TOWARDS PERFORMANCE ANALYSIS OF NON-BLOCKING CONCURRENT DATA STRUCTURES IN THE LINUX KERNEL

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Lock Free Data Structures

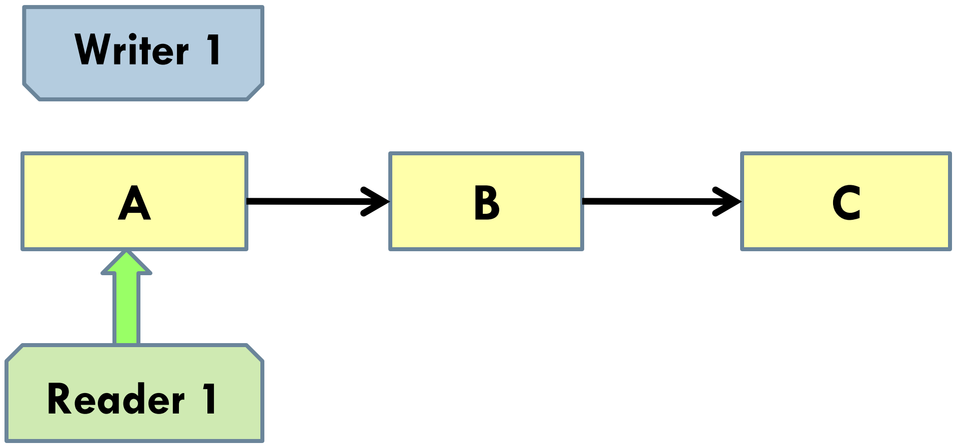
- Allows multiple threads to work in parallel on a particular data structure of interest.
- No wastage of CPU-cycles for waiting for a mutex lock.
- Other major problems to consider:
  - ABA problem
  - Memory Reclamation

Read Mostly Lock Free Data Structures

- Lock Free Data Structures are often compiled with memory reclamation methods.
- Research for Read Mostly Lock Free Data Structures
  - Read Copy Update Mechanism
  - Read Log Update Mechanism

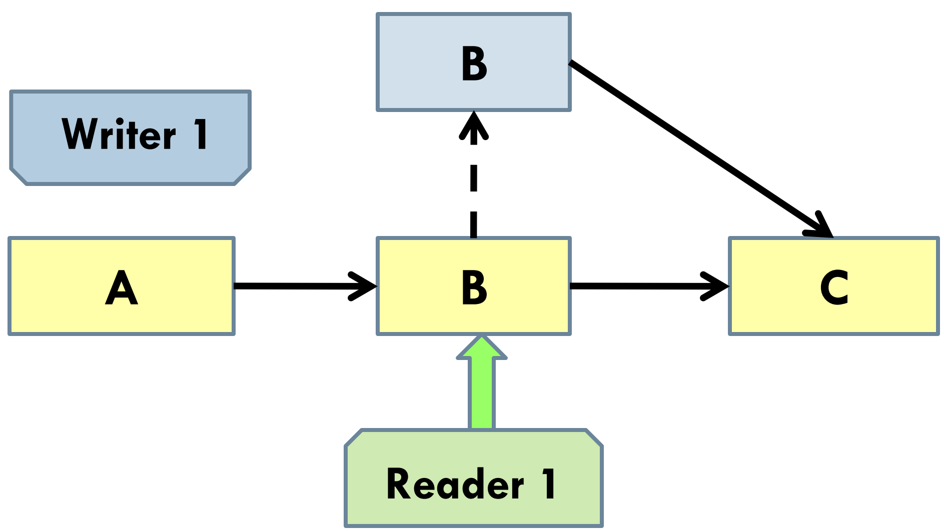
Read Copy Update

- Never Block Readers
- Writer synchronization left to the developers
- The Mechanism:
  - Read:



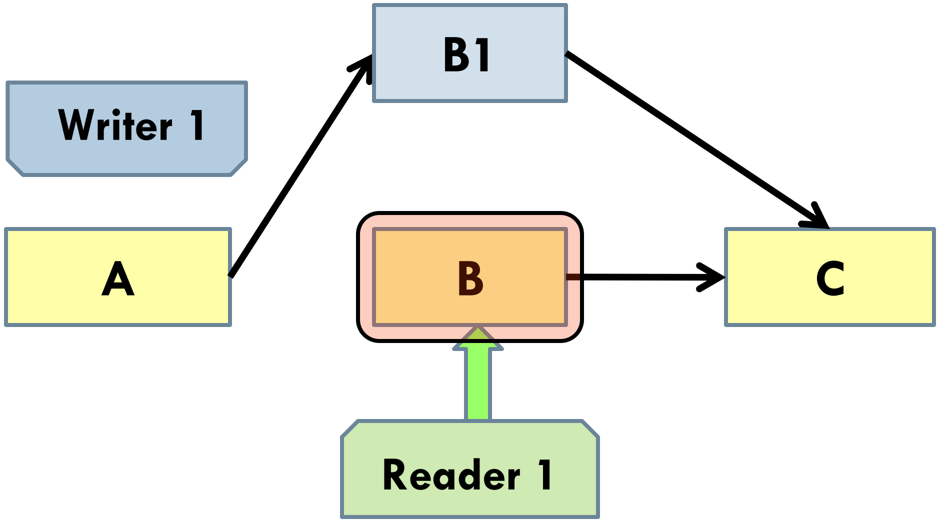
Read Copy Update

- Never Block Readers
- Writer synchronization left to the developers
- The Mechanism:
  - Copy:



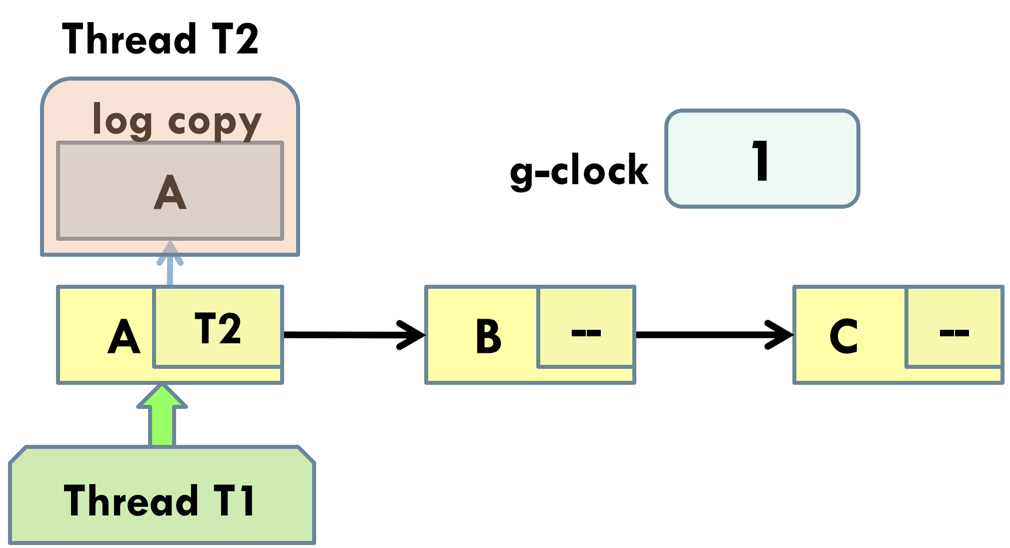
Read Copy Update

- Never Block Readers
- Writer synchronization left to the developers
- The Mechanism:
  - Update:



Read Log Update

- Provides a per thread log for concurrent writers
- Easy to use writer synchronization
- The Mechanism:
  - Read-Log:



Read Log Update

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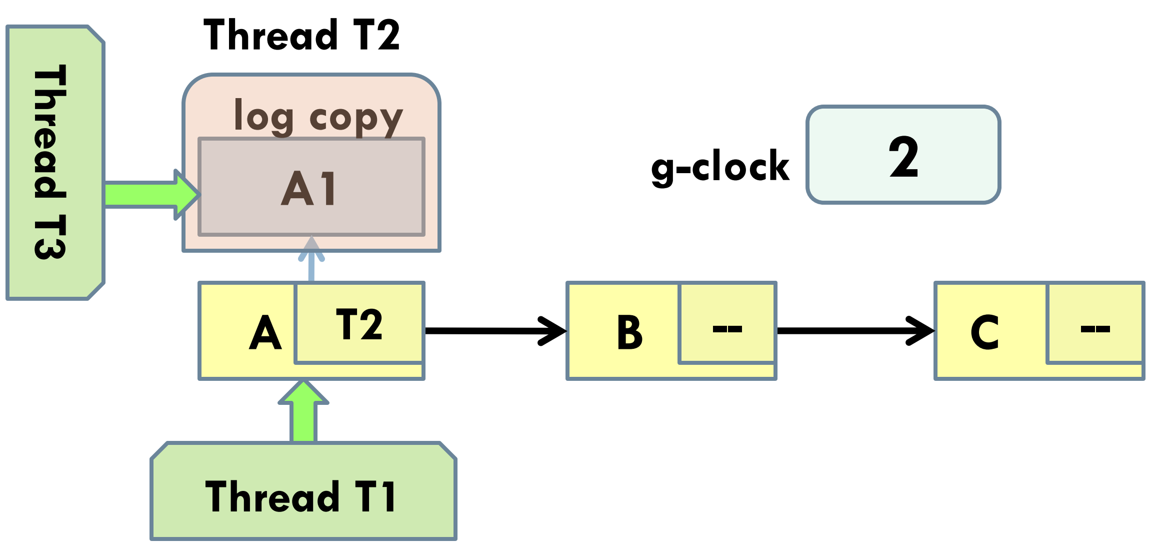


Contents

Problem Statement

- Compare existing Read Mostly Lock Free Mechanisms.
- Answers to find:
  - Should writers be helped to improve overall performance?
  - Can we improve existing list based semantics in use to improve cache utilization?

Contents

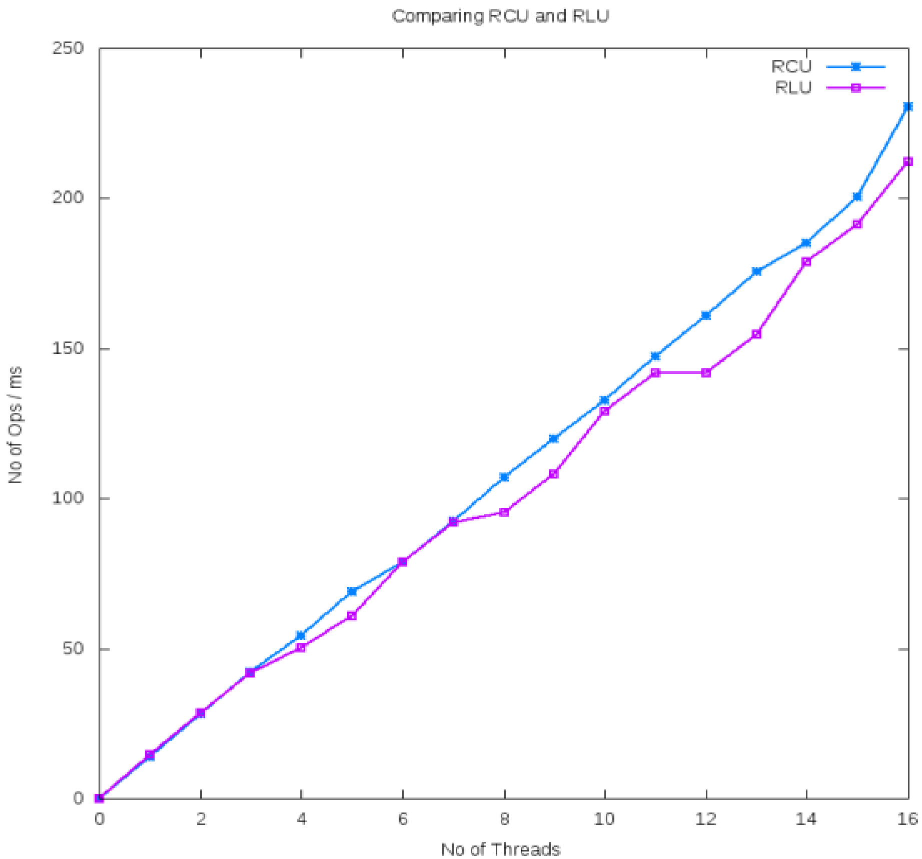
- Introduction
- Problem Statement
- Establishing Claims
- Conclusion and Stage-2 Plans

Verifying Read-Log-Update Claims

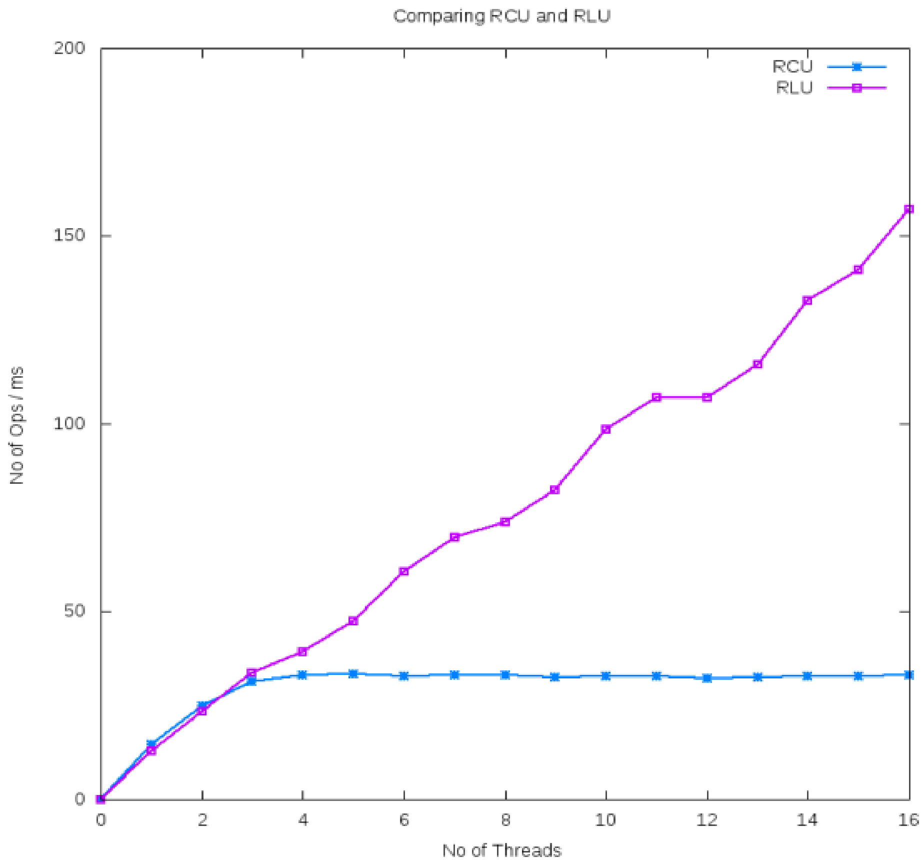
- Questions:
  - Is RLU better than RCU?
  - Does Node-Size matter in the comparisons?

- Experiments for Comparing RCU and RLU
  - System: 16 core blade server(Intel Xeon) supporting 16 Hardware threads.
  - Compared using benchmark used by RLU authors

Comparing Linked Lists



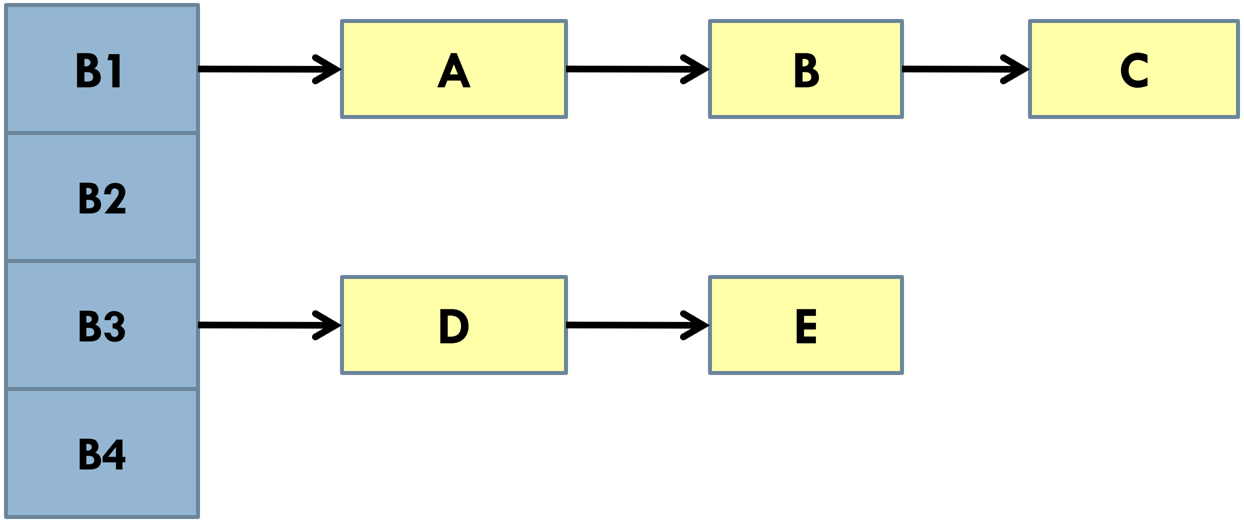
Comparison with no updates



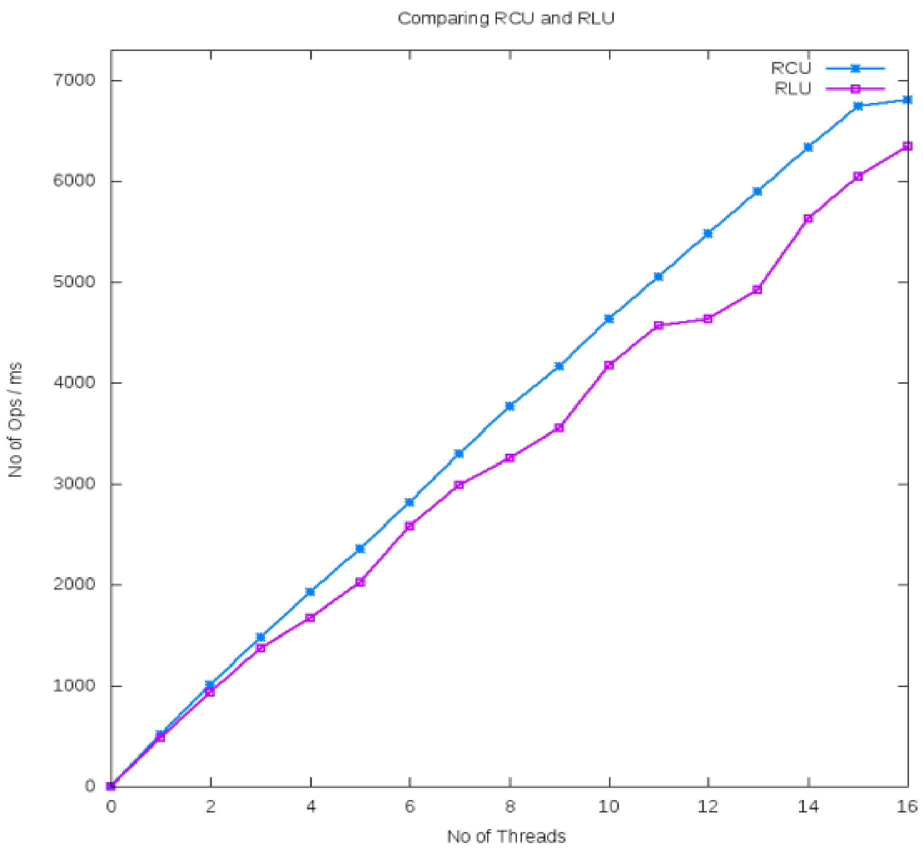
Comparison with 40% updates

Comparing Hash Lists

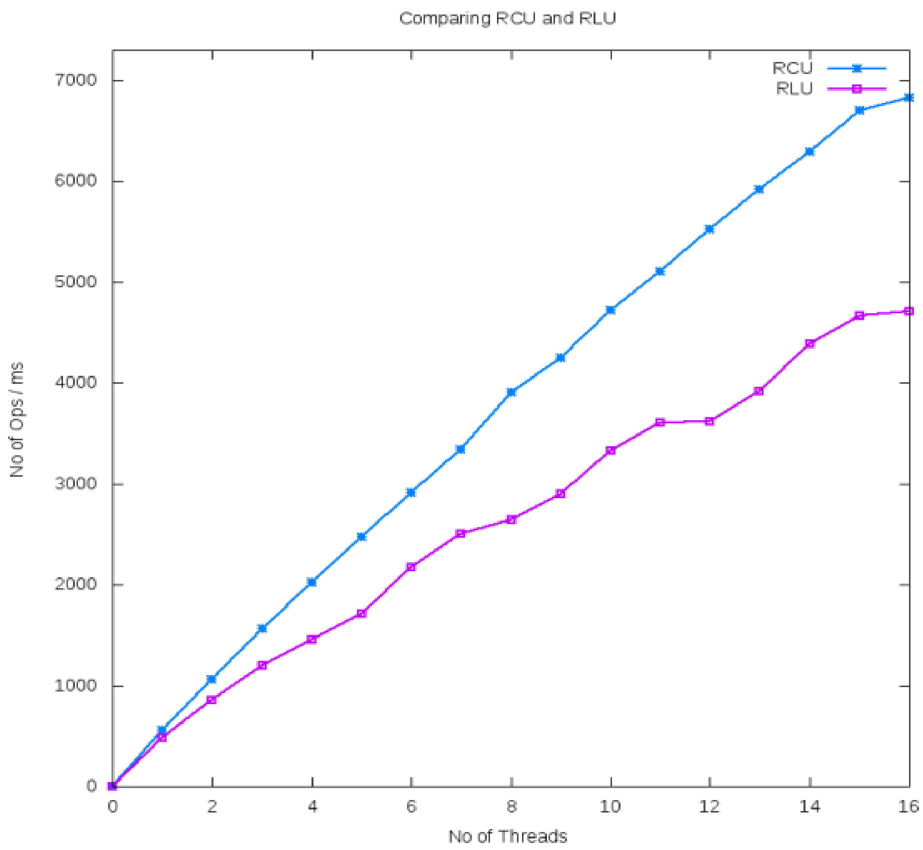
- Hash Lists protected by RCU and RLU in use



Comparing Hash Lists

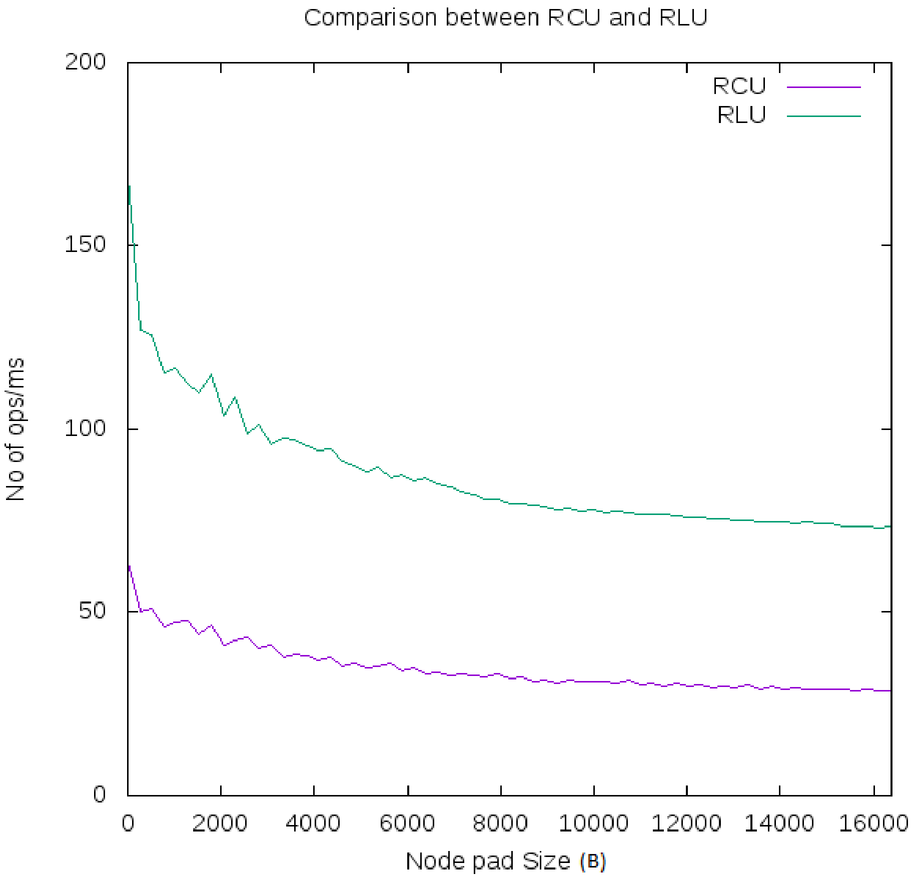


Comparison with no updates

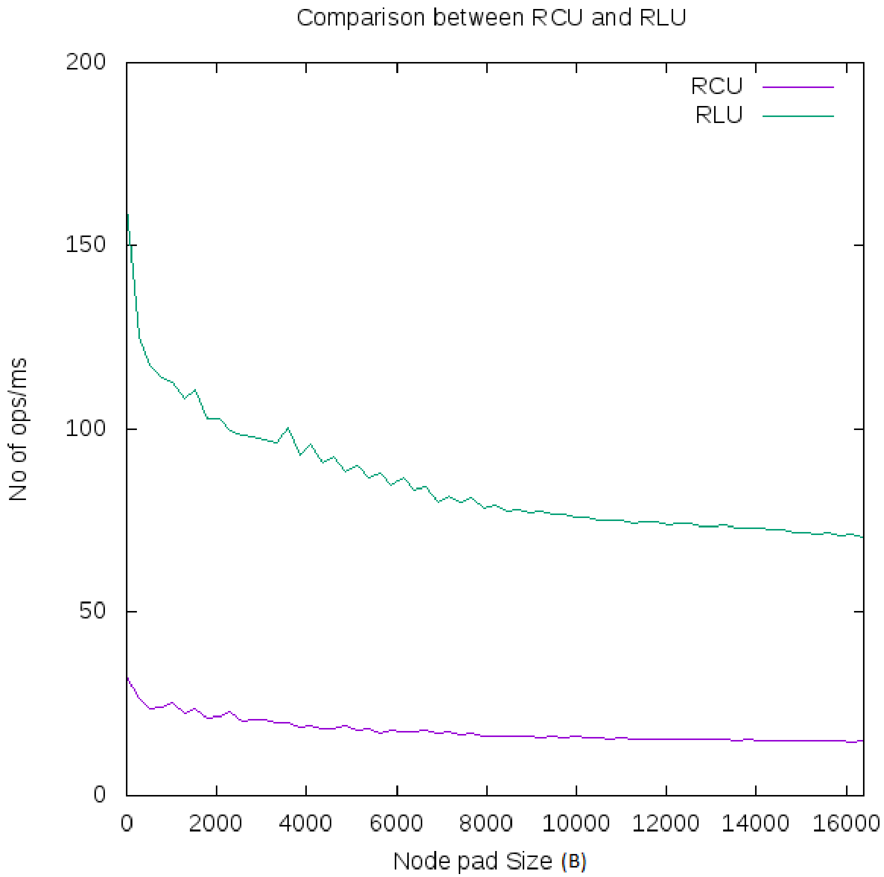


Comparison with 40% updates

Does Node Size Matter?



Linked List with 20% updates



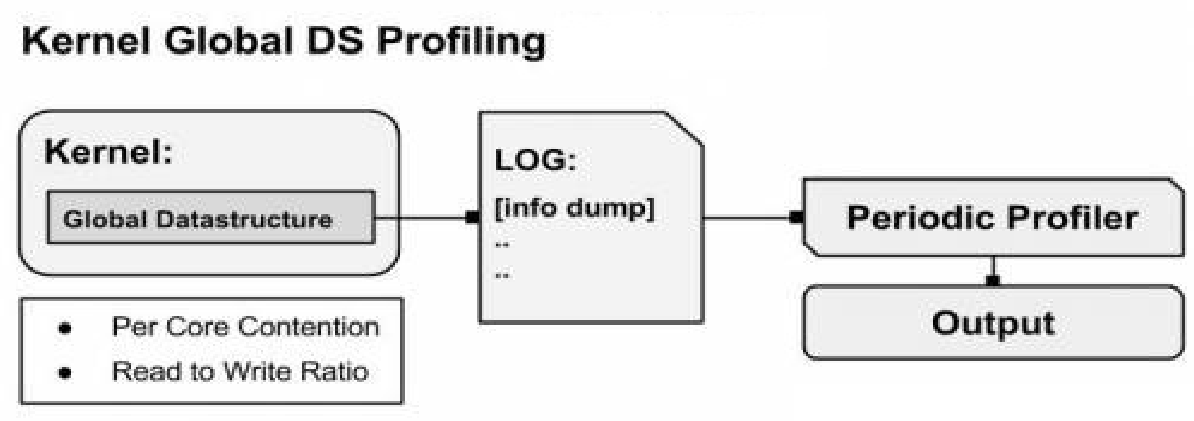
Linked List with 40% updates

Kernel Side of the Story

- Question:
  - Do the writers need any optimization?
- Understand the usage behavior of the currently used RCU protected data structures
  - Read-Write Ratio
  - Write Contention

Experiments:

- System: 4 core Intel i5 processor(1.2GHz), 8GB Ram
- Design:



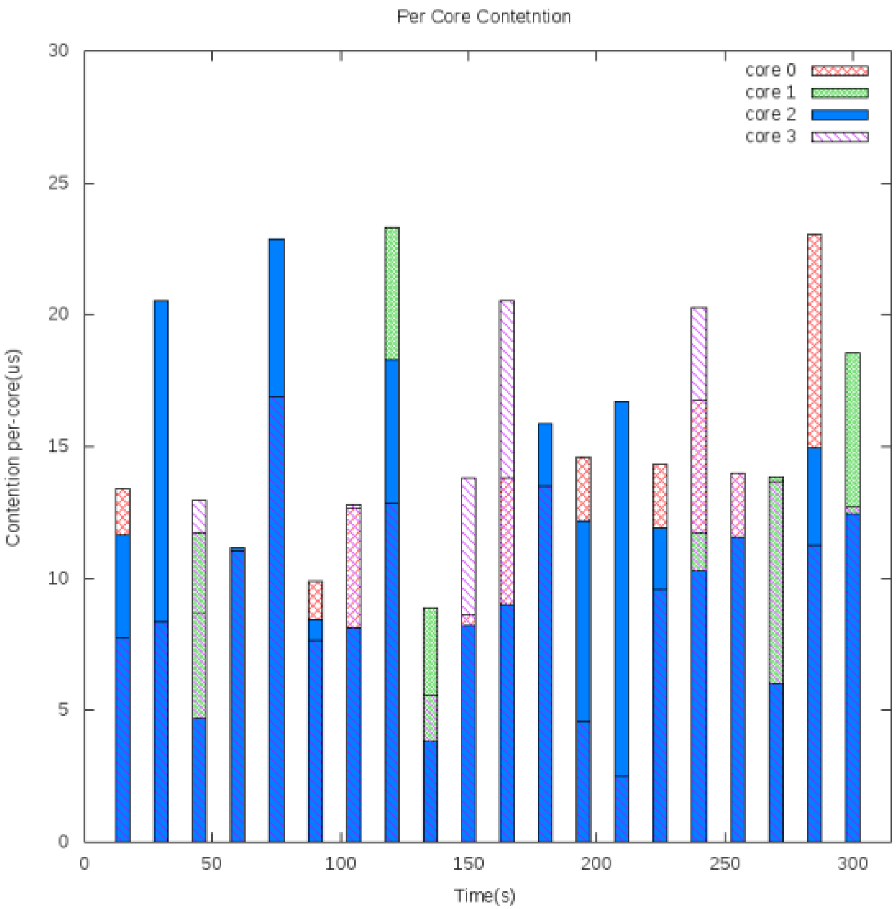
- Workload:
  - Web Server Workload
  - Process List Stress Workload

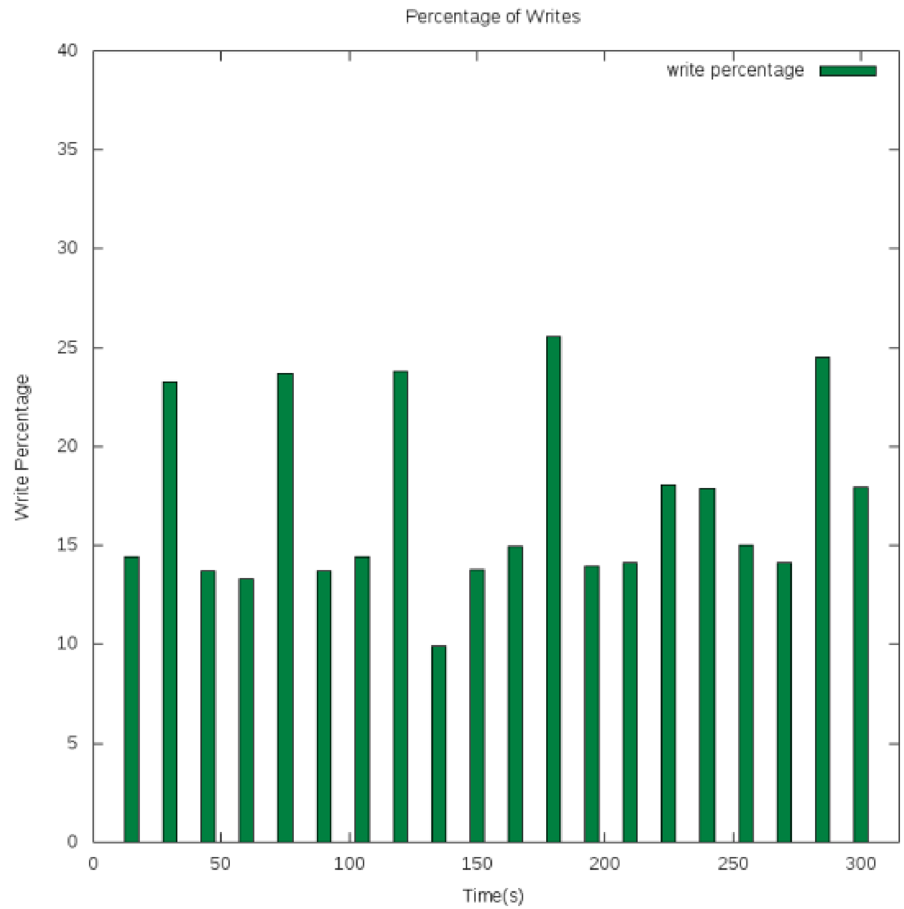
Profiling Data Structures

- List to Track: epoll file descriptor list
- Server in use:
  - Nginx local server that uses epoll to serve multiple client requests
- Client Statistics:
  - 1000 parallel clients created every 5 seconds
  - Each client making 10000 requests in parallel to localhost.

Profiling Data Structures

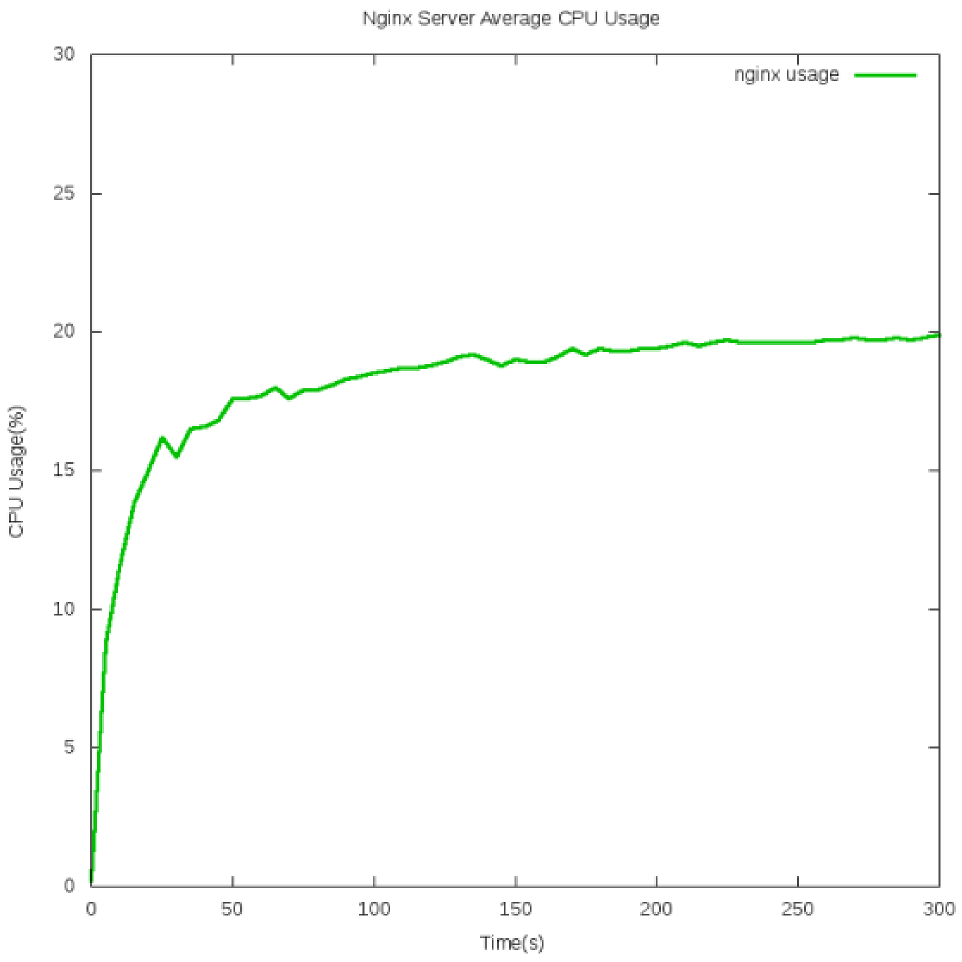
- Workload Load: Web Server Workload





Profiling Data Structures

- Workload Load: Web Server Workload

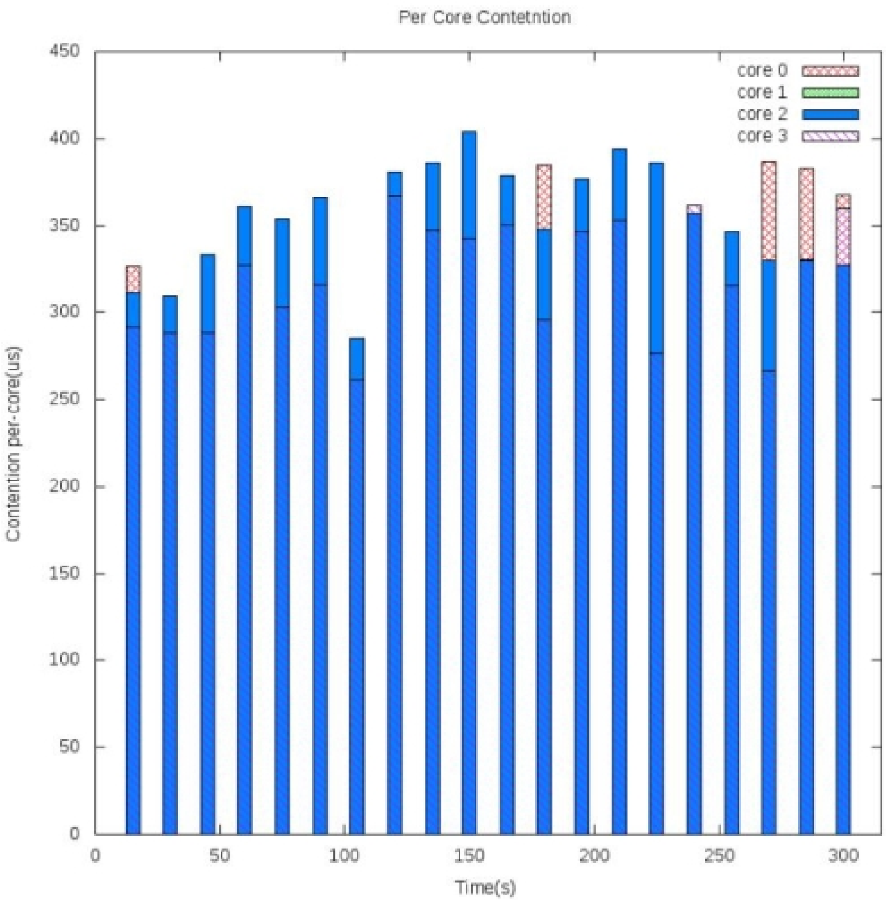


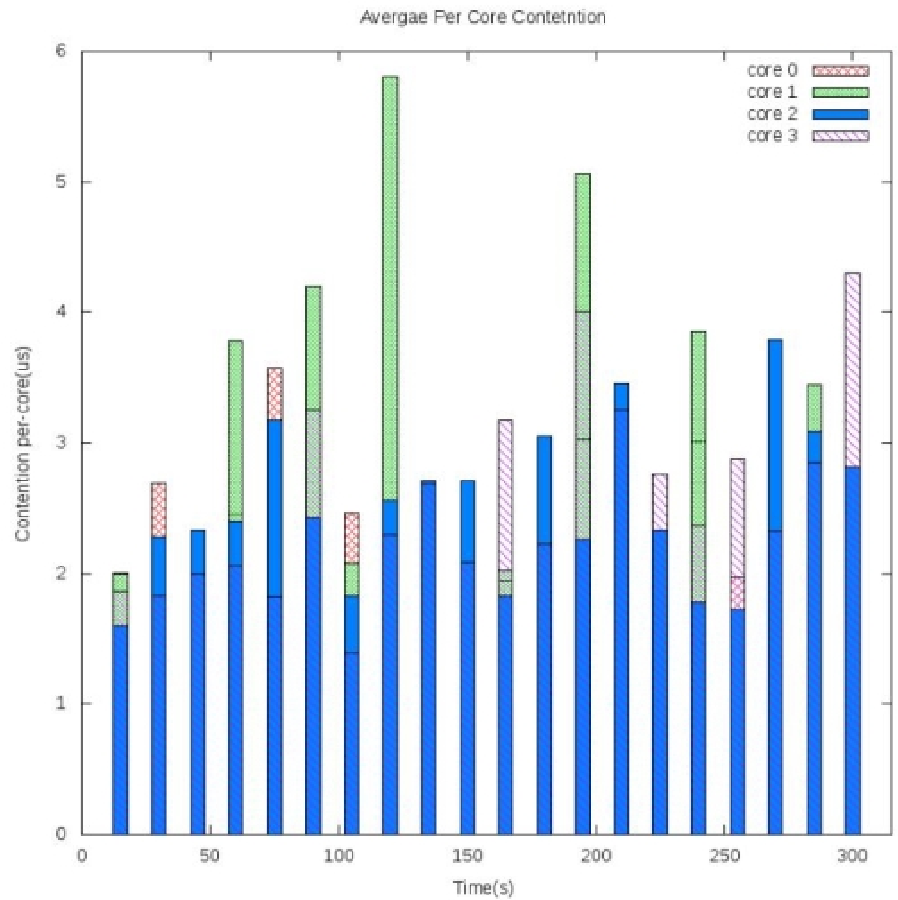
Profiling Data Structures

- List to Track: List of all processes
- Synthetic Workload:
  - 250 parallel threads
  - Each thread creating 500 empty threads every 5 seconds

Profiling Data Structures

- Workload Load: Synthetic Stress Workload





Helping the Readers

- Questions:
  - Can we provide a cache friendly way of traversal?
  - Should the list based semantics be changed?
- Kernel data structures uses list based semantics
- But, arrays provide better cache utilization than lists

Observations

- Are the lists ordered?

Name of List Head	Insertion Behavior	Deletion Behavior
List of process with same thread-id	Inserts at head	Delete anywhere
List for epoll file descriptors	Inserts at tail	Delete anywhere
List of all running processes	Inserts at head	Delete anywhere

Table 1: Usage Behavior Observations

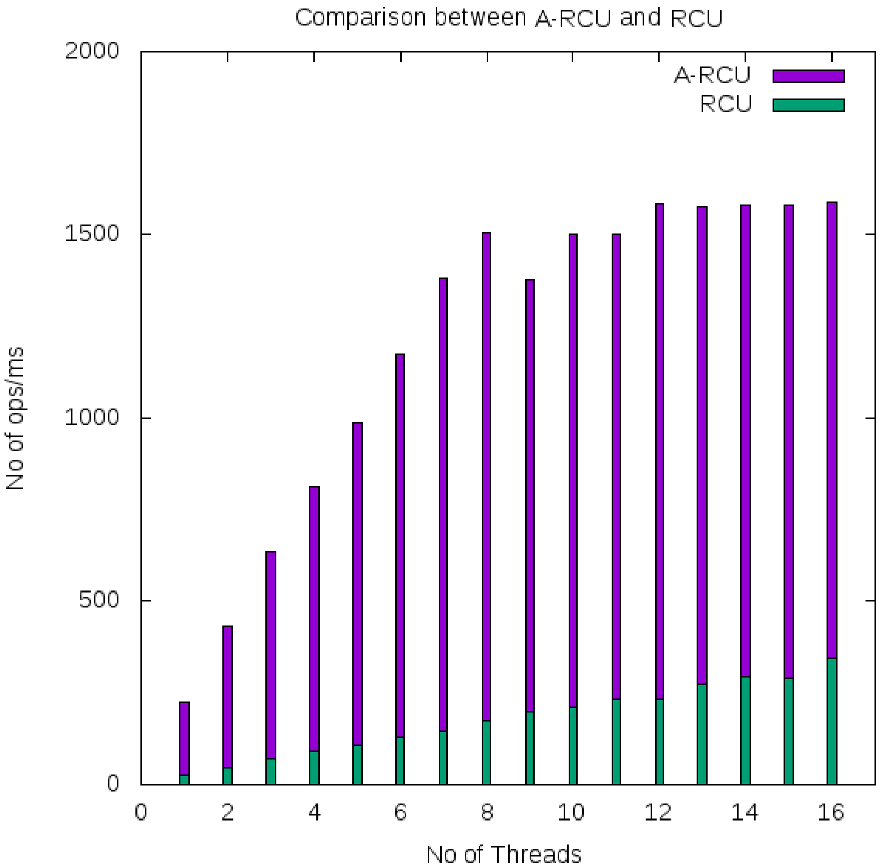
Usage Statistics	Linked List	Hash List
No of such RCU protected data structures in the Kernel	236	71
Inserts at list tail	109	–
Inserts at head	127	71

Table 2: Usage Statistics Assumptions

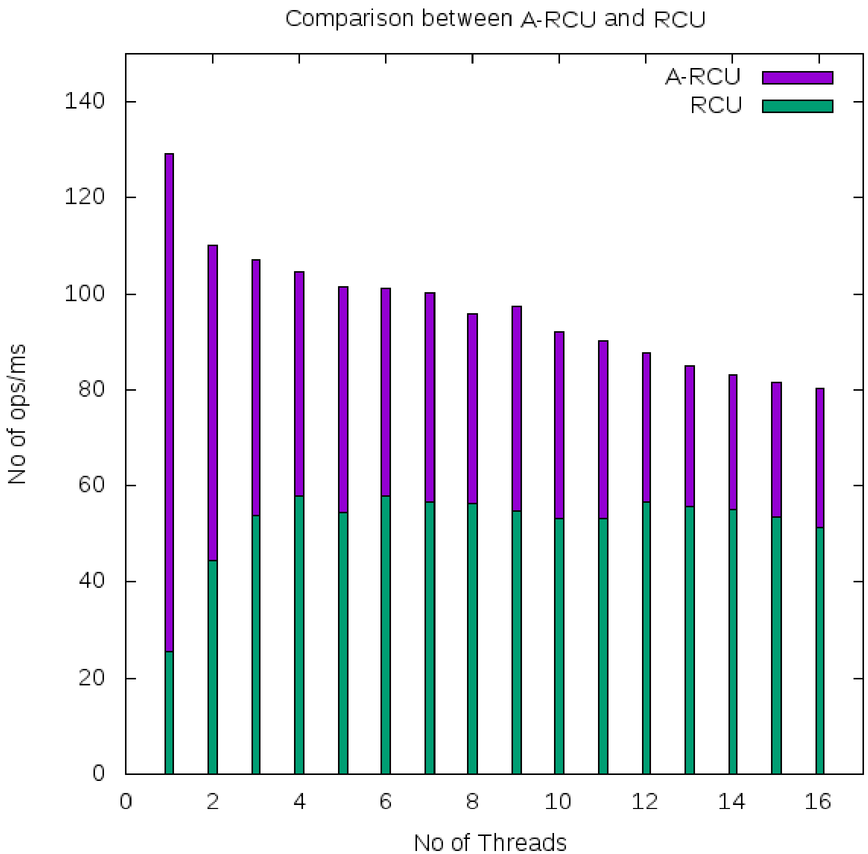
RCU Protected Arrays

- Can RCU protected Arrays prove better?
- Experiment:
  - Comparison using RCU array(A-RCU) and RCU protected linked list
  - Benchmark used by RLU authors for comparing RCU and RLU
  - System: 16 core Xeon Blade Server processor supporting 16 hardware threads.

RCU Protected Arrays

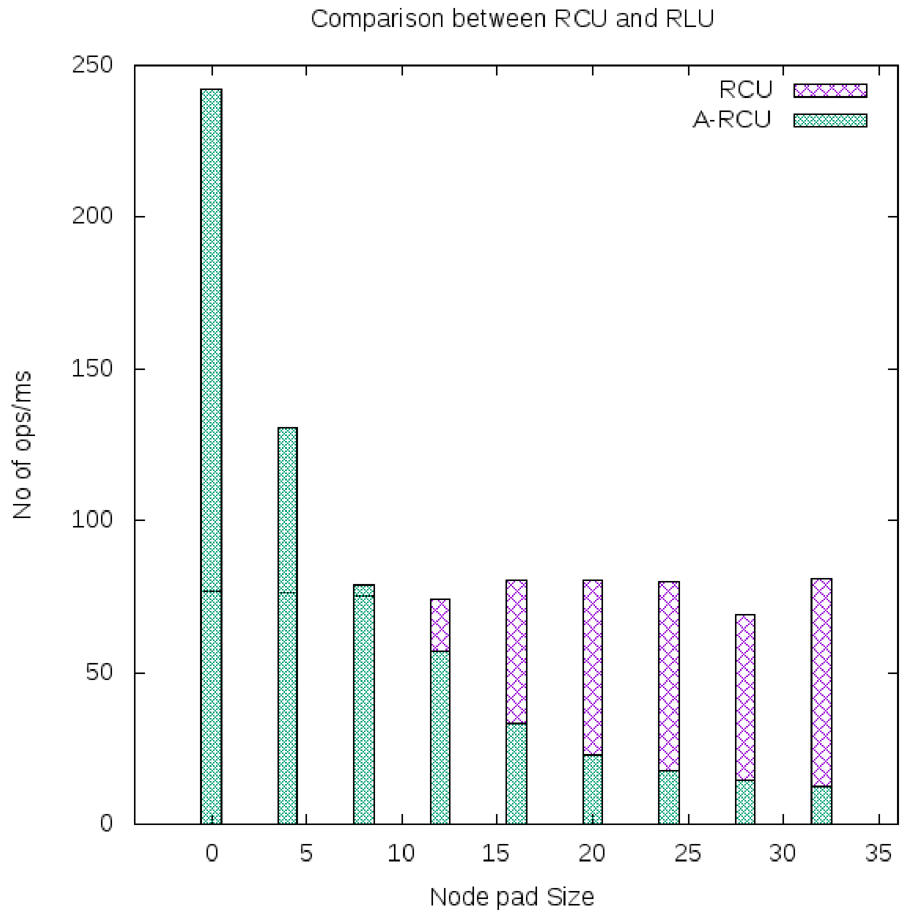


Comparison with no updates



Comparison with 40% updates

Does Node Size Matter?



Comparison with 20% updates

Conclusion

- Studied the behavioral aspects of RCU Usage in the Linux Kernel.
- Need to look at Reader Perspective in Stage-2.
- Design a lock free mechanism from that supports:
  - More cache utilization
  - Supports larger node size
- Change a particular Kernel subsystem to use the array based design and compare with existing model.

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