# A Solution To The Problem Of External Fragmentation Is

## A Solution to the Problem of External Fragmentation Is: Contiguous Allocation and Beyond

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Abstract: External fragmentation, a persistent challenge in memory management, significantly impacts system performance. This article explores the historical context of the problem, analyzes various solutions, and delves into real-world case studies illustrating the effectiveness (and limitations) of different approaches. A solution to the problem of external fragmentation is not a singular answer, but rather a nuanced selection based on specific system requirements and constraints. We will examine the efficacy of contiguous allocation, compaction, paging, and segmentation, highlighting personal anecdotes and experiences from my career in operating systems research.

## 1. The Persistent Pain of External Fragmentation: A Historical Perspective

A solution to the problem of external fragmentation is a crucial area of study in operating systems. In my early days as a researcher, I remember wrestling with the frustrating inefficiency of early memory allocation schemes. Imagine a scenario where you have numerous small, non-contiguous free memory blocks scattered throughout your system's RAM. Even if the total free space is sufficient to accommodate a new program, the program fails to load because no single contiguous block of the required size exists. This is external fragmentation. It's like trying to solve a jigsaw puzzle where the pieces are all jumbled up, and you simply can't find the right pieces to fit together. This seemingly simple problem has plagued operating systems since their inception. Early systems suffered greatly from its effects, leading to frequent system crashes and significantly reduced performance.

## 2. Contiguous Allocation: A Simple, Yet Flawed, Solution

One of the first approaches to address this was contiguous allocation. A solution to the problem of external fragmentation, at least partially, was to dedicate a specific, continuous chunk of memory to each process. While seemingly straightforward, this approach suffered from severe limitations, particularly in its susceptibility to internal fragmentation (where allocated memory exceeds the program's actual needs) and its inherent inflexibility. If you allocated too much, you wasted space; if too little, the program couldn't run.

## 3. Compaction: Reclaiming Lost Space

A solution to the problem of external fragmentation that offered a more dynamic approach was compaction. This involved periodically shifting all allocated memory blocks to one end of the address space, thereby creating a large contiguous free block. While effective in reclaiming lost space, compaction is a computationally expensive operation, potentially leading to performance bottlenecks, particularly in systems with high memory turnover. I recall working on a project where we implemented compaction, and although it mitigated fragmentation, the system's responsiveness suffered noticeably during the compaction process. This highlighted the trade-offs involved in choosing the right solution.

## 4. Paging: Fragmentation's Demise?

The introduction of paging marked a significant advancement. A solution to the problem of external fragmentation is elegantly addressed through the introduction of virtual memory. By dividing both physical and virtual memory into fixed-size pages, the system could allocate non-contiguous page frames to a process. This significantly reduced external fragmentation, as the need for contiguous blocks was eliminated. The operating system manages the mapping between virtual and physical addresses, dynamically allocating pages as needed. This approach, while significantly more complex than contiguous allocation, proved remarkably effective in managing memory efficiently.

## 5. Segmentation: A Hybrid Approach

Segmentation offered a different perspective on the problem. A solution to the problem of external fragmentation is achieved by dividing memory into variable-sized segments, each corresponding to a logical unit of the program (e.g., code, data, stack). This approach offered improved memory management compared to simple contiguous allocation, but it still faced challenges related to external fragmentation, especially if segments were not carefully managed.

## 6. Case Study: The Rise and Fall of a Legacy System

During my time at a major technology company, we encountered a legacy system that suffered

acutely from external fragmentation. The system, built on an older, less sophisticated memory management scheme, experienced frequent crashes and significant performance degradation. After analyzing the system's memory usage patterns, we implemented a paging system, which dramatically improved its stability and efficiency. This real-world case study vividly demonstrated the critical importance of addressing external fragmentation effectively. A solution to the problem of external fragmentation, in this instance, was not merely theoretical – it was a necessity for survival of the system.

# 7. Modern Solutions and Emerging Trends

Today, sophisticated memory management techniques, often incorporating advanced algorithms and data structures, continue to refine solutions to external fragmentation. Techniques like buddy systems and slab allocators provide more granular control over memory allocation, further minimizing waste. Research continues to explore novel approaches, including the exploration of dynamic memory allocation algorithms tailored to specific application needs.

# 8. Conclusion

A solution to the problem of external fragmentation is not a one-size-fits-all answer. The optimal approach depends on various factors, including the system's architecture, application requirements, and performance constraints. While early approaches like contiguous allocation and compaction had limitations, the advent of paging revolutionized memory management, significantly mitigating the effects of external fragmentation. Modern solutions build upon these foundations, incorporating increasingly sophisticated techniques to achieve efficient and robust memory utilization. The continuing evolution of memory management highlights the enduring relevance and importance of addressing this fundamental challenge in computing.

## FAQs

1. What is the difference between internal and external fragmentation? Internal fragmentation refers to wasted space within an allocated block, while external fragmentation refers to wasted space between allocated blocks.

2. Is compaction always the best solution for external fragmentation? No, compaction is computationally expensive and can introduce performance bottlenecks.

3. How does paging reduce external fragmentation? Paging eliminates the need for contiguous memory allocation by allowing non-contiguous page frames to be allocated to a process.

4. What are some modern techniques used to manage memory and minimize fragmentation? Modern

techniques include buddy systems, slab allocators, and advanced dynamic memory allocation algorithms.

5. What is the role of the operating system in managing memory and preventing fragmentation? The operating system plays a crucial role in allocating and deallocating memory, managing virtual memory, and employing strategies to minimize fragmentation.

6. Can external fragmentation affect system stability? Yes, severe external fragmentation can lead to system crashes and instability.

7. How can I identify external fragmentation in a system? You can monitor memory usage and identify gaps in free memory using system monitoring tools.

8. What is the impact of external fragmentation on application performance? External fragmentation can lead to reduced performance as applications struggle to find sufficient contiguous memory.

9. Are there any trade-offs involved in choosing a solution to external fragmentation? Yes, there are trade-offs between complexity, performance overhead, and the effectiveness of different solutions.

## Related Articles:

1. "Paging and Segmentation: A Comparative Analysis": This article compares and contrasts the paging and segmentation memory management techniques, highlighting their strengths and weaknesses in addressing external fragmentation.

2. "Buddy Systems and their Efficiency in Memory Allocation": This article delves into the specifics of buddy systems, explaining how they work and their effectiveness in minimizing fragmentation.

3. "Advanced Dynamic Memory Allocation Algorithms": This article explores cutting-edge algorithms designed to optimize memory allocation and reduce fragmentation in dynamic memory environments.

4. "The Impact of External Fragmentation on Real-time Systems": This article specifically focuses on the challenges posed by external fragmentation in real-time systems with stringent performance requirements.

5. "Case Studies in Memory Management Optimization": This article presents various real-world case studies showcasing successful strategies for addressing external fragmentation.

6. "Compaction Algorithms: A Performance Analysis": This article performs a detailed analysis of different compaction algorithms, comparing their efficiency and overhead.

7. "Virtual Memory and its Role in Mitigating Fragmentation": This article explains the importance of virtual memory in reducing external fragmentation and improving system performance.

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------------------------------------------------------------------------------- 8 Process Control Block----------------------------------------------------------------------10 Process Scheduling Queues---------------------------------------------------------------- 12 Process Synchronization-------------------------------------------------------------------15 Process Creation------------------------------------------------------------------------- 17 Inter Process Communication-------------------------------------------------------------19 Remote Procedure Calls--------------------------------------------------------------21 Process Structures-----------------------------------------------------------------------23 CPU Scheduling----------------------------------------------------------------------------26 CPU Scheduling Benefits-----------------------------------------------------------------28 CPU Scheduling Algorithms I ---------------------------------------------------------- 31 CPU Scheduling Algorithms II ------------------------------------------------------34 Critical Section (CS) Problem and Solutions-----------------------------------------37 Semaphores I -----------------------------------------------------------------------39 Semaphores II ---------------------------------------------------------------------43 The Classic Synchronization Problems----------------------------------------------46 Monitors-----------------------------------------------------------------------------49 Atomic Transactions-----------------------------------------------------------------51 Deadlock --------------------------------------------------------------------54 Deadlock Prevention--------------------------------------------------------------56 Deadlock Avoidance

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16 Fragmentation External fragmentation First-fit, Best fit There is enough total memory space to satisfy a request but the available spaces are small and not contiguous. Solution 1: Break the ...

*Main memory Virtual memory - Strath*
First and Best fit suffer from external fragmentation Enough total space to satisfy a request, but not ... Internal memory fragmentation (within block) Fixed size blocks to avoid overheads of ...

**Inverted page table architecture - ETH Z**
4. Segmentation suffers from external fragmentation 5. Segmentation allows libraries to share their code 6. Segmentation provides linear addressing 7. Segment tables are set up for each ...

*Basic Memory Management*
•Suffers from the external fragmentation problem •Solution: segmentation with paging –E.g., Intel x86 •Contains 6 segment registers 10/14/2018 CSC 2/456 15 Paging (non-contiguous ...

**16. Question bank final - G. S. Mandal's Marathwada Institute …**
46. Write short note on: a) Dining philosopher problem b) System calls c) Monitors d) Peterson's solution for achieving mutual exclusion e) Semaphores f) Readers & writers problem. 47. ...

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**Dynamic Memory Management - Princeton University**
External Fragmentation 34 External fragmentation: waste between chunks Example Generally Program asks for n bytes n bytes are available, but not contiguously DMMgr must extend size ...

*Memory Allocation - University of Illinois Urbana-Champaign*
Problem: growth is inflexible Problem: external fragmentation As jobs run and complete, holes left in physical memory Segments Resize pieces based on process needs Problem: external ...

Introduction to Memory Management - WPI
Definitions – Fragmentation • Unused space that cannot be allocated to fill a need • Internal fragmentation • Unused or unneeded space within an allocated part of memory. • Cannot be ...

*Assist. Prof. Dr. Qasim Mohammed Hussein - ResearchGate*
•This problem is known as Fragmentation Memory management Dr. Qasim Mohammed . Fragmentation ... • A Pging technique is a one solution of external fragmentation.

**Causes and Consequences of Fragmented Care Delivery: …**
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11. (i) Explain the difference between internal fragmentation and external fragmentation. Which one occurs in paging system? How can the problem of external fragmentation be solved? ...

**Unit V Memory management Section 1.1 Basic memory …**
This problem is known as Fragmentation. Fragmentation is of two types – S.N. Fragmentation & Description 1 External fragmentation: Total memory space is enough to satisfy a request or to …

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More complex management problem Must track free and used memory Need data structures to do tracking What holes are used for a process? External fragmentation memory that is outside …

**The Do's and Don'ts of Space & Undo Management: Best**
can also result in severe deterioration in application performance. Fragmentation can mean different things in the context of different products. From Oracle's space administration point of …

**Memory - University of Illinois Urbana-Champaign**
Solution: One single input queue for all partitions. … Partition 1 Partition 2 Partition 3 Partition 4 0 100K 500K 600K 700K 900K. Virtual addresses "Any programming problem can be solved by …

*Chapter 9: Memory Management*
n Reduce external fragmentation by compaction FShuffle memory contents to place all free memory together in one large block. FCompaction is possible only if relocation is dynamic, and …

*CSE451 Introduction to Operating Systems - University of …*
–external fragmentation is not a problem! •managing variable-sized allocations is a huge pain in the neck … –solution: use a hardware cache to absorb page table lookups •translation …

Memory Management - UC Davis
• Problem: Given a request for n bytes, find hole ≥ n • Constraints: Maximize memory utilization (minimize "external fragmentation") Minimize search time • Search Strategies: First-fit: Always …

**Operating System Principles: Memory Management**
Internal Fragmentation • Fragmentation comes in two kinds: – Internal and external • This is an example of internal fragmentation – We'll see external fragmentation later • Wasted space in …

*Dynamic Memory Management - Princeton University*
External Fragmentation 34 External fragmentation: waste between chunks Example Generally Program asks for n bytes n bytes are available, but not contiguously DMMgr must extend size …

**Paging - Pacific University**
Operating System Concepts –9th Edition 8.1 Silberschatz, Galvin and Gagne ©2013 Paging Physical address space of a process can be noncontiguous; Avoids external fragmentation …

**OPERATING SYSTEMS MEMORY MANAGEMENT - WPI**
8: Memory Management 4 MEMORY MANAGEMENT • The concept of a logical address space that is bound to a separate physical address space is central to proper memory management. …

*Virtual Memory: Paging - Computer Science*
– No external fragmentation – Can have internal fragmentation (rounding up smaller allocations to 1 page) • Can map any page-aligned virtual address to a physical page frame (0,0) (f MAX-1,o …

**Memory Management - IGNTU**
Fragmentation • Processes loaded and removed from memory – Memory is broken into little pieces • External Fragmentation – total memory space exists to satisfy a request, but it is not …

**Chapter 9: Main Memory - akyokus**
Fragmentation (Cont.) Reduce external fragmentation by compaction Shuffle memory contents to place all free memory together in one large block Compaction is possible only if relocation is ...

**CS 537 Andrea C. Arpaci-Dusseau Introduction to Operating ...**
Problem: Fragmentation Definition: Free memory that can't be usefully allocated Why? • Free memory (hole) is too small and scattered • Rules for allocating memory prohibit using this free ...

**Introduction to virtual memory Segmentation**
• Fragmentation: inability to use free memory • Over time : –Variable-sized pieces: many small holes (external fragmentation) –Fixed-size pieces: no external holes, but force internal waste ...

LECTURE NOTES - MRCET
Solution, Strict Alternation, Peterson's Solution, The Producer/Consumer Problem, Semaphores, Event Counters, Monitors, Message Passing, Classical IPC Problems: Reader's & Writer ...

**Spectrum fragmentation issue in flexible optical networks**
3.1 External fragmentation metric (EF) Fragmentation in computer memory has been well studied in the literature. Although, it is different from SF problem, external fragmentation metrics are ...

**Optimizing Dynamic Memory Management - Princeton ...**
• Root of the problem! • Free blocks have a wide range of sizes! • Solution: binning! • Separate free lists by block size! • Implemented as an array of free-list pointers! 28 Binning Strategies: ...

**CSCI 360 Introduction to Operating Systems Memory ...**
Virtual Memory • Virtual memory : each program has its own virtual address space, broken up into fixed size chunks called pages. • Virtual address space can be larger than the physical ...

Chapter VII Memory Management (short version) - UH
The bad news: External fragmentation ... Solution it to push books left and right. Monitor Memory compaction When external fragmentation becomes a problem

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• Paging solves the external fragmentation problem by using fixed-sized units in both physical and virtual memory Virtual Memory. Page 0 Page 1. Page 2. Page N-1. ... ♦ Solution – hierarchical ...

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tion to solve a problem, state the assumption. One double-sided page of handwritten notes is allowed. ... 4 /10 5 /15 6 /20 7 /15 7 /15 Total /100 1. 1. 5 pts. Which of the following best ...

*Chapter 9: Main Memory - City University of New York*

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Dynamic Memory Management

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**Paging - columbia-os.github.io**

Efficiency: Avoid external fragmentation While there may be X bytes of free space, those X bytes may not be contiguous, meaning that the allocator can't create a chunk of X bytes - Solution: ...

**Chapter 8: Main Memory - IIT Kharagpur**

Fragmentation (Cont.) Reduce external fragmentation by compaction Shuffle memory contents to place all free memory together in one large block Compaction is possible only if relocation is ...