Implementing an Efficient Shuffle Operator for Streaming Database Systems

Bachelor Thesis

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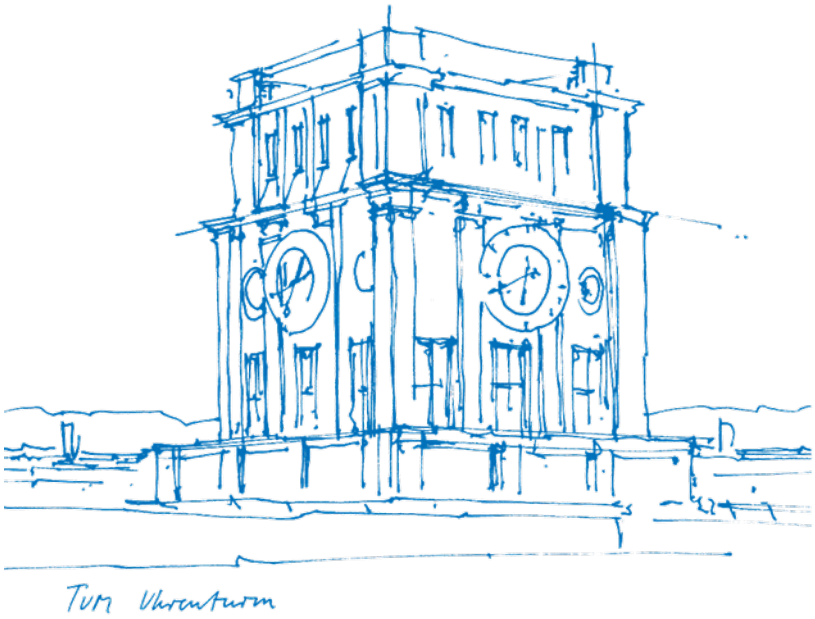

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Problem Setting

Key Contribution: Efficient, multithreaded shuffle operator implementations.

Streaming Shuffle Simulation:

1. **Tuple Generation:** Randomly generated tuples with 32-bit keys and optional data fields.
2. **Data Shuffle:** Tuples stored in partition buckets using slotted pages.
3. **Storing on Slotted Pages:** Thread-local vs. shared (locking/lock-free) write-out strategies.

Naive approach: *OnDemand*

- **OnDemand:** Tuples are directly written to the partition buckets.
- **Problems:**
  - Each tuples causes a write-out to a shared slotted page.
  - Very high contention on partition buckets.

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Optimized approach: *Smb*

- **Software Managed Buffers (SMBs):**
  - Cacheline-sized, thread-local buffers for each partition.
  - Flush partition when buffer is full.
- **Problems:**
  - High contention on partition buckets.

Histogram-based approach: *Radix*

- **Histogram:**
  - Thread-local histograms for each partition.
  - Flush when histogram is full.
- **Problems:**
  - High contention on histograms.

Histogram-based approaches: *Radix* and *Hybrid*

- **Histogram:**
  - Thread-local histograms for each partition.
  - Flush when histogram is full.
- **Problems:**
  - High contention on histograms.

Reducing contention: *CmpProcessingUnits*

- Partition threads into *Processing Units*
- Within each Processing Unit:
  - Each thread is assigned an exclusive partition range
  - No overlap between partition ranges
  - Only a single thread writes to a partition

Problems:

- Each tuple must be processed by all threads of a Processing Unit

Avoiding contention: *LocalPagesAndMerge*

Thread-local Pages:

- Each thread has its own slotted pages
- Avoids synchronization

Merging Phase:

- All non-full pages have to be merged
- We assign each thread a group of partitions to merge
- Each thread merges the pages of its assigned partitions without synchronization

Problems:

- Huge initial memory consumption

Evaluation

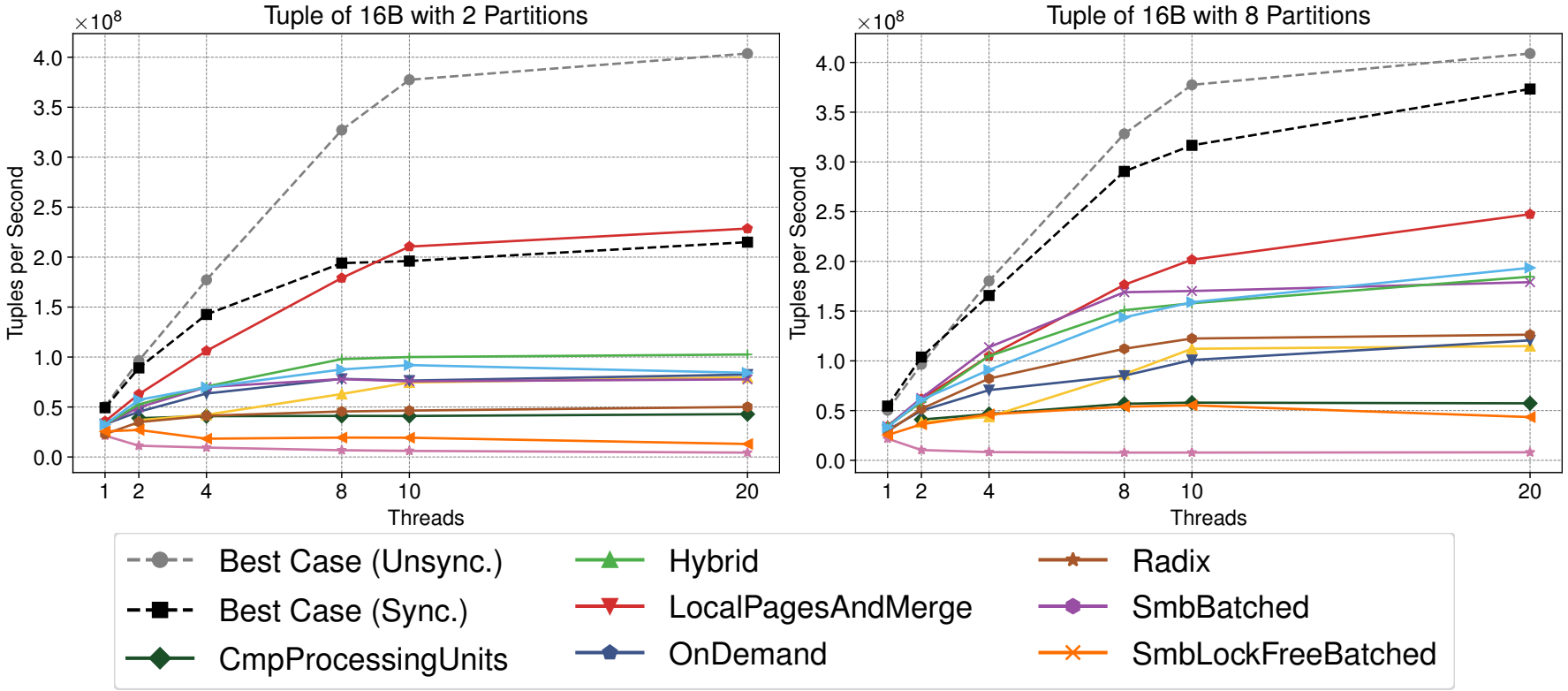

Figure: Benchmark Plots for Tuple of 16B with 2 and 8 Partitions

Evaluation

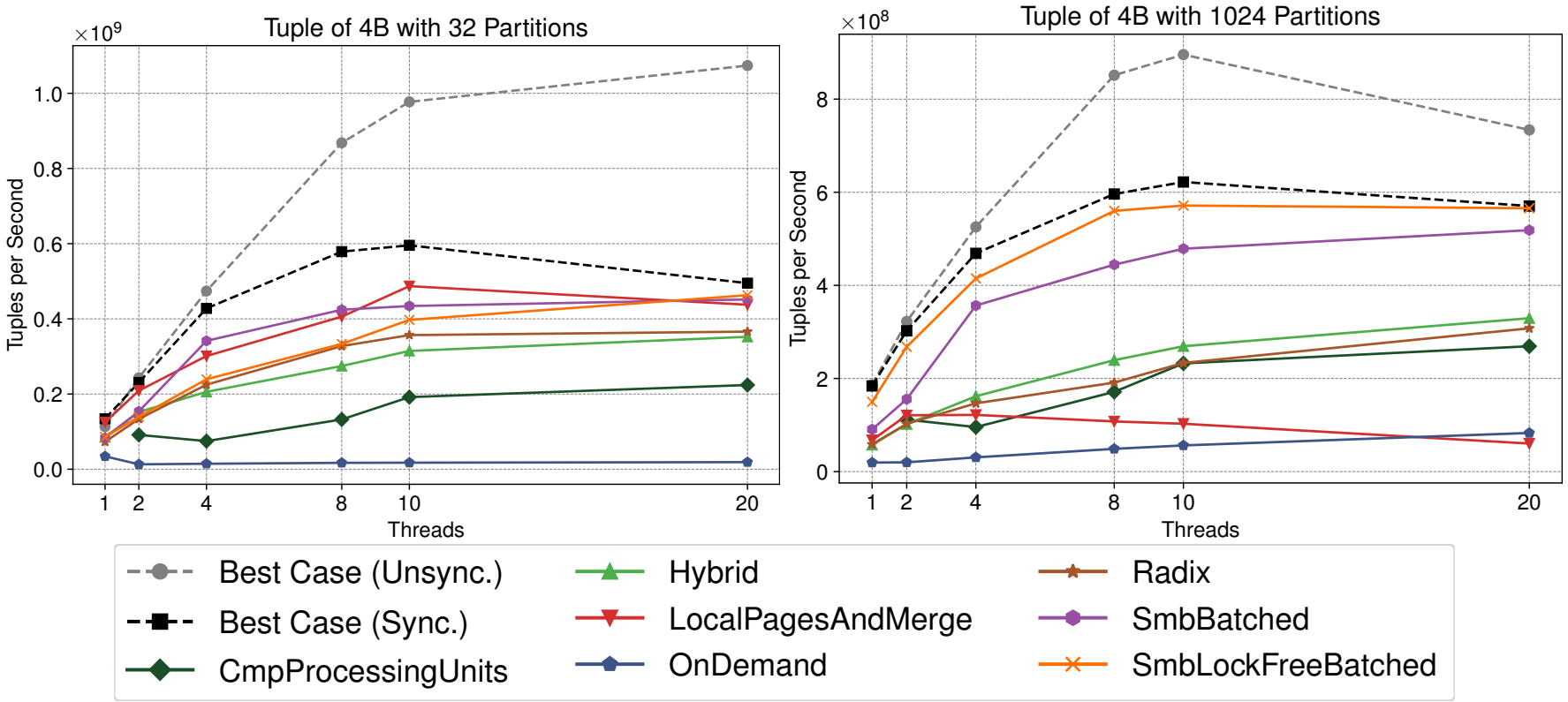

Figure: Benchmark Plots for Tuple of 4B with 32 and 1024 Partitions

Evaluation

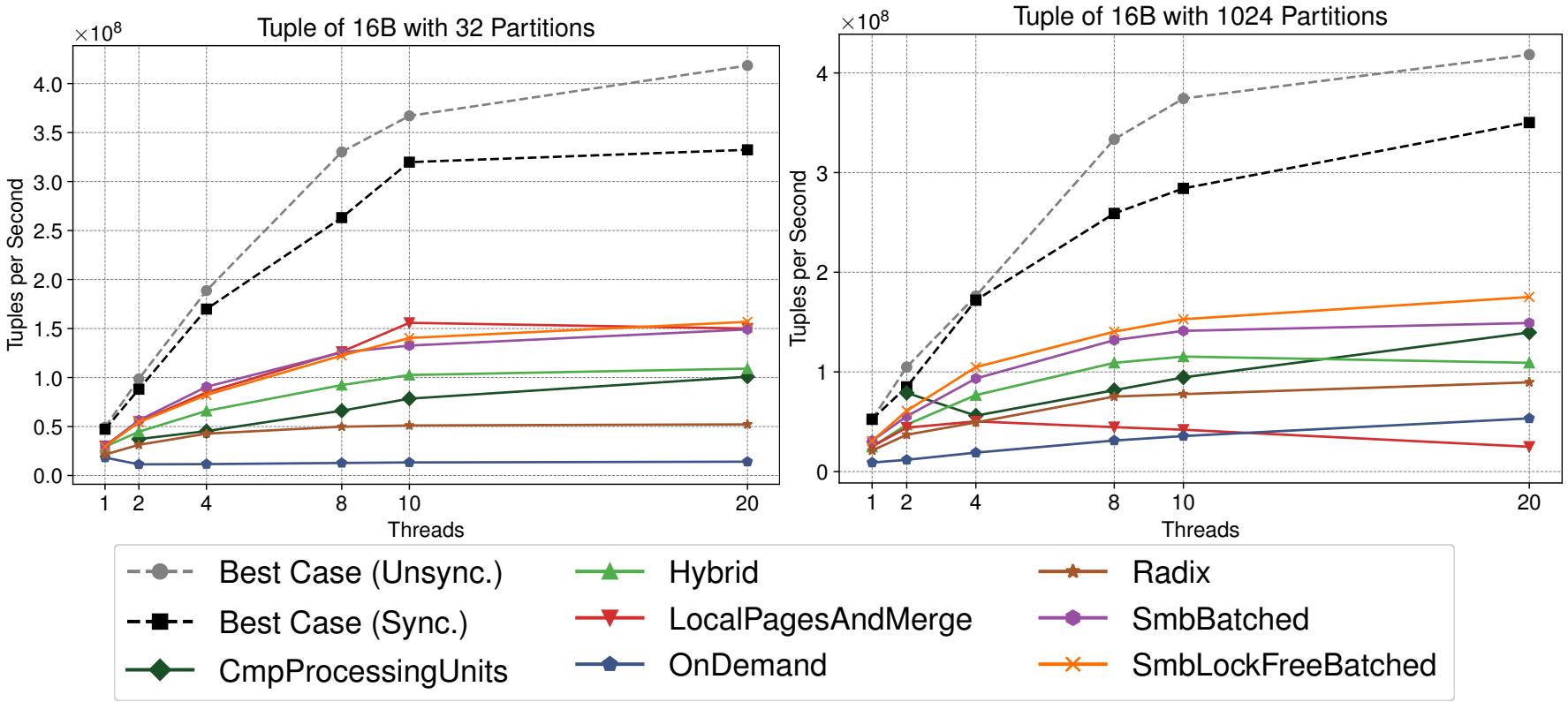

Figure: Benchmark Plots for Tuple of 16B with 32 and 1024 Partitions

Evaluation

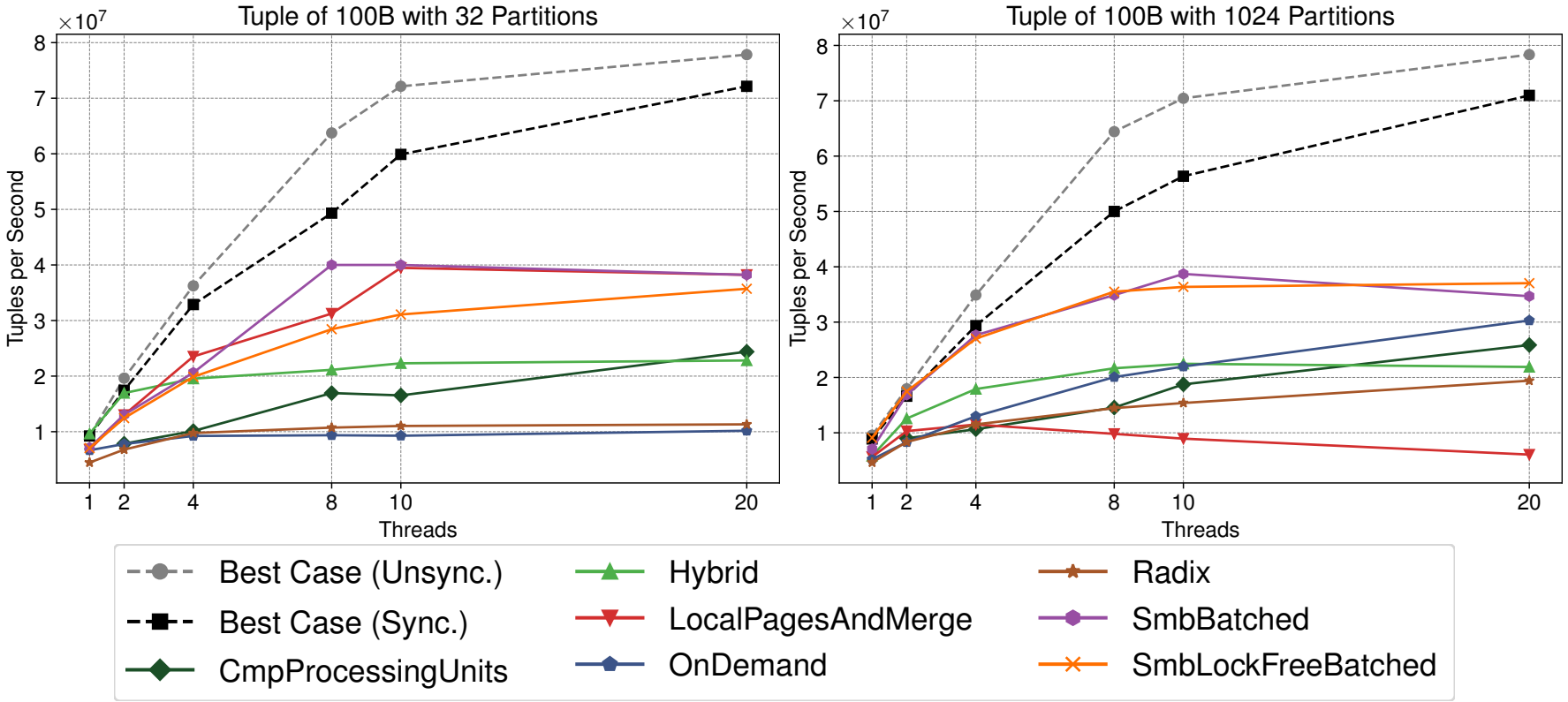

Figure: Benchmark Plots for Tuple of 100B with 32 and 1024 Partitions

Peak Heap Memory

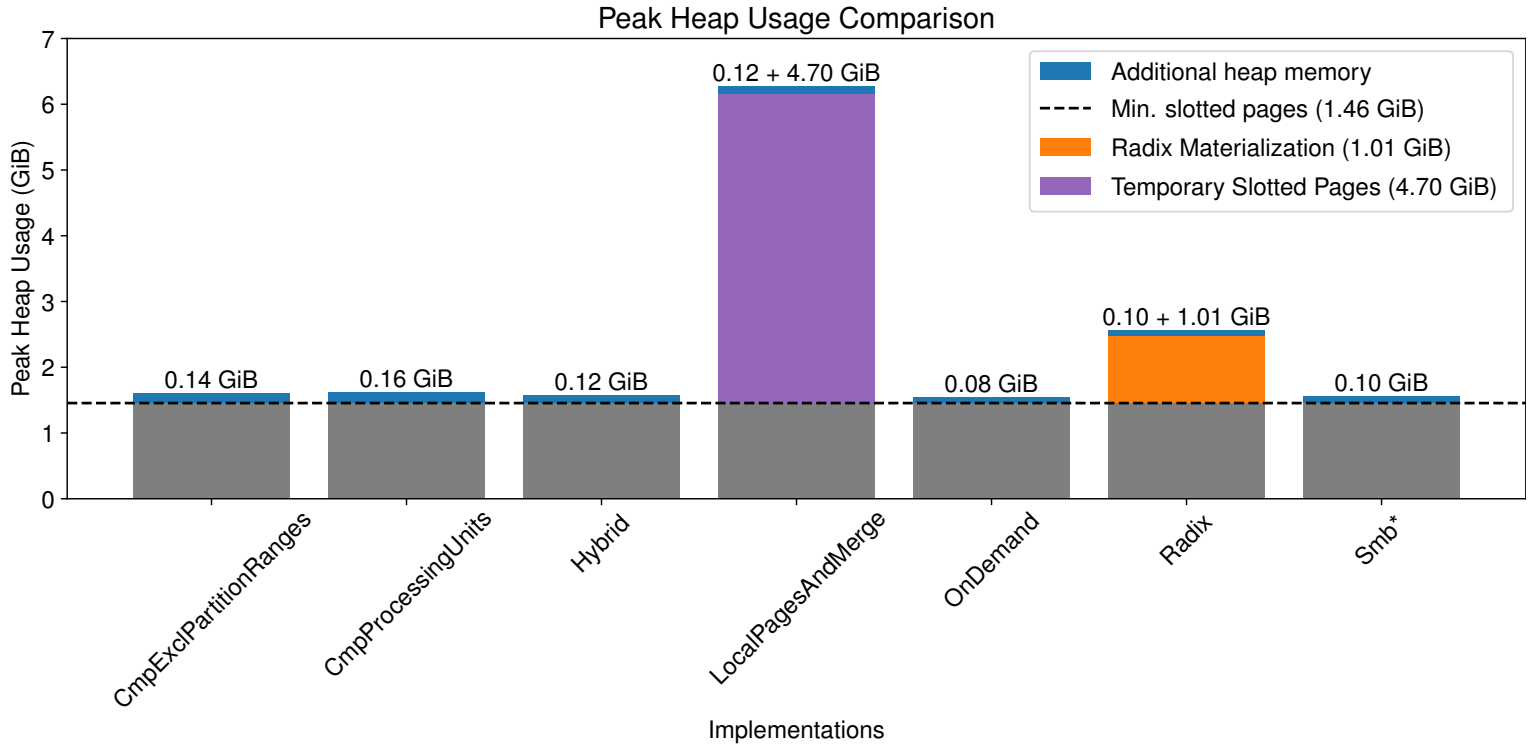

Figure: Peak Heap Usage when using 32 Partitions, 40 Threads and 67.2 Mio. 16B Tuples (1 GiB)

Comparison with Apache Flink

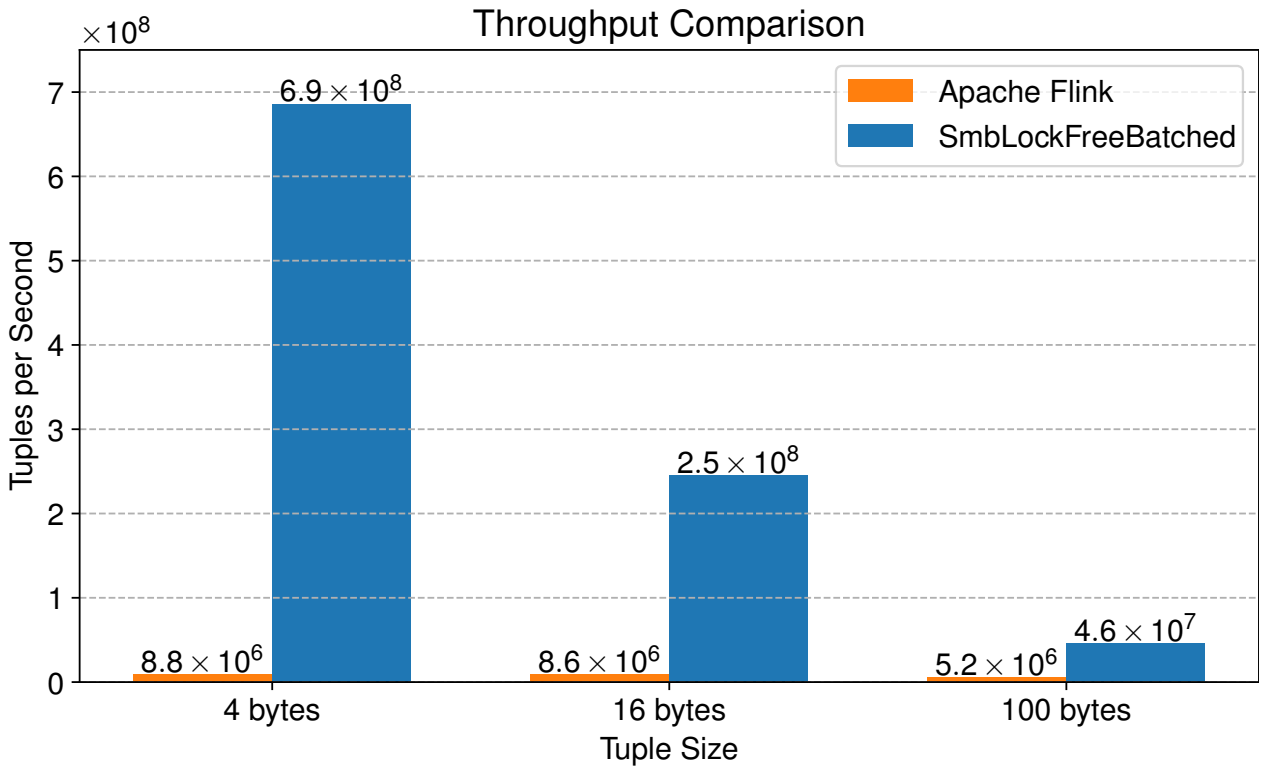

Figure: Tuples per Second Comparison when using 1024 Partitions

Conclusion

- Thread-local slotted pages are optimal for low partition counts.
- SMB-based methods scale best for high partition counts.

Future Work

- Further reducing contention on machines with 20+ cores.
- Evaluate the implementations in a real-world streaming system.