Lecture V: The Item RAM Strikes Back!

Towards a practical dynamic bulk storage system for use in the real world

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Instructor: Andrews54757

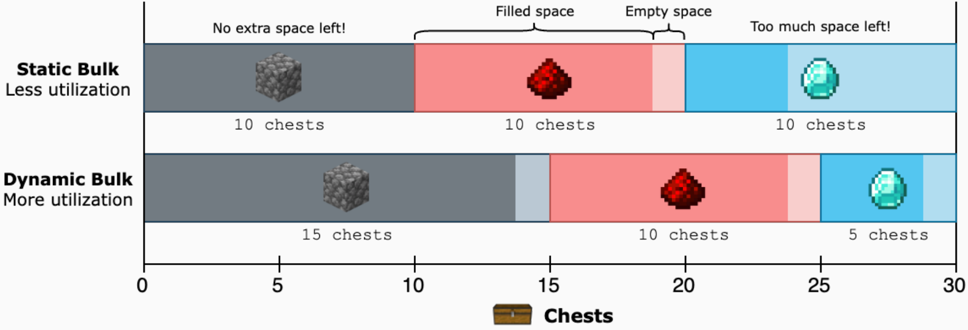
CSE269: Introduction to Encoded Storage
S∞ntech Annals

Overview

1. What is dynamic bulk?
2. Fast and compact data storage is hard
   2.1 Internal logic has problems
   2.2 Item RAMs are fast but large
   2.3 Disk Drives are too slow
3. Solution: Linked-list based dynamic bulk
   3.1 Analysis of the problem
   3.2 Implementation
4. Conclusion and future steps

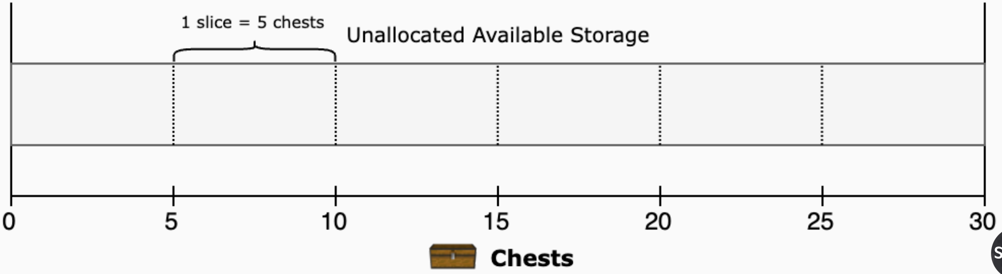
1. What is dynamic bulk?

- **Static bulk** has a fixed capacity for each item type
- **Dynamic bulk** automatically expands and shrinks capacity for items



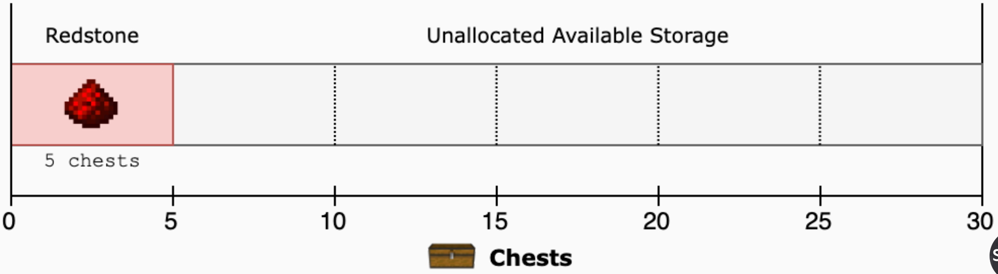
1. What is dynamic bulk? Contd.

- Divide your storage into **slices** of fixed size
- Each slice can store a fixed number of items
- The size of your slice determines the minimum non-zero amount of storage space you can allocate to an item type



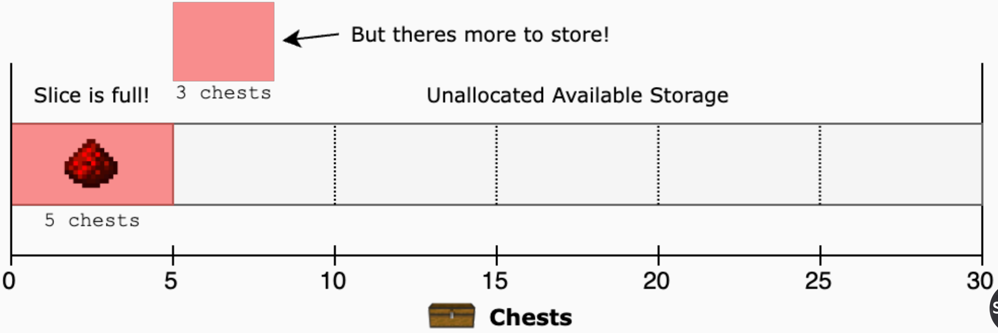
1. What is dynamic bulk? Contd.

- Let's store 8 chests of redstone
  - Do we have a slice assigned to redstone? **No!**
  - Allocate an available slice to redstone
  - Now we have space to start storing redstone!



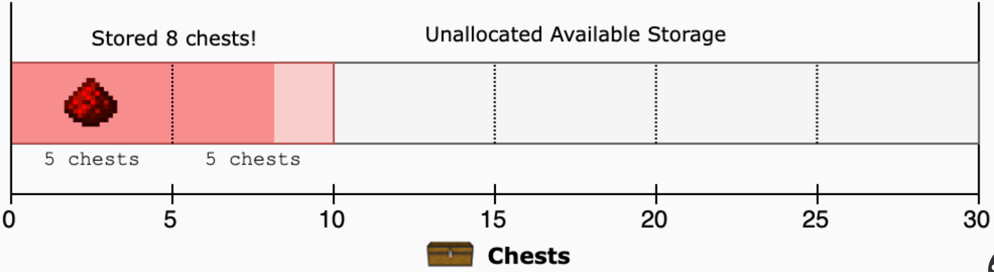
1. What is dynamic bulk? Contd.

- Let’s store 8 chests of redstone
  - Fully filled one chest with 5 chests of redstone
  - But we have more 3 more chests of redstone to store!



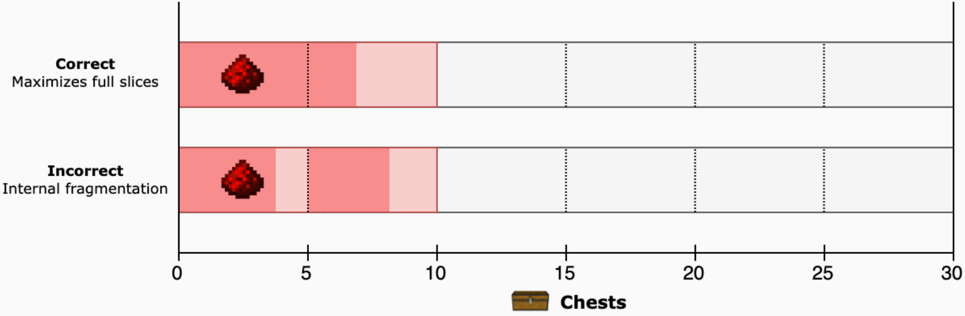
1. What is dynamic bulk? Contd.

- Let’s store 8 chests of redstone
  - One slice is **fully** filled with redstone (5 chests)
  - Another slice is **partially** filled with redstone (3 chests / 5 chests)



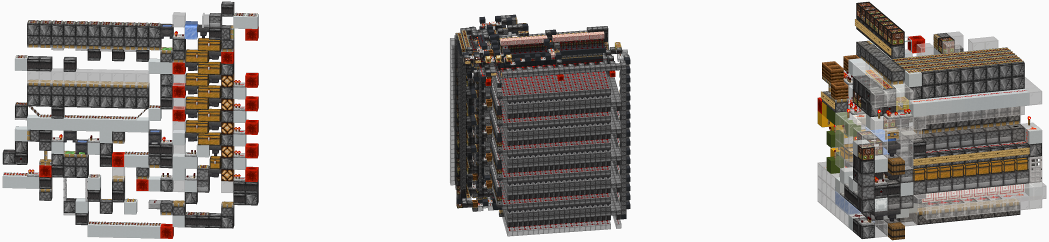
1. What is dynamic bulk? Contd.

- Retrieve 1 chest of redstone
  - Pull from the partially filled slice first!
  - Minimize internal fragmentation



2. Fast and compact data storage is hard

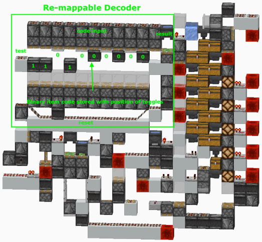
- We need to keep track of what slices are assigned to each item type
- Must store that information in a way that is quickly accessible
- Storage must be dense so that it is compact

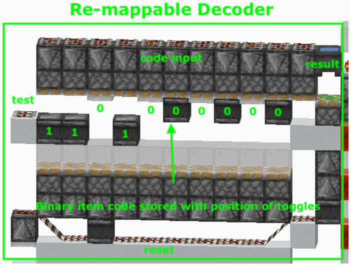


From left to right: PallaPalla's Dynamic Slice, 1000 Item RAM, Obi's Disk Drive

2.1 Internal logic has problems

- PallaPalla, original inventor of dynamic bulk, uses a binary re-mappable decoder to store assigned item code within each slice.
- Almost every piston in each slice's decoder is fired to write/test item codes. Laggy and higher chance of data corruption.
- Allocation logic is internal to the slice, so each slice is large and complex.





- What if we externalized the slice allocation logic?
  - Each slice is now just a simple static encoded bulk unit
  - Store information about slice allocation in a separate memory unit
  - Externalized logic is simpler and more compact

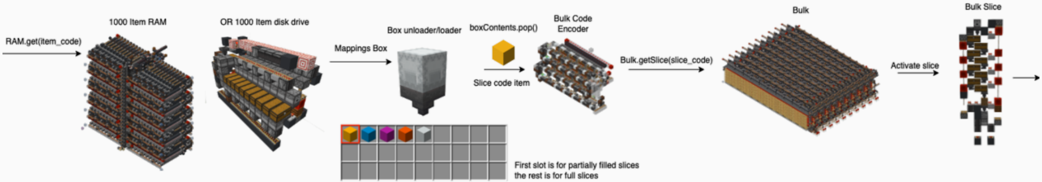


Figure 12: Diagram of dynamic bulk with externalized logic

2.1 Internal logic has problems. Contd.

- How is slice allocation information stored externally?
  - Represent slices with an encodeable item called the **slice code item**. One slice code item corresponds to one slice.
  - Maintain a list of slice code items in box dedicated to one item type
  - Store the list of slice code items in an external item memory unit in the address corresponding to the item type

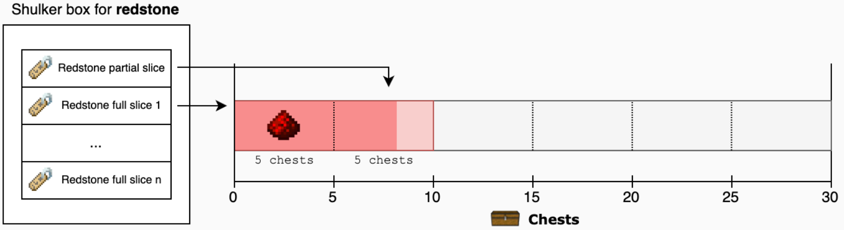


Figure 12: Externalized dynamic bulk data layout

2.2 Item RAMs are fast but large

- An item RAM is a memory unit that stores items in an addressible way
- Each item type is assigned a unique address
- The item RAM can be read from and written quickly in constant time (O(1))

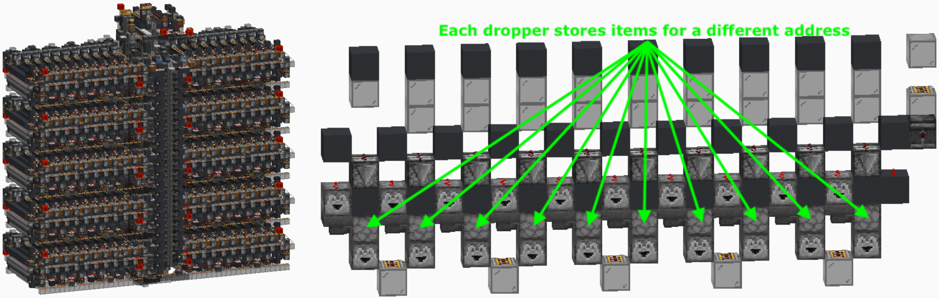


Figure 13-14: 1000 address item RAM and its slice. 46gt call latency.

2.2 Item RAMs are fast but large. Contd.

- Unfortunately, item RAMs are very big.
- Latest advancements have doubled the density, but still too big.
- 17 x 41 x 33 blocks for 1000 addresses

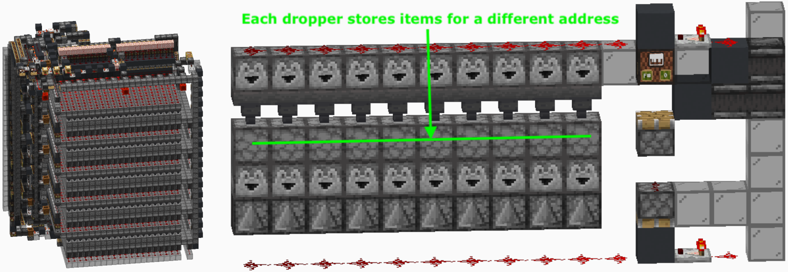


Figure 15-16: Improved 1000 address item RAM and its slice. 46gt call latency.

- What if, we stored multiple boxes from different addresses in a single block?
- Store up to 54 boxes in a double chest
- Cycle through the boxes to find the correct one

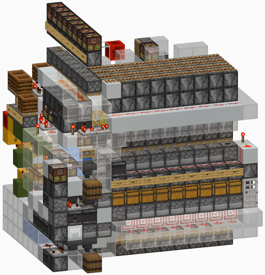


Figure 17-18: Obi's Disk Drive, 256 addresses.

2.3 Disk drives are small but slow. Contd.

- Cycling through slots is slow, 8gt per slot.
- Box at the 32nd slot takes a minimum 248gt to access, which is 12.4 seconds.
- Need something faster!

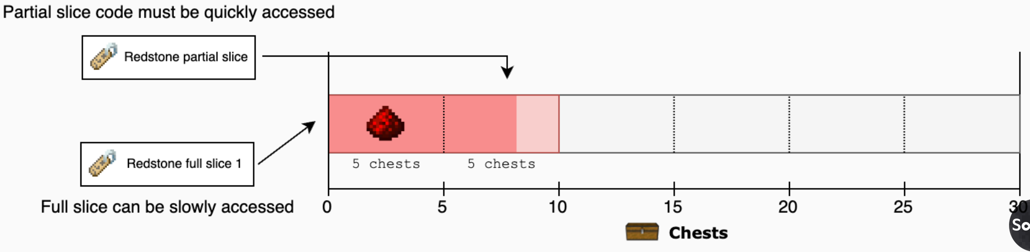
Figure 19: Minimum time in seconds to reach slot in a disk drive

3.1 Analysis of the problem

- Item RAMs are fast but too big
- Disk drives are compact but too slow
- We need something that is both fast and compact
- **Towards a solution:** Get inspiration from computer science

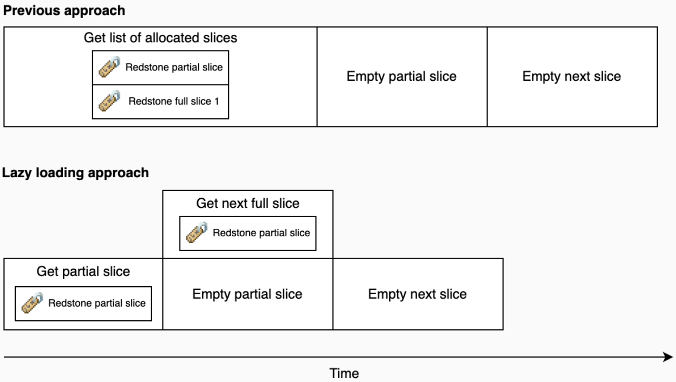
3.1 Analysis of the problem. Contd.

- Observations:
  - System only needs to know the partial slice first
  - Filling and emptying takes a while
  - Rest of the slices can be slowly found in the background
- **Idea:** Seperate the storage of partial slice information from the rest

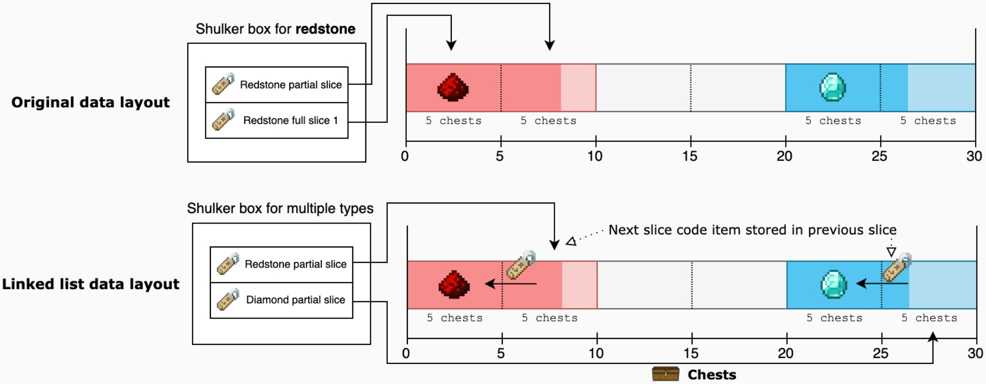


3.1 Analysis of the problem. Contd.

- **Lazy loading:** Defer loading an object until it is needed
- Store only the partial slice codes in a separate storage device with rapid access
- Slowly access information about other slices in the background as needed



- **Linked list:** Sequence of elements where each element points to the next
- Efficient insertion and deletion at the start of the list
- Slower access time to elements in the middle and end



3.2 Implementation

- If instead of storing boxes, we store a single non-box slice code item per address
- Can pack multiple addresses in a single shulker box for higher density

Figure 24: Non-box item RAM storage scheme

3.2 Implementation. Contd.

- Using hoppercarts, can pull items from shulker boxes every game tick
- 8x faster cycling than traditional disk drives. Item at the 20th slot takes only 1 second
- We can quickly bring boxes to the ultrafast slot cycler using instant droppers

Figure 25-26: 1 slot/gt slot cycler with internal layout

Soon™ A5

- Combine slot cycler with 50 item RAM (21gt call latency)
- Can access 1000 addresses within 55gt
- Result: Both fast and compact!

Figure 27: 1000 address non box item RAM

3.2 Implementation. Contd.

- Maintaining the linked list for **insertion** is simple.
  1. Obtain a slice code item at a slot corresponding to the item code using the 1000 non-box-item RAM.
  2. Insert boxes into the corresponding slice.
  3. If slice is full, pull a new slice code item from storage to allocate a new empty slice
  4. Put the now-full slice code item into the newly allocated slice and put the rest of the boxes into the newly allocated slice. Repeat 3-4 as needed.
  5. Store the remaining slice code item into the 1000 non-box-item RAM at the slot corresponding to the item code to finish insertion.

3.2 Implementation. Contd.

- Maintaining the linked list for **retreival** is also simple.
  1. Obtain a slice code item at a slot corresponding to the item code using the 1000 non-box-item RAM.
  2. Retrieve boxes from the corresponding slice. Test items if they are boxes, if one is not a box then hold it for later, it is the slice code item for the next slice.
  3. If slice is empty and you have found a code item for the next slice, then switch to the next slice. Put the now empty slice code item back into storage.
  4. Keep retreiving boxes, repeat 2-3 as needed.
  5. If you have found the slice code item for the next slice, put it back into the slice.
  6. Store the remaining slice code item into the 1000 non-box-item RAM at the slot corresponding to the item code to finish insertion.

4. Conclusion and future steps

- Linked-list based dynamic bulk has the potential to be both fast and compact
- Future work: Implement the linked-list based dynamic bulk and test its performance
- Further optimizations: Reduce the latency of the non-box item RAM
- **This is an assignment for you!** Unfortunately I have no time to implement this myself. Good luck!
    - I have posted the schematic of the 1000 address non-box item RAM in the description to help you get started