 的经验总结

- **Linux** 可以运行以难以置信的种类的工作
  - 嵌入式、实时、桌面、网络、服务器和超级计算机 ...
- **Linux** 为重要网络基础结构提供强大支持
  - Linux *可被看作防火墙; 没被保护但胜过防火墙*
- **Linux** 运行实时工作负荷
  - 实时的影响普遍深入
- 大量内核开发者情况 (数千)
  - If 一人每年节省1% 时间:
    - Linux: ~10,000 开发者~每年节省 100 人-年
      - 不到四天便回收成本
      - 即使只有 500 全职开发者，意味着十周即可实现盈利
    - 所有者: ~40 开发者 ~每年节省0.4 人-年
      - 两年多可以收回投资成本
- 在受保护环境中开发出来的技术需要更多的修改!!!
  - 为 Linux 引入技术是一项有益的学问

结论

为 Linux贡献技术及其有益

但不轻松!!!

法律声明

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- **IBM, IBM (标识), e-business (标识), pSeries, e (标识) server, xSeries** 等是国际商业机器公司在全球的注册商标.
- **Linux** 是**Linus Torvalds**的注册商标.
- 其他公司、产品和服务的名称可能是其他公司的注册商标.

问题?