Simulation of Tape Systems

Fermilab Final Presentation

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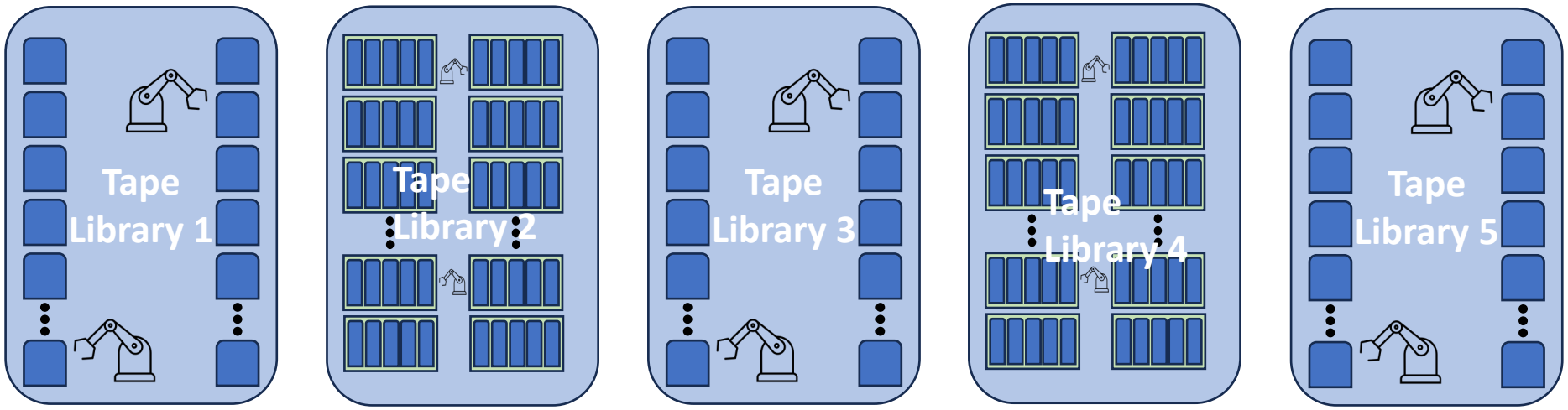
About the Project and Goals of Project

- Tape storage systems continue to play a crucial role in long-term data retention for various industries, such as scientific research, and archival repositories, particularly at National Laboratories like Fermilab
- Goals:
  - Present a comprehensive understanding of the current tape storage system
  - Accurately model the behavior of modern tape storage systems, including various components such as tape drives, libraries, and media
  - Identify key factors influencing system performance, such as data compression, and tape utilization patterns

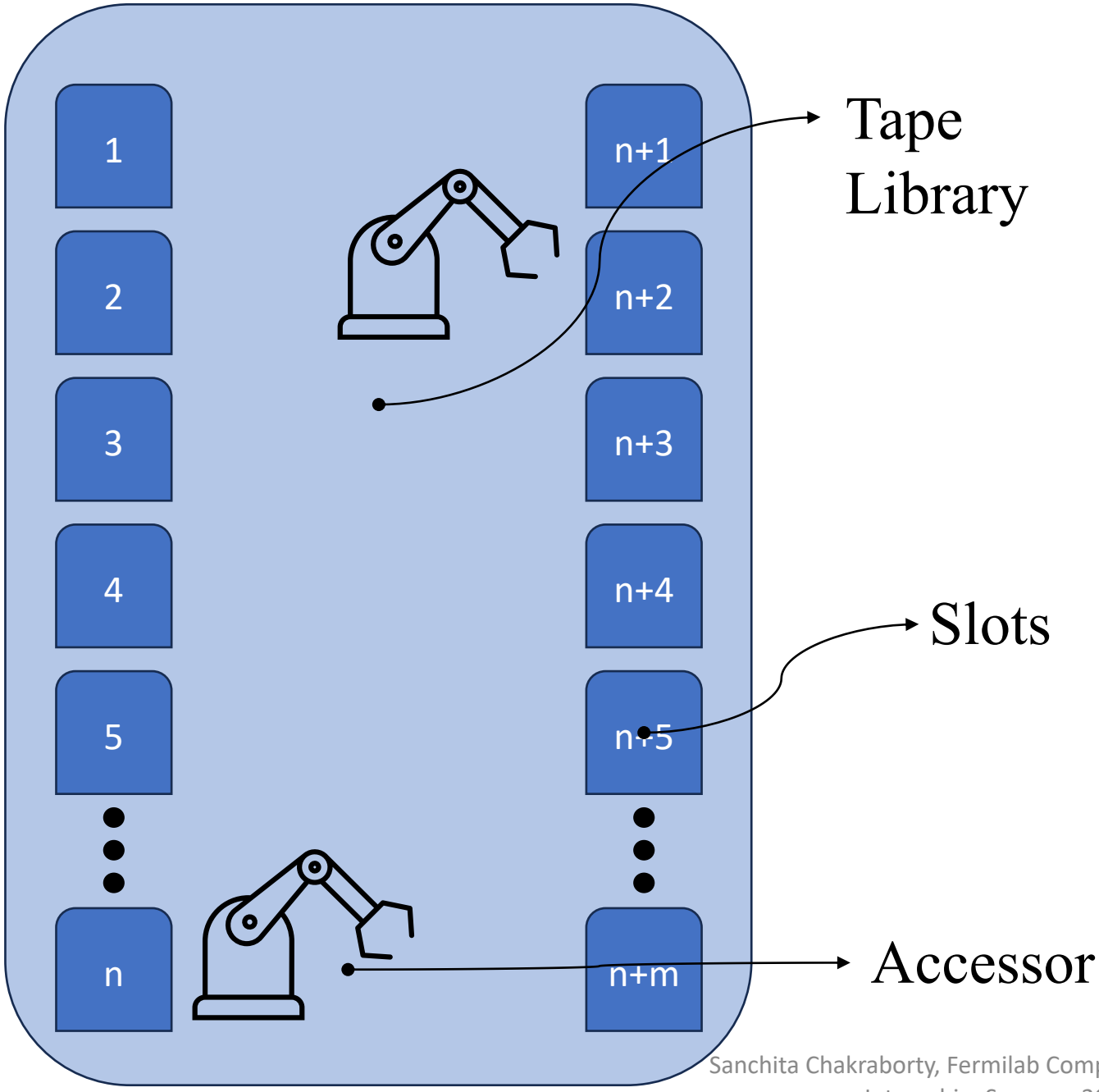
Tape Library Characteristics



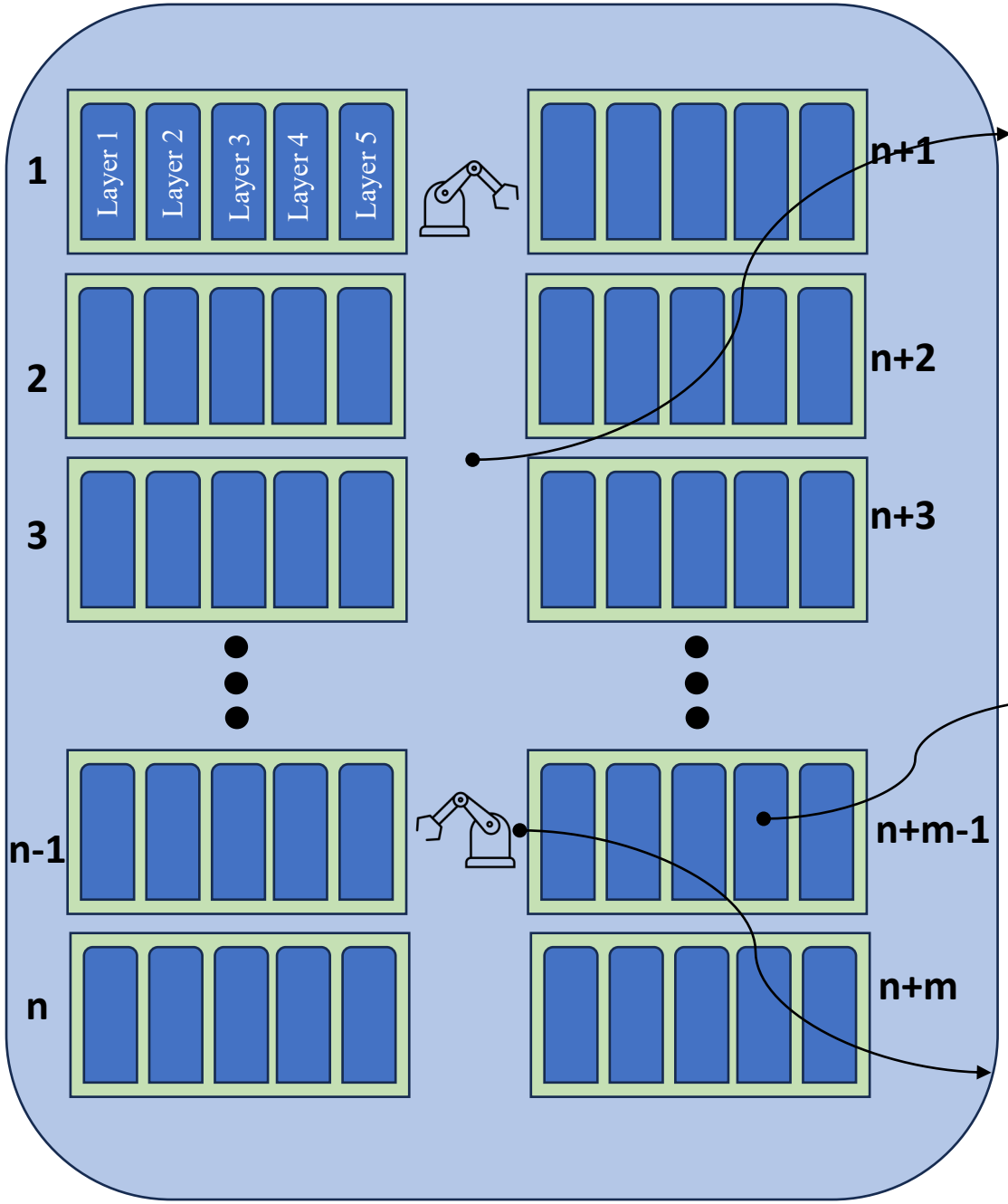
State of Tape Library:
state_S1, state_S2, state_S3, state_S4, state_S5: 0, 1, or 2 to describe occupied or not
Number of Departures Per Tape Library :
num_of_departures1, num_of_departures2, num_of_departures3, num_of_departures4, num_of_departures5
Total Departure Time of Tape Library :
dep_sum_S1, dep_sum_S2, dep_sum_S3, dep_sum_S4, dep_sum_S5
Departure Time From Tape Library :
t_departure_S1, t_departure_S2, t_departure_S3, t_departure_S4, t_departure_S5
Type of Storage Tape Library : based on user input
TYPE_S1, TYPE_S2, TYPE_S3, TYPE_S4, TYPE_S5

Organization Schematic of Servers

Non-IBM Tape Library



IBM Tape Library



Tape Library

Slots

Accessor

Tape Characteristics

Tape Addresses - Alphanumeric

cpfes53f12e5kv4g	ja0fl2nbjj6dwju9	qrozoxi6bpj295k8	• • •	a99zjgvo84j5krdz	9mzk1d0vmhhu6bsi
0	1	2		num_tapes - 2	num_tapes - 1

Tape Location – Information about Tape Library, Slot, and Layer: tape_location[index] = [library, slot, layer]

[tape library, slot, layer]	[tape library, slot, layer]	[tape library, slot, layer]	• • •	[tape library, slot, layer]	[tape library, slot, layer]
0	1	2		num_tapes - 2	num_tapes - 1

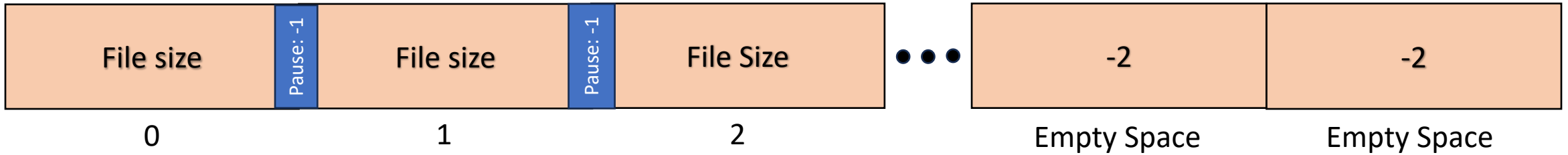
Tape Type – randomized between LTO6, LTO7, LTO8, LTO9 based on user input of how many of each per server

LTO6	LTO8	LTO7	• • •	LTO9	LTO9
0	1	2		num_tapes - 2	num_tapes - 1

Tape Linear Density – Based on Tape Type

48078.9990373 bytes/inch	65620.8645647 bytes/inch	60623.4172634 bytes/inch	• • •	68132.2882086 bytes/inch	68132.2882086 bytes/inch
0	1	2		num_tapes - 2	num_tapes - 1

Tape Storage – Sample Tape with Files



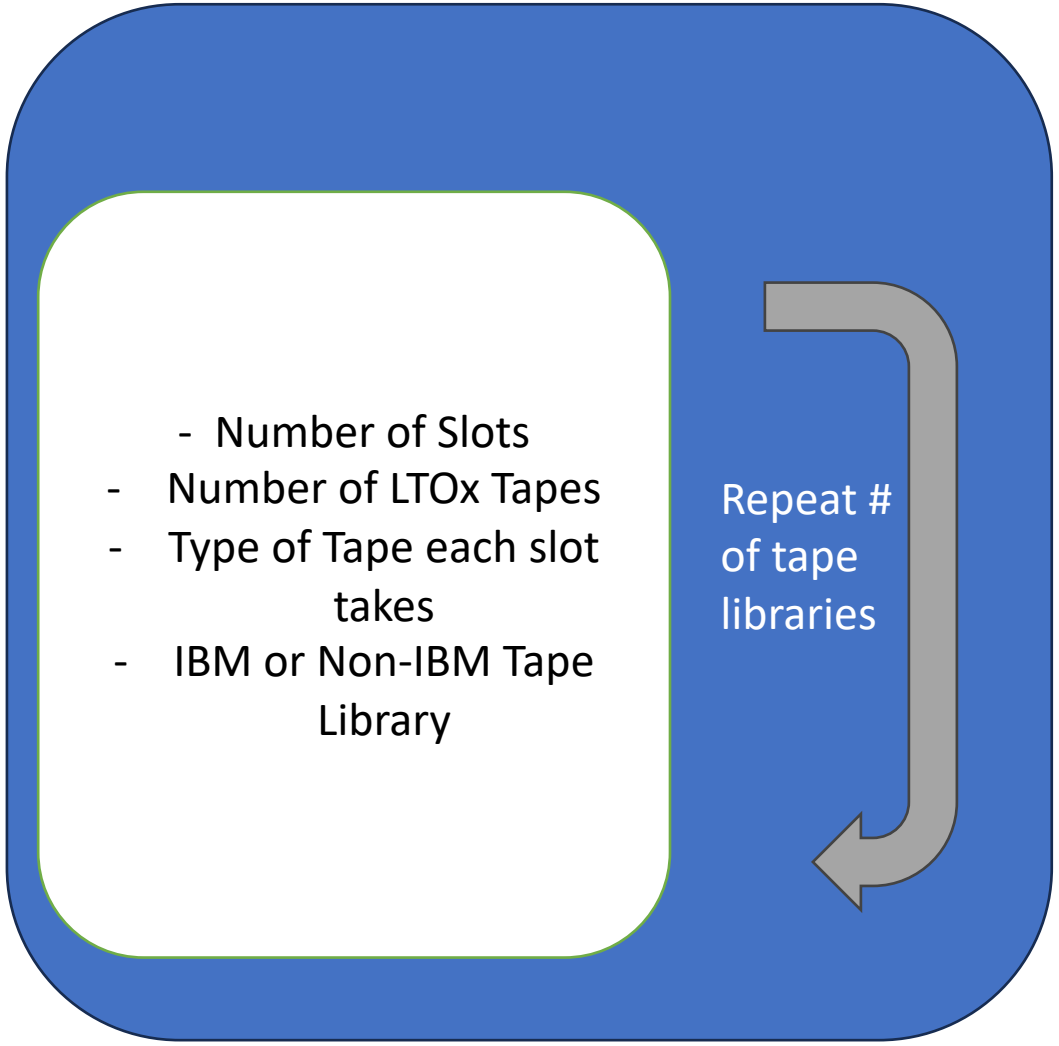
Number of Tapes: user-input for each type
num_tapes: total number of tapes
Num_lto6, num_lto7, num_lto8, num_lto9: each type

Storage: dependent on type of tape and compressed/uncompressed status
LTO6_storage_uncompressed = 2.5E6, LTO6_storage_compressed = 6.25E6
LTO7_storage_uncompressed = 6E6, LTO7_storage_compressed = 1.5E7
LTO8_storage_uncompressed = 1.2E7, LTO8_storage_compressed = 3E7
LTO9_storage_uncompressed = 1.8E7, LTO9_storage_compressed = 4.5E7

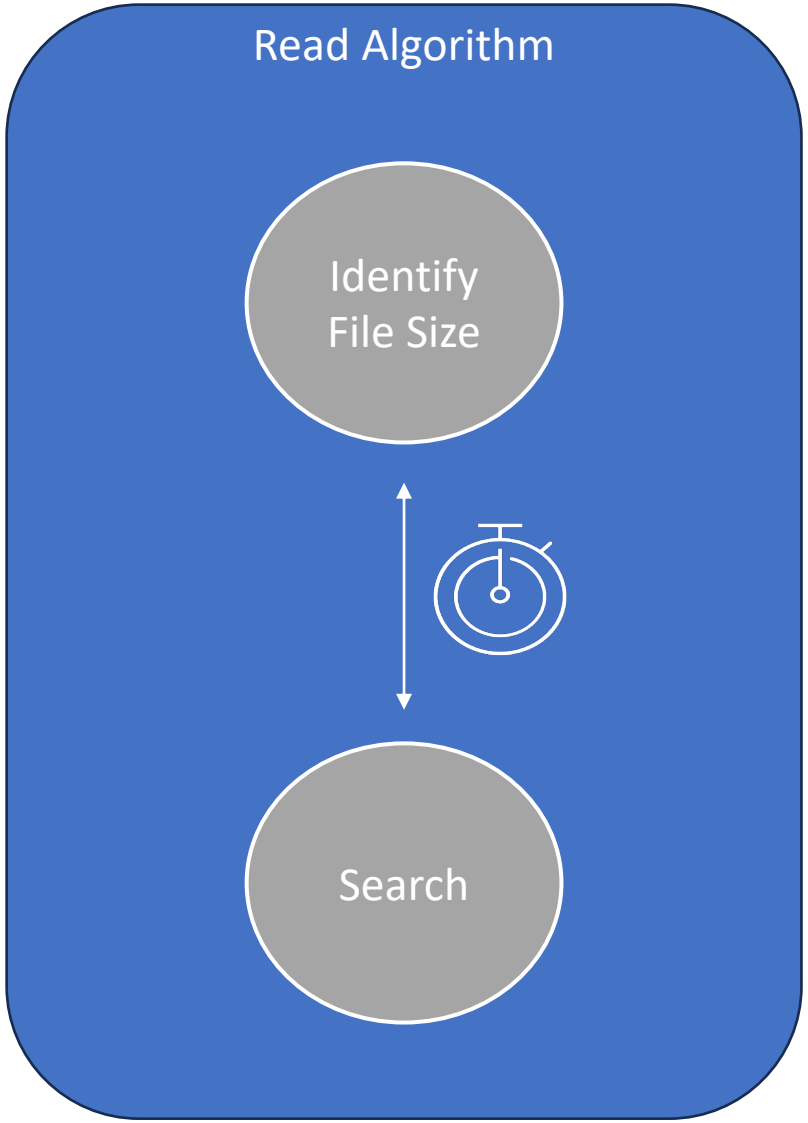
Assumptions:
- Each tape has an assigned location, type, storage capacity

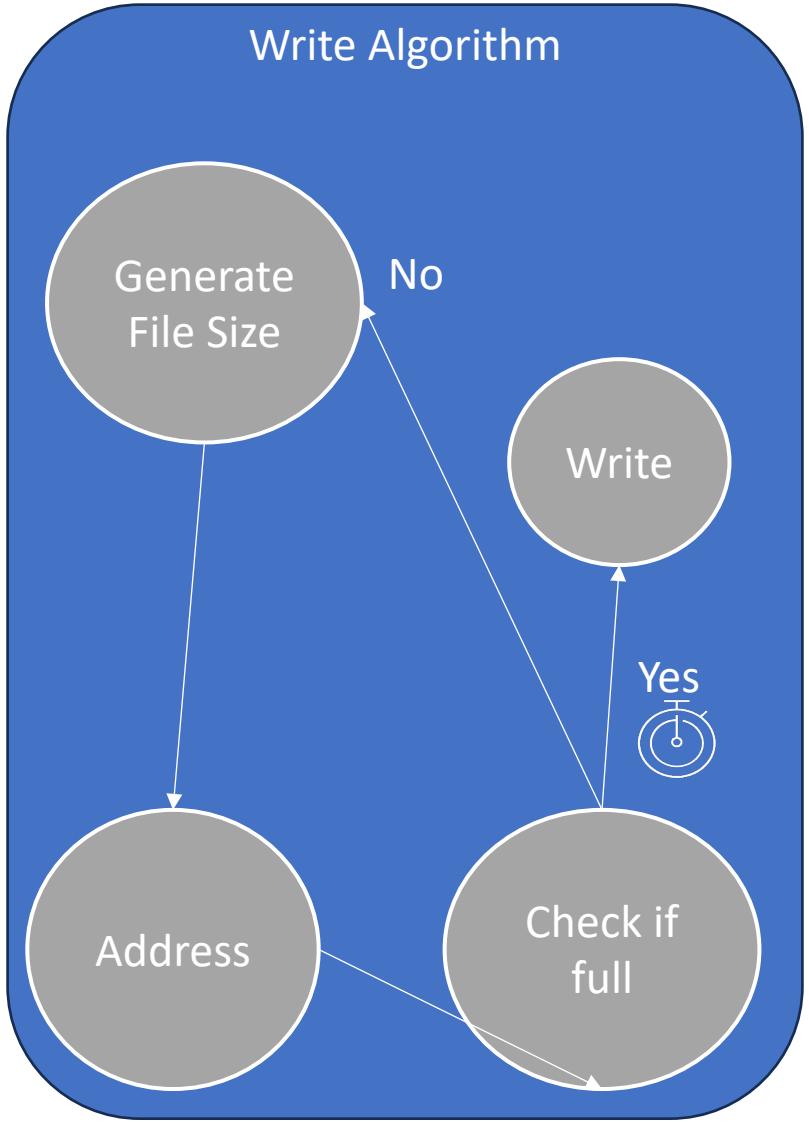
Assumptions and Design of Model

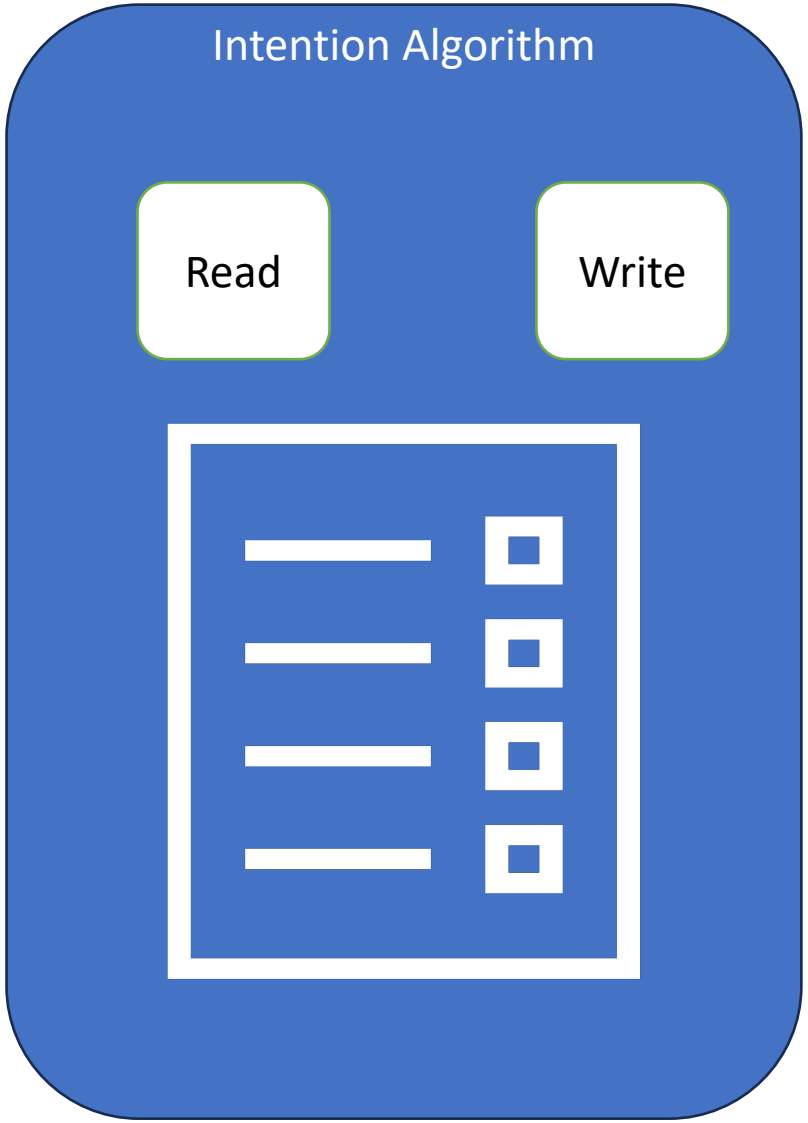
User Input


- Number of Slots
- Number of LTOx Tapes
- Type of Tape each slot takes
- IBM or Non-IBM Tape Library
Repeat # of tape libraries

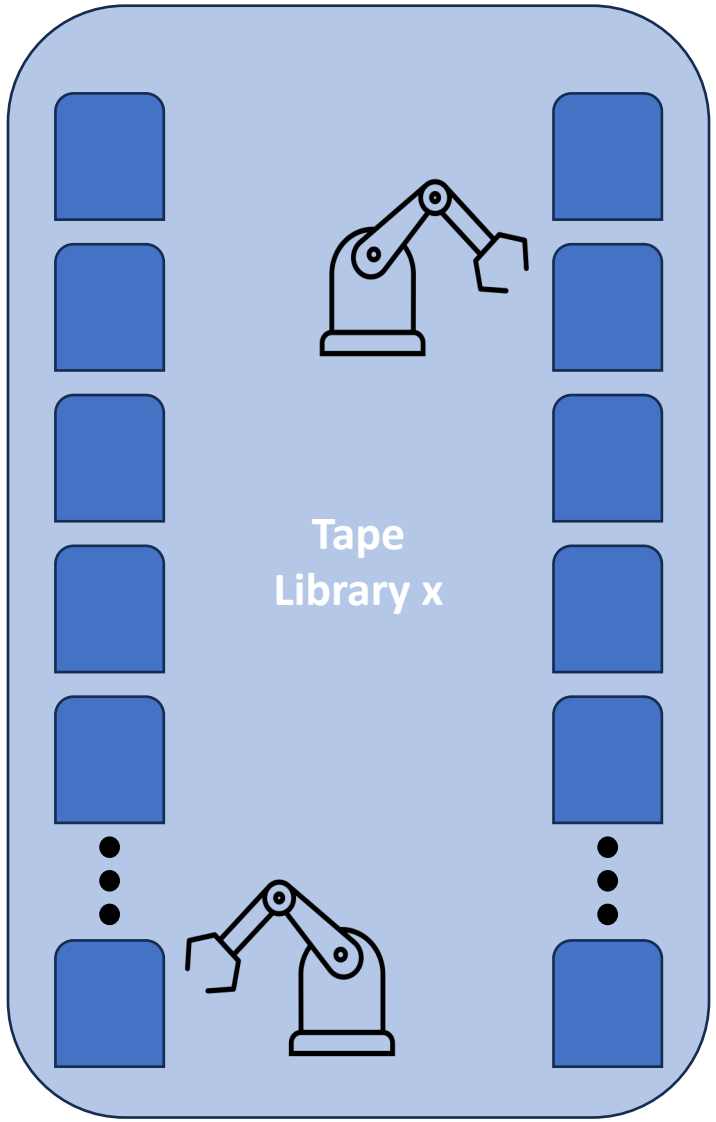
3 Key Algorithms







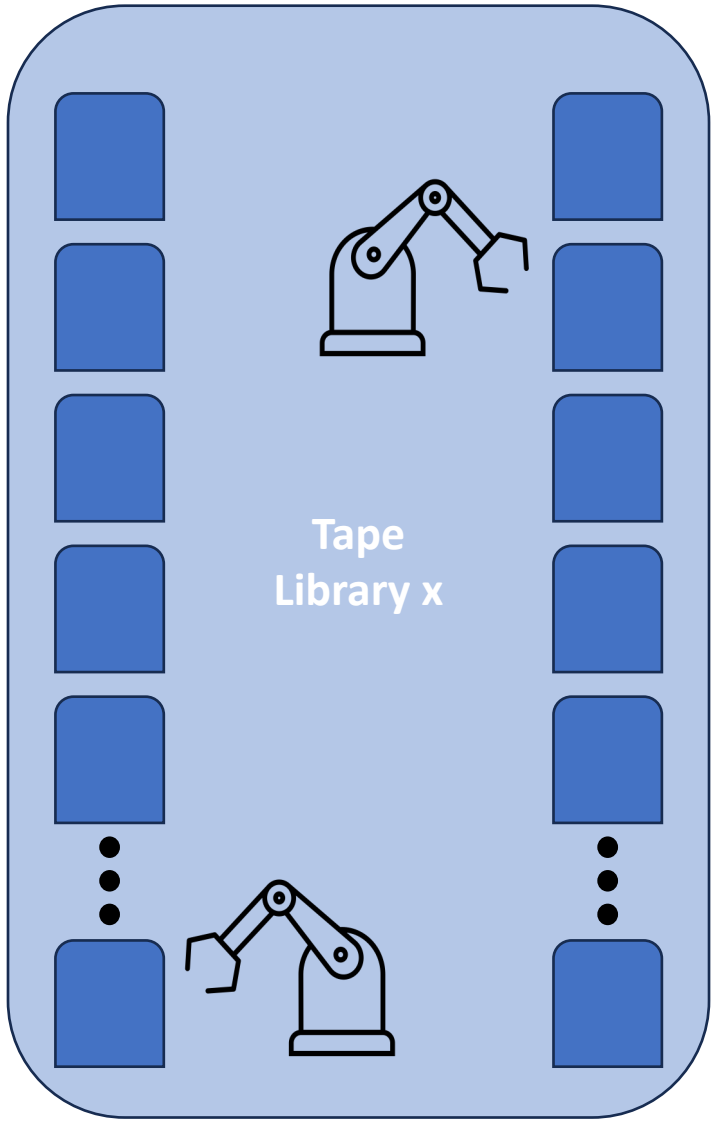
Address Match and Times Accessed



Alphanumeric Address

cpfes53f12e5kv4g

Address Match and Times Accessed



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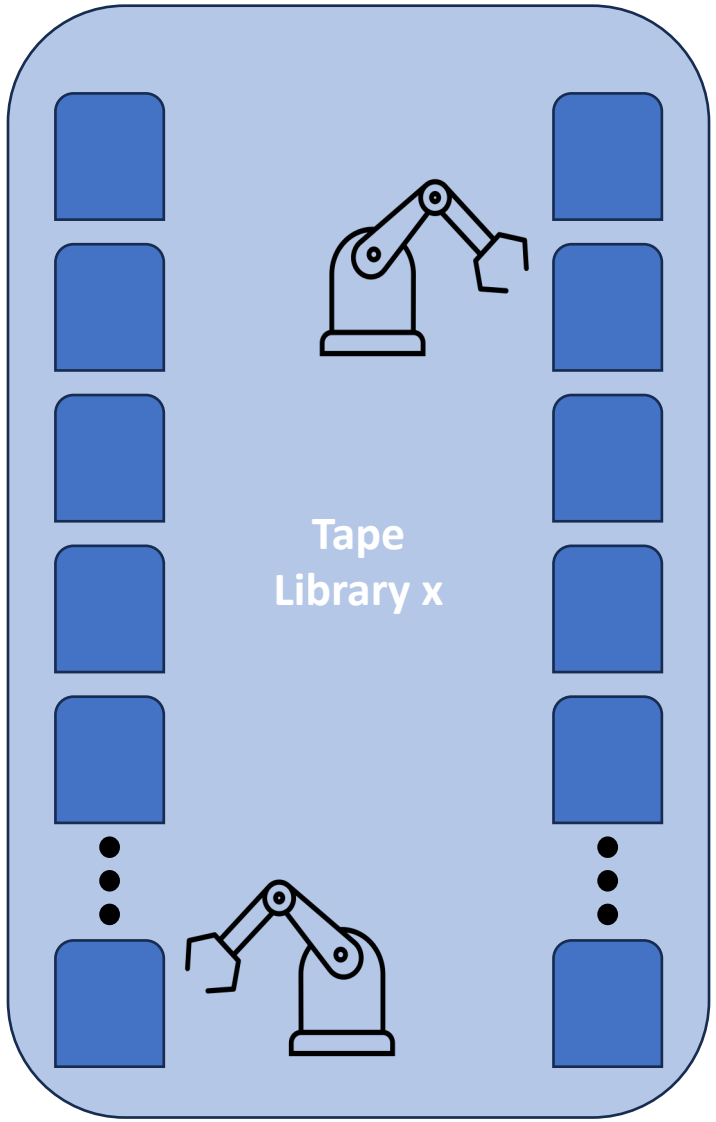

Alphanumeric Address

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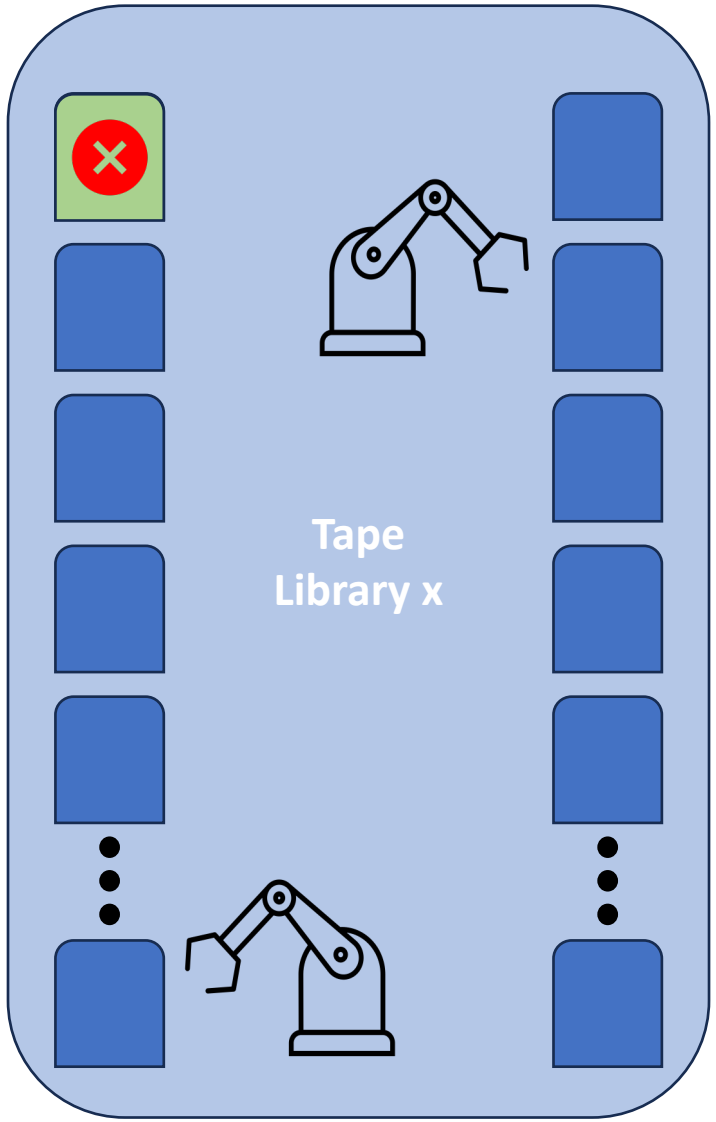
Linked Location Address

[tape library, slot number, layer (IBM only)]

Address Match and Times Accessed



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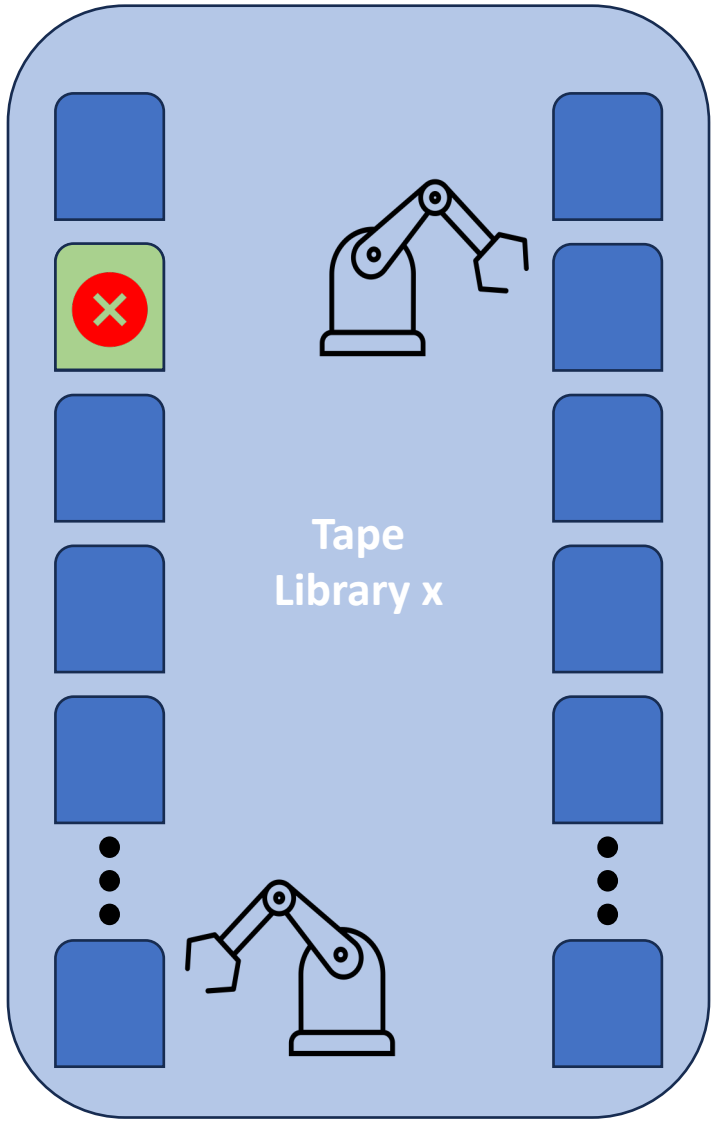

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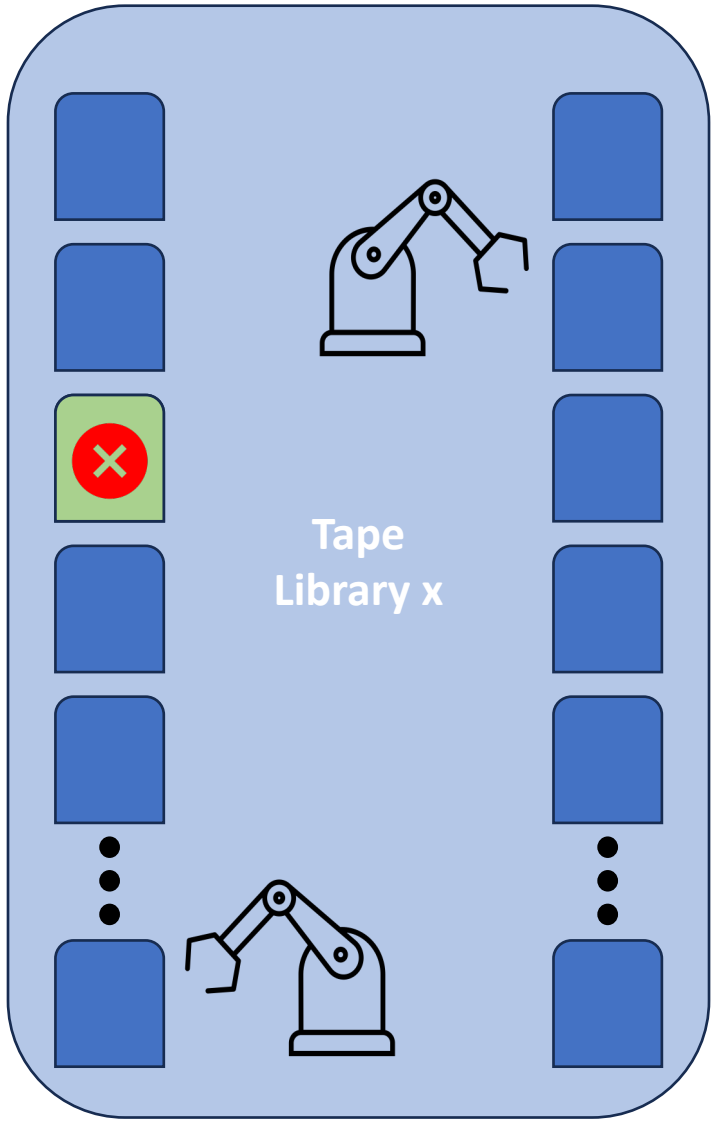

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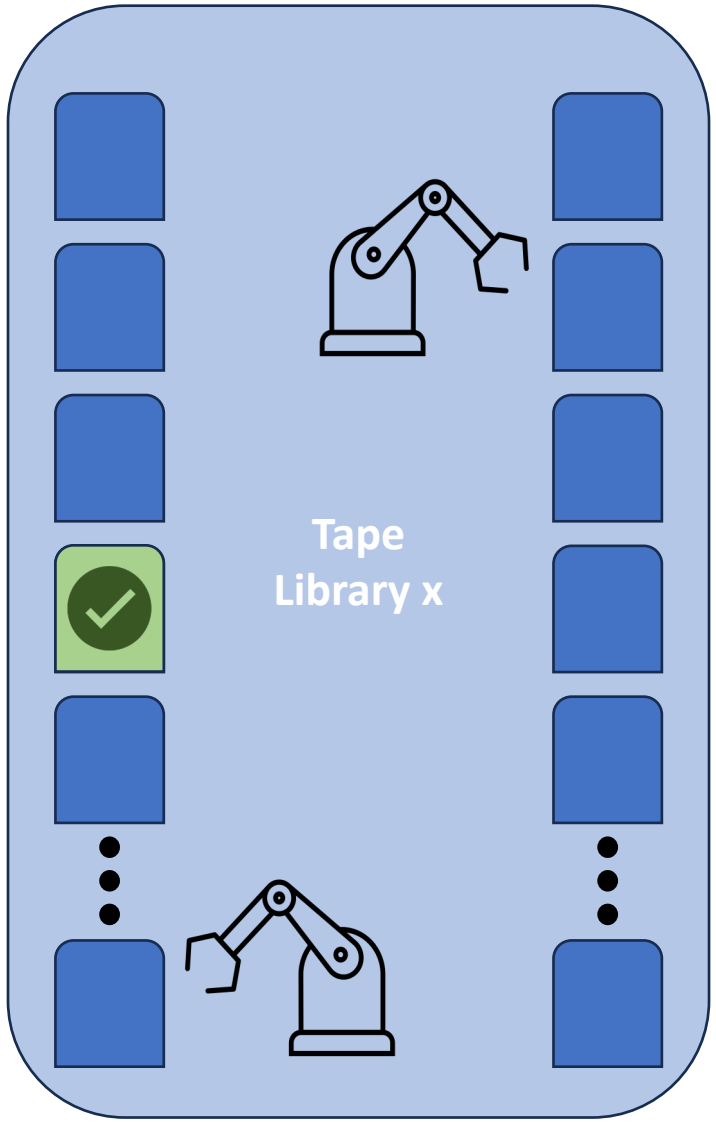


Alphanumeric Address

cpfes53f12e5kv4g

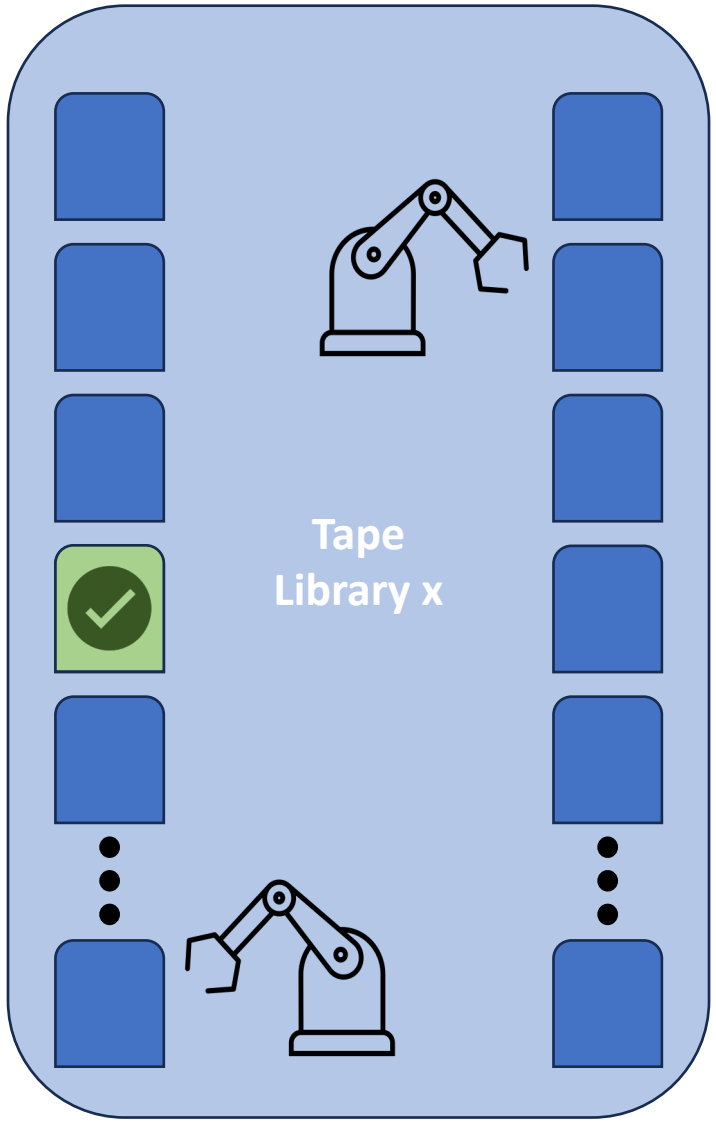
Linked Location Address

[tape library, slot number, layer (IBM only)]

Read

Write

Address Match and Times Accessed



Alphanumeric Address

cpfes53f12e5kv4g

Linked Location Address

[tape library, slot number, layer (IBM only)]

Move + Shuffle ?

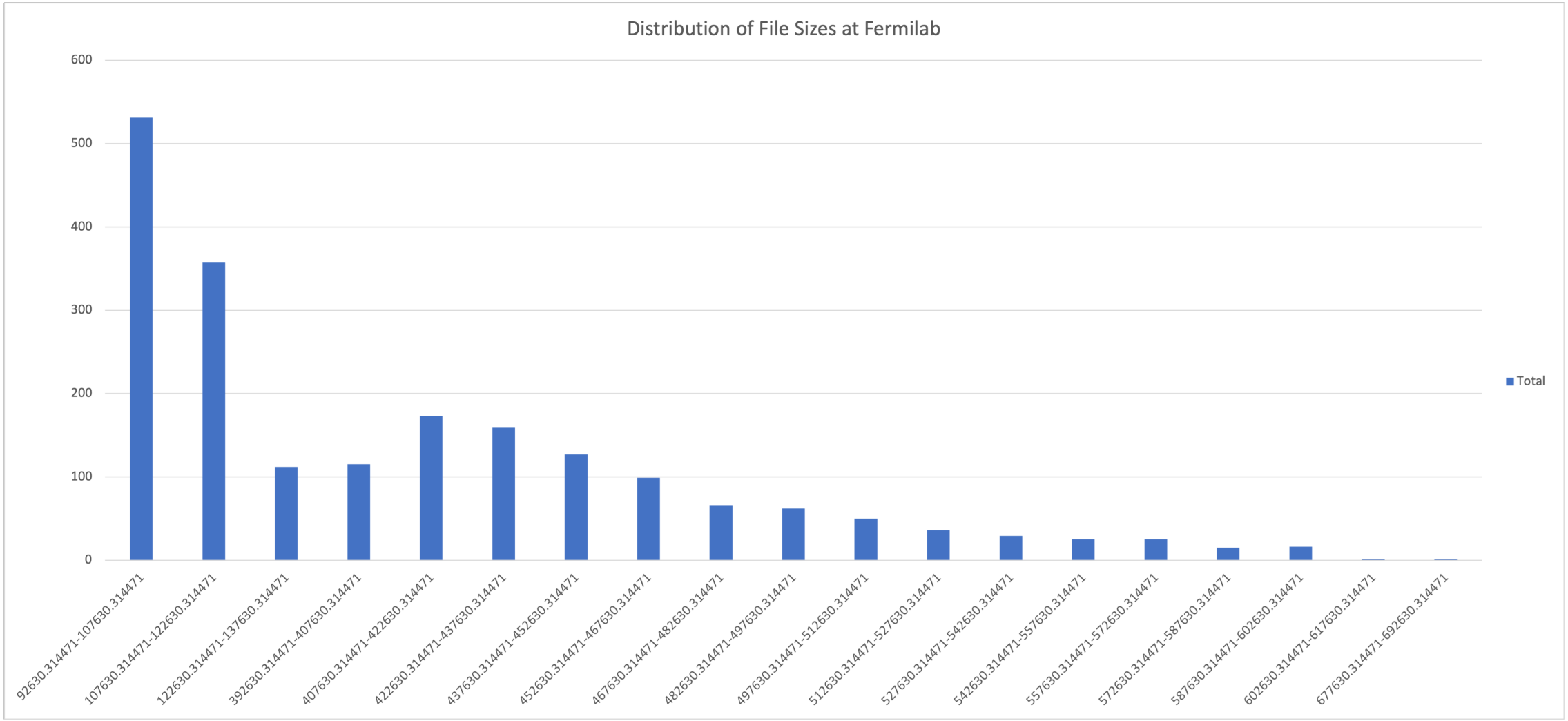
Read

+ times accessed

Write

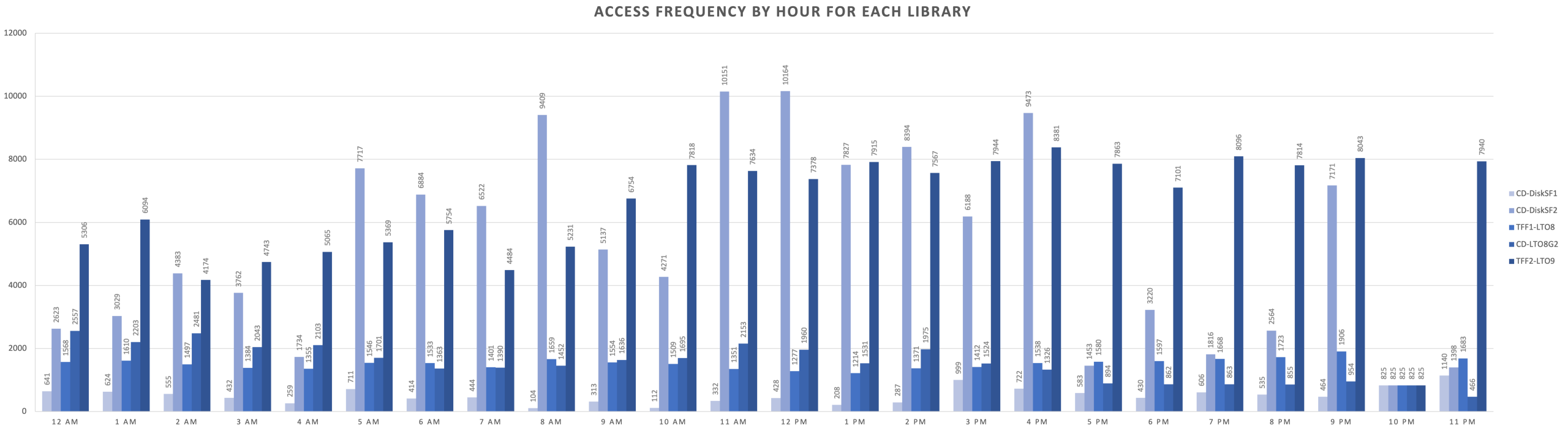
Data Analysis

Data Analysis: Distribution of File Sizes – Read and Write



Left-skewed distribution of file sizes read and written

Data Analysis: Access Times



Normal Distribution of Access Tines
Peaks at 11 AM-12 PM
Adjusted Inverse Sampling Distribution to Normal Distribution for Arrival Times of Requests

Results

Results: Based on Manufacturing Manuals

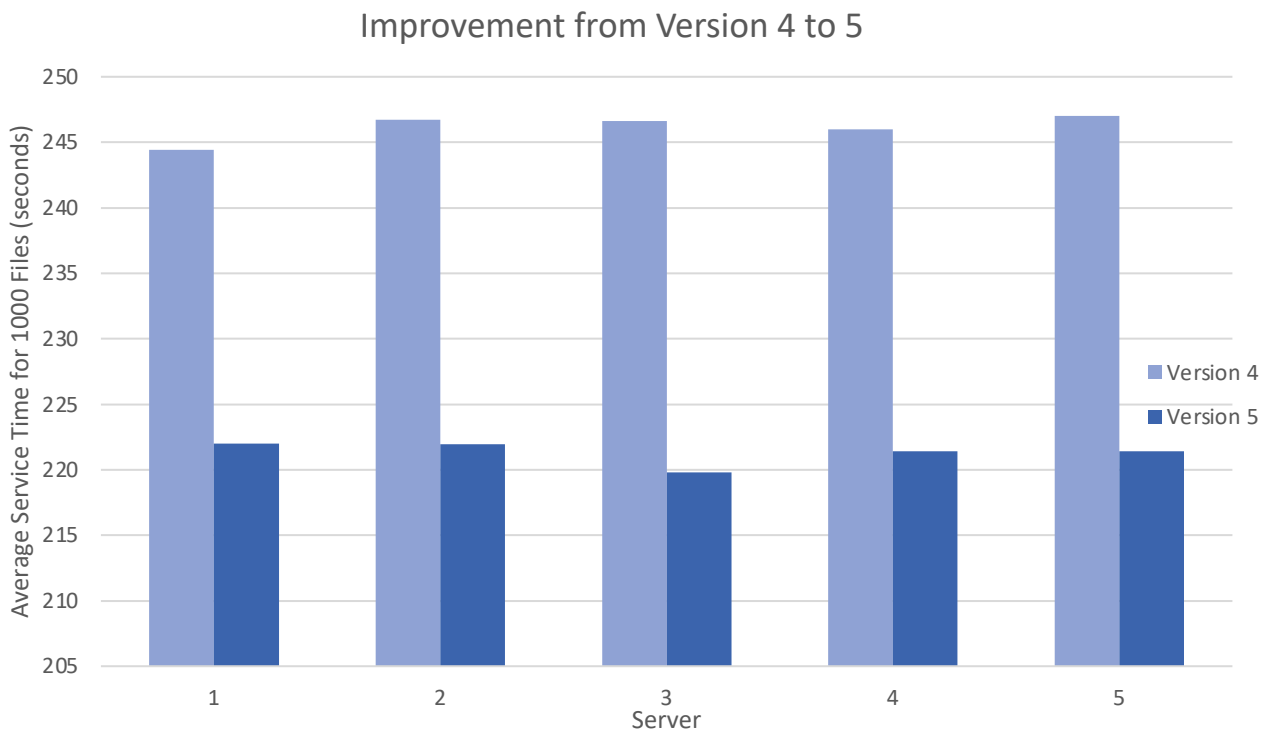
	Average interarrival time (s)	Average service time Server 1 (s)	Average service time Server 2 (s)	Average service time Server 3 (s)	Average service time Server 4 (s)	Average service time Server 5 (s)
0	0.021177743	222.6797094	226.2905221	217.6368678	217.579552	220.5822731
1	0.020980267	231.8249564	228.0940903	229.5558468	233.7142599	235.5518304
2	0.004221989	223.9307743	225.1946658	229.9163698	224.8797972	226.8100741
3	0.00422199	218.2228448	221.6342372	223.4628225	218.7605043	217.8048146
4	0.020870801	212.4394327	221.7980155	219.5758844	210.7681087	216.1303661
5	0.020841632	212.2457673	208.9031728	211.5783937	213.096015	211.5178248

Inputs:

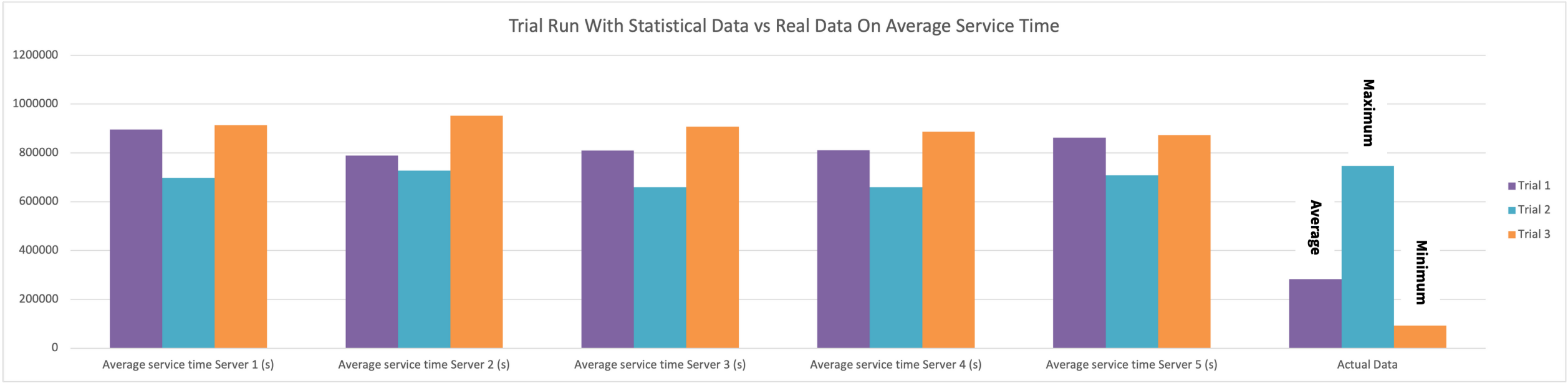
Tape Library 1: IBM, 7 slots
Tape Library 2: IBM, 12 slots
Tape Library 3: Non-IBM, 15 slots
Tape Library 4: Non-IBM, 10 slots
Tape Library 5: Non-IBM, 20 slots

0 LTO-6 tapes
6 LTO-7 tapes
10 LTO-8 tapes
15 LTO-9 tapes

Ran 10 sample trials on 1000 files
Max Inter-arrival Time: 60 seconds
Improvement: 9-10% per server: Find closest slot



Post-Statistical Data Implementation



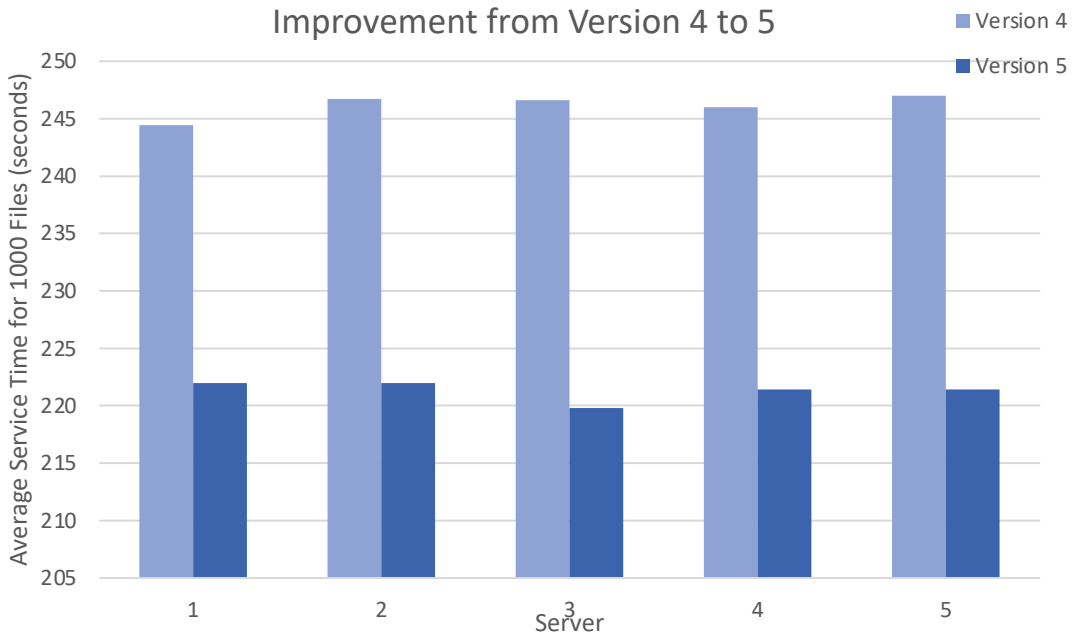
Average Service Time for 5 Different Tape Library Compared to Actual Data

Key Differences and Similarities

- Data matches relatively closely for maximum service time
- Simulation does not do as great a job of capturing the skewed-binomial distribution (see previous slide)
- Data file sizes need to be drawn from a skewed binomial distribution instead of a normal distribution

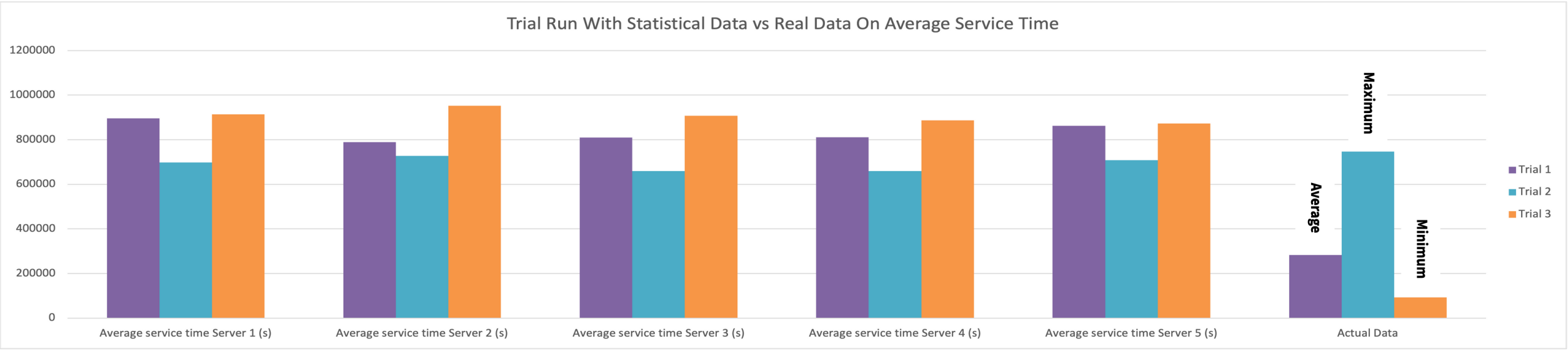
Point of Interest

Stark Difference Between Manufacturing and Actual Speed Claims



Potential Causes

- Huge slowdowns when accessing larger files vs smaller files
- Manufacturing data may be based on much smaller data sets and for use starkly different from that of Fermilab
- Number of individuals accessing files at the same time



Next Steps

Between Now and 09/01/23

- Move the characteristic of LTO8, LTO9 to Slots
- Gather data on efficiency change of acquiring a new tape library, slot, etc. to help determine what the optimal storage system setup may be
- Instead of 2 tasks being completed at a library at a time, change to on average 1.2-1.5 tasks being completed at a library at a time

Questions?

Thank you for your time!