Smart Cache Management for Big Data

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Agenda

- Introduction and Problem statement
- Introduction of Spark & Tachyon
- Performance testing and key learning
- Summary

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Introduction

- Intel Cloud and BigData Engineering Team
  - Working with the community to optimize Apache Spark and Hadoop on Intel platform
  - Improve Spark scalability and reliability
  - Deliver better tools for management, benchmarking, tuning – HiBench, HiMeter
  - Working with China Internet company to build Spark based solution

Problem statement

- In memory becomes more important and popular
  - Cost / capacity of Memory is lower and lower, which makes it possible to handle huge size of data in memory
  - Many computation frameworks leverage memory
- How to manage memory and other fast storage media to hold data is an interesting problem
  - There are still some challenges, such as GC overhead and data sharing
  - When data is huge, memory can't fit it in, external storage is still needed
- We share our learning w/ spark and tachyon in a customer workload

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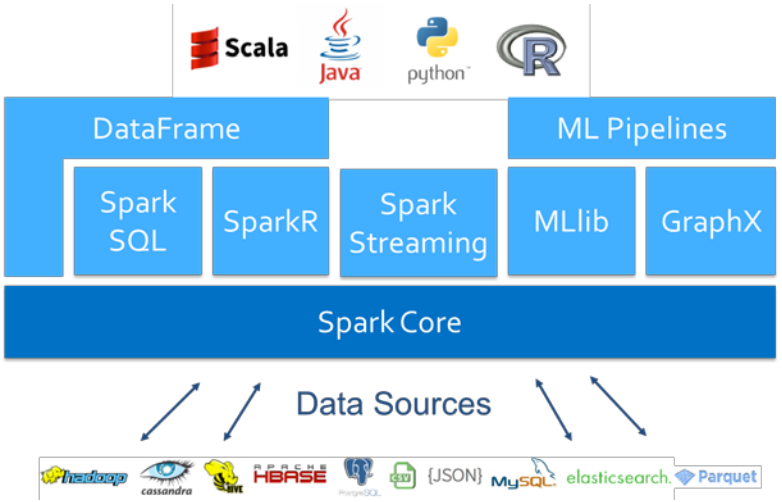
Introduction of Spark

http://spark.apache.org/

- Spark is a fast and general in-memory cluster computing system, interoperable with Apache Hadoop
  - Write programs in terms of coarse-grained transformations on distributed datasets
  - Concept: resilient distributed datasets (RDDs)
- Improves efficiency through:
  - In-memory computing primitives
  - General execution graphs
- Improves usability through:
  - Rich APIs in Java, Scala, Python, R
  - Interactive shell

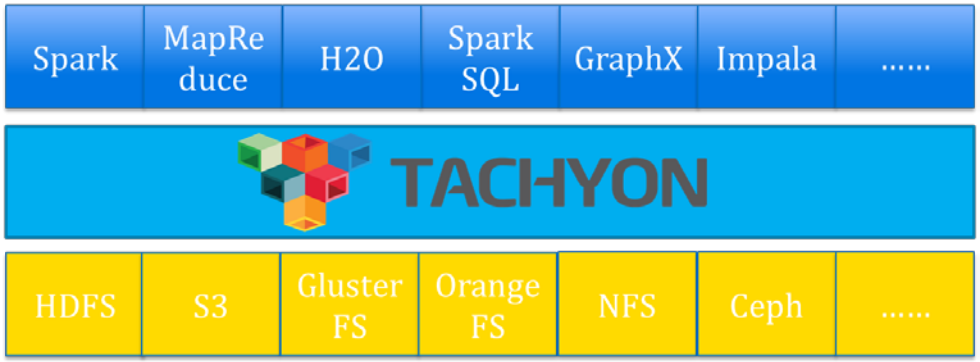


Source: https://dn-idzvideo.qbox.me/Spark_AMPCamp_China.pdf

Introduction of Tachyon

http://www.tachyonproject.org/

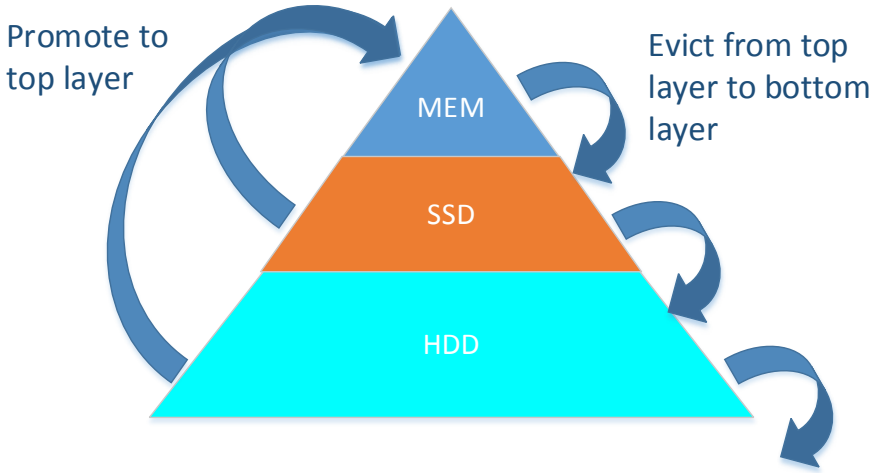
- Tachyon is an memory-centric distributed storage system enabling data sharing at memor-speed acorss cluster frameworks, such as Spark Mapreduce etc.
  - Caches working set files in memory and off-heap
  - Enables different jobs/queries and frameworks to access cached files at memory speed
  - Avoids GC overhead on caching data
- Features
  - Java-like file API
  - Hadoop File system compatible
  - Pluggable under layer file system
  - Command line interface
- Tiered block storage



Source: http://www.cs.berkeley.edu/~haoyuan/talks/Tachyon_2014-10-16-Strata.pdf

Tiered storage in Tachyon

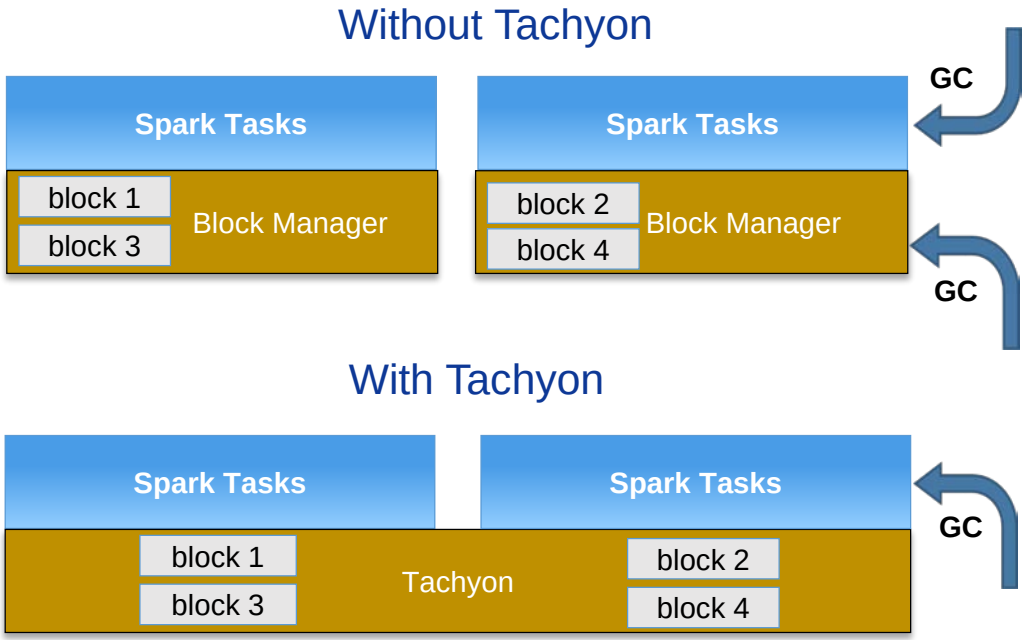
- Tiered block storage is used to extend Tachyon's caching space with external storage, such as SSD HDD etc.
  - Different tiers have different speed and priority
  - "Hot" data and "warm" data are putted on different layers
  - Multiple directories in single tier
- Data migration among tiers
  - "Hot" data can be evicted to lower layer, when it is not "hot" any longer by eviction strategies.
  - "Warm" data can be promote to top layer, when it becomes "hot" again.
- It is available since Tachyon 0.6 Release
  - The JIRA for tiered storage: TACHYON-33



Spark & Tachyon Integration

- Tachyon is default Off-heap solution for Spark currently. And there are two work model of using Tachyon in Spark jobs.
  - Input/Output data with Tachyon
    - Take Tachyon as input/output file system, just like HDFS
  - Persist Spark RDDs into Tachyon
    - Setting storage level of RDD to OFF_HEAP
- By integrating Tachyon into Spark, it will bring:
  - Fast data access at memory speed
  - Eliminate GC overhead by placing data to OFF_HEAP

GC overhead in Spark



- GC overhead can be divided into two parts:
  - Over temporary data generated during task execution
  - Over caching data in Spark's block manager
- Tachyon can eliminate the second part of GC overhead

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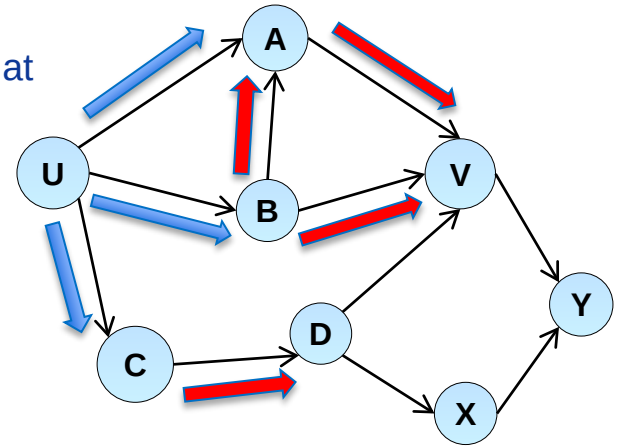
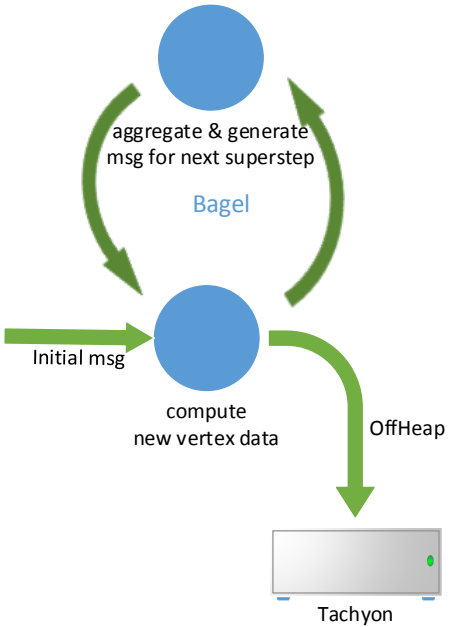
Test case description

- Compute associations between two vertices that are n-hop away
  - Way of getting Vertices that have N degree association
  - Weightn(u, v) = $\sum_{k=1}^{M} \boldsymbol{Wp}\ (\boldsymbol{U},\boldsymbol{V})\boldsymbol{k}$ (M is the number of paths that have exactly n edges)
  - $\boldsymbol{Wp}(\boldsymbol{U},\boldsymbol{V})\boldsymbol{k} = \prod_{e=1}^{n} We$ (We is the weight of edge)
- A Graph Analysis case
  - E.g., friends of friend in social network
- Graph-parallel implementation
  - Bagel (Pregel on Spark)



Bagel over Tachyon

- Bagel is a Spark implementation of Google's Pregel graph processing framework.
  - In Pregel programming model, jobs run as a sequence of iterations called supersteps.
  - In each superstep, each vertex in the graph runs a user-specified function that can update state associated with the vertex and send messages to other vertices for use in the next iteration.
  - The message generated and new vertex data will be cached after each iteration
- Intermediate data can be cache in Tachyon
  - Eliminate GC overhead because of huge data size and long running time



Test Bed

- One master node with four worker nodes

Worker node Configuration	
CPU	SNB 2660 @ 2.2G 32 logical cores
Memory	192GB DDR3 @ 1066 MHZ
Disk	4 * 400G SSD（S3700）
OS Distribution	Redhat 6.2 (kernel 2.6.32-220.el6.x86_64)
JDK version	JDK1.7.0_79 (64 bit server)
Spark version	1.4.1 release
Tachyon version	0.7.0-SNAPSHOT
Hadoop version	2.3.0

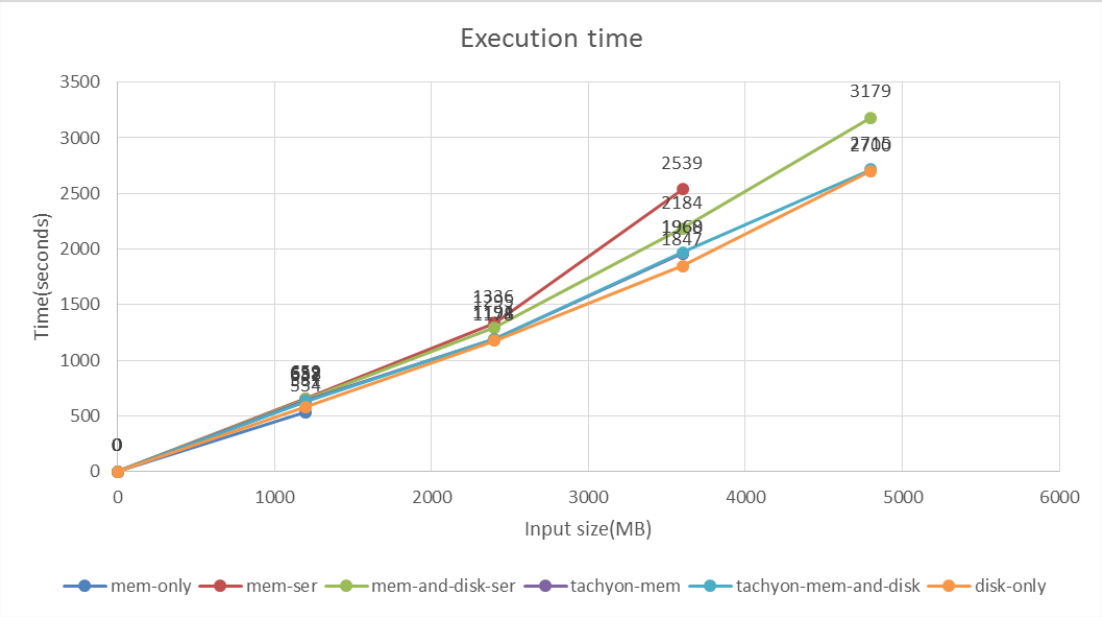
Common configuration

- Total memory size used on each machine: 140G
  - Size of SPARK_MEM + TACHYON_MEM
- Spark configuration:
  - Spark local directory: 4 SDD
  - GC strategy: Parallel GC
- Tachyon tiered storage configuration
  - Level1: MEM
  - Level2: 4 SSD

Workload configuration

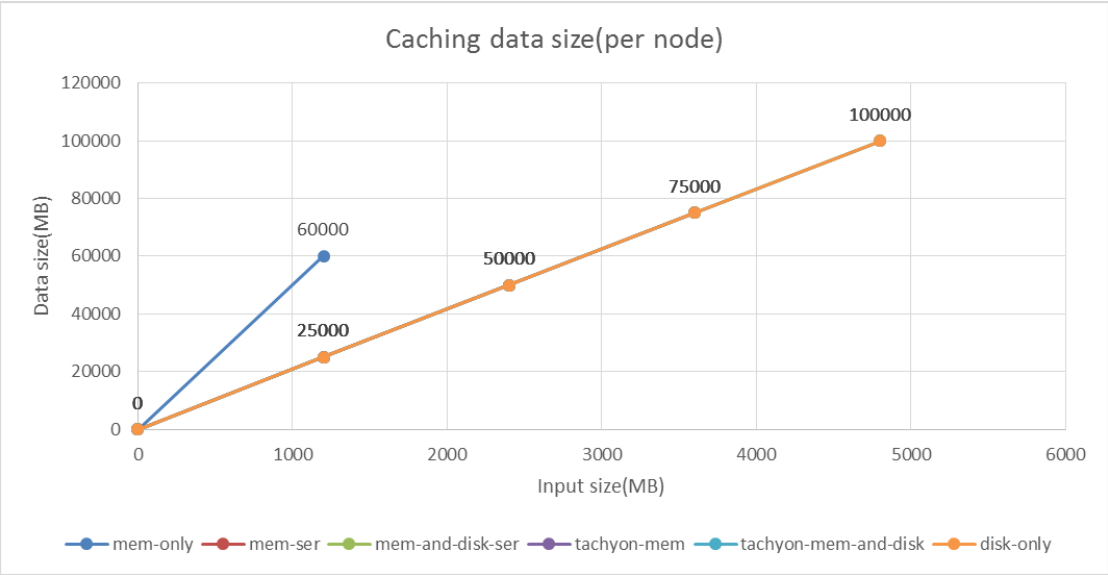
Data size	Configuration					
	MEM_ONLY	MEM_SER	MEM_AND_DISK_SER	DISK_ONLY	TACHYON_MEM	TACHYON_MEM_AND_DISK
1200MB	SPARK_MEM=140G MEM_FRACTION=0.6	SPARK_MEM=140G MEM_FRACTION = 0.6	SPARK_MEM=140G MEM_FRACTION = 0.1	SPARK_MEM=140G MEM_FRACTION = 0.1	SPARK_MEM=115G TACHYON_MEM=25G MEM_FRACTION = 0.1	SPARK_MEM=125G TACHYON_MEM=15G MEM_FRACTION = 0.1
2400MB	N/A	SPARK_MEM=140G MEM_FRACTION=0.6	SPARK_MEM=140G MEM_FRACTION = 0.2	SPARK_MEM=140G MEM_FRACTION = 0.1	SPARK_MEM=90G TACHYON_MEM=50G MEM_FRACTION = 0.1	SPARK_MEM=115G TACHYON_MEM=25G MEM_FRACTION = 0.1
3600MB	N/A	SPARK_MEM=140G MEM_FRACTION = 0.8	SPARK_MEM=140G MEM_FRACTION = 0.3	SPARK_MEM=140G MEM_FRACTION = 0.1	SPARK_MEM=65G TACHYON_MEM=75G MEM_FRACTION = 0.1	SPARK_MEM=105G TACHYON_MEM=35G MEM_FRACTION = 0.1
4800MB	N/A	N/A	SPARK_MEM=140G MEM_FRACTION = 0.35	SPARK_MEM=140G MEM_FRACTION = 0.1	N/A	SPARK_MEM=100G TACHYON_MEM=40G MEM_FRACTION = 0.1

Test result – execution time



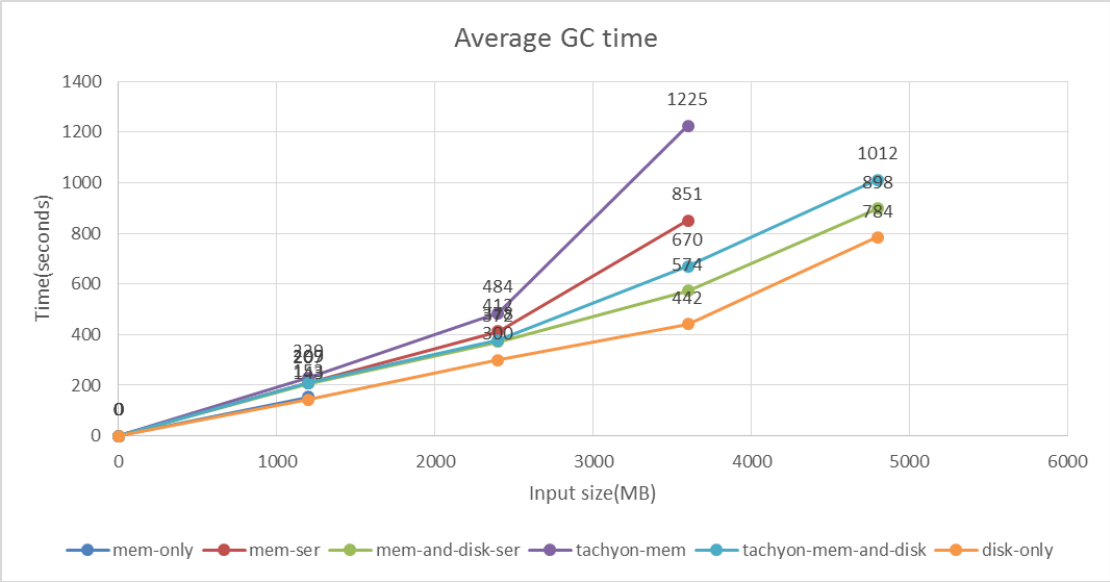
- With small data size(1200MB), MEM_ONLY gets the best performance, others are similar
- With medium data size(2400MB), MEM_ONLY failed to run because of huge caching data size.
- With large data size(3600MB), TACHYON_MEM and TACHYON_MEM_AND_DISK out performs MEM_SER and MEM_AND_DISK_SER(10+%), DISK_ONLY gets the best performance
- With huge data size(4800MB) , TACHYON_MEM and MEM_SER failed to run because of huge caching data size, TACHYON_MEM_AND_DISK outperforms MEM_AND_DISK_SER(10+%), DISK_ONLY and TACHYON_MEM_AND_DISK are very similar

Test result – caching data size



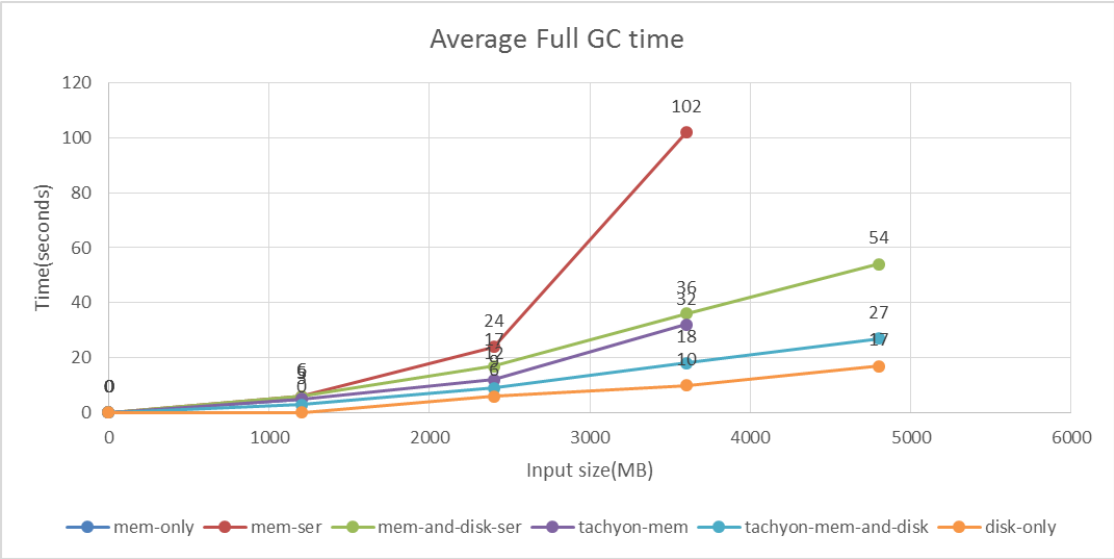
- The data size without serialization is about three times of the size with serialization.
- Without serialization, the application can only successfully run on small data size, though it gets the best performance

Test result – total GC time



- GC time is very related to the HEAP size that allocated to the Spark executor engine
- DISK_ONLY has the least GC overhead, because it uses disk space to act as memory
- TACHYON_MEM has the biggest GC overhead, because it allocates smallest HEAP size, much memory is used as Tachyon's cache space

Test result – full GC time



- Full GC time is very related to both the memory allocated to Spark executor and long live caching data size on heap
- MEM_SER has the biggest full GC overhead, because all caching data is on HEAP
- DISK_ONLY has the least Full GC overhead

Test summary

- Performance
  - With SSD, Spark with DISK_ONLY gets the best performance
  - When memory is not enough, use external storage(large but slower) as additional storage will speed up execution, compared with memory only
  - TACHYON_MEM and TACHYON_MEM_AND_DISK outperforms MEM_SER and MEM_AND_DISK_SER in Spark, The performance gain comes from:
    - Enhancement of disk IO throughput
    - Eliminate GC overhead
- GC overhead
  - DISK_ONLY gets the least GC overhead, including full GC overhead
  - Tachyon can not eliminate GC overhead all the time
    - Take the memory space that can be allocated to application
    - Have good effect for full GC overhead

Key learning

- Not use memory only mode (including ser etc) – because the run fail ratio may be high
- When memory size is too big – the GC overhead may become higher and higher – in this case, we suggest to use off heap mode - TACHYON_MEM_AND_DISK out performs MEM_SER and MEM_AND_DISK_SER(10+%)
- Current DISK_ONLY and TACHYON_MEM_AND_DISK are very similar – however, we believe TACHYON_MEM_AND_DISK can provide better flexibility – e.g.
  - Mem+SSD+HDD w/ higher disk size and better performance.
  - Hot data will be cached in memory – thus reduce the read latency
- We are working on asynchronous mode – which is expected to improve TACHYON_MEM_AND_DISK performance
  - The JIRA for asynchronous eviction: TACHYON-334

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Summary

- Memory is the new disk
- Memory management (GC) is the key problem for big data application
- Tiered storage (mem+SSD+HDD) w/ offheap can provide better performance

Q & A

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