EE275 Mini Project III (Fall 2022)

Project: Cache Simulator

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In [1]:
```python
import math
import random
from enum import Enum
import matplotlib.pyplot as plt
import pandas as pd

trc_limit=1.0 # % of trace to process [ between 0.0 to 1.0], reduce it for shorter simulation
```

Reading Address Trace

In [2]:
```python
lines = ()
with open("addr_trace.txt", "r") as f:
    lines = f.read().splitlines();

addr_trace = [int(i) for i in lines]
#print (addr_trace)
```

Translating Trace

In [3]:
```python
prevAddr = 0
for idx in range(len(addr_trace)):
    addr_trace[idx] += prevAddr
    prevAddr = addr_trace[idx]
#print (addr_trace)
```

Main Memory Implementation

In [4]:
```python
# Main memory reads are supported simply by returning a line of random bytes
def getRandDataLine(b_size):
    line = []
    for i in range(b_size):
        line.append(random.randint(0,pow(2,8))) ## every location holds 8-bit of data
    return line
```

Performance Recorder

In [5]:
```python
## Recorder tracks all the hits/misses
class Recorder:

    def __init__(self):
        self.history = []
        self.hitCount = 0;
        self.missCount = 0;
        self.hitRate = 0.0;
        self.total = 0;

    # called when after a read is processed
    def record(self, addr, hit):
        self.history.append({'addr': addr, 'hit': hit});
        if(hit):
            self.hitCount += 1
        else:
            self.missCount += 1
        self.hitRate = (self.hitCount / (self.hitCount + self.missCount)) * 100.0
        self.total = self.hitCount + self.missCount

    # show total hits and misses
    def showRecord(self):
        print("Total:", self.total,
              "Hit:", self.hitCount,
              "Miss:", self.missCount,
              "hitRate(%)=", '{0:.3f}'.format(self.hitRate))

    # show hits and misses for each address reads in trace
    def showHistory(self):
        for item in self.history:
            print('{0: >15}'.format(item['addr']), ' ', '{0: >5}'.format(item['hit']))
```

Replacement Policy Manager

In [6]:
```python
# Enum for replacement policies
class Policy(Enum):
    LRU = 1
    FIFO = 2
    RANDOM = 3
```

In [7]:
```python
# ReplacementPolicy: Keeps track of all the reads for LRU, FIFO and Random policies
class ReplacementPolicy:

    def __init__(self, associativity, policy):
        self.associativity = associativity
        self.policy = policy
        self.entryQueue = []
        self.usedQueue = []
        for i in range(associativity):
            self.usedQueue.append(0)

    # called when a line is loaded from MM to Cache
    def reportLoad(self, lineNum):

        # for FIFO : update the FIFO queue
        self.entryQueue.append(lineNum)
        if(len(self.entryQueue) > self.associativity):
            self.entryQueue.pop(0)

        #for LRU : initialize the 'used count' for the loaded line
        self.usedQueue[lineNum] = 1

    # called when a line in cache needs to be replaced
    # returns the line number to replace
    def getLoadableIdx(self):

        # for FIFO: pop from the front of FIFO queue
        if(self.policy == Policy.FIFO):
            if(len(self.entryQueue) == 0):
                return 0
            elif(len(self.entryQueue) < self.associativity):
                return len(self.entryQueue)
            else:
                return self.entryQueue[0]

        # for LRU: get the line that has the lowest 'used count'
        elif(self.policy == Policy.LRU):
            tmp = min(self.usedQueue)
            return self.usedQueue.index(tmp)

        # for RANDOM: just return the random line
        else:
            return random.randint(0,self.associativity-1)

    # called when a line is read
    # LRU updates the line count accordingly
    def reportLookup(self, lineNum):
        self.usedQueue[lineNum] += 1
```

Cache Implementation

1. Cache Structure

In [8]:
```python
######## a single cache line ########
class CacheLine:

    def __init__(self, blockSize, associativity):
        self.cBlocks = []
        self.tag = 0;
        self.associativity = associativity
        for i in range(blockSize):
            self.cBlocks.append(0)

    # show the line
    def show(self, setNum, lineNum):
        frmt = "{:>5}"*len(self.cBlocks)
        print("set=", '{0: >5}'.format(setNum), " | line=", '{0: >5}'.format(lineNum + setNum * self.associativity), " | ", frmt.format(*self.cBlocks))

    # find given block in the cache line
    def lookup(self, lookupObj):
        lookupObj.data = self.cBlocks[lookupObj.offset]

    # load the cache line with new data
    def load(self, loadObj):
        self.tag = loadObj.tag
        self.cBlocks = loadObj.dataList

######## a single set of Cache ########
class CacheSet:

    def __init__(self, linesInSet, blockSize, associativity, policy):
        # create multiple cache lines
        self.rPolicy = ReplacementPolicy(associativity, policy)
        self.cLines = []
        self.associativity = associativity
        for i in range(linesInSet):
            self.cLines.append(CacheLine(blockSize, associativity))

    # show the set
    def show(self, setNum):
        for lineNum in range(len(self.cLines)):
            self.cLines[lineNum].show(setNum, lineNum)

    # find the given line in this set
    def lookup(self, lookupObj):
        lookupObj.hit = False;
        lookupObj.data = 0;
        for i in range(len(self.cLines)):
            if(self.cLines[i].tag == lookupObj.tag): #hit
                lookupObj.hit = True
                lookupObj.line = i
                self.cLines[i].lookup(lookupObj)
                self.rPolicy.reportLookup(i)

    # load one of the lines in set with given data
    def load(self, loadObj):
        loadIdx = self.rPolicy.getLoadableIdx()
        self.cLines[loadIdx].load(loadObj)
        self.rPolicy.reportLoad(loadIdx)


######## Main Cache ########
class Cache:

    def __init__(self, cacheSize, blockSize, associativity, policy):
        self.recorder=Recorder();
        # create multiple cache sets
        numOfLines = cacheSize // blockSize
        numOfSets = numOfLines // associativity
        linesInSet = numOfLines // numOfSets
        self.cSets = []
        for i in range(numOfSets):
            self.cSets.append(CacheSet(linesInSet, blockSize, associativity, policy))

    # show the cache contents
    def show(self):
        for setNum in range(len(self.cSets)):
            print("--------------------------")
            self.cSets[setNum].show(setNum)

    # find the given physical address in cache
    def lookup(self, lookupObj):
        self.cSets[lookupObj.set].lookup(lookupObj)
        self.recorder.record(lookupObj.addr, lookupObj.hit)

    # load the given data in cache line
    def load(self, loadObj):
        self.cSets[loadObj.set].load(loadObj)
```

2. Cache Lookup and Load information

In [9]:
```python
### Lookup Object: this object holds all the information about an instance of cache read operation
class LookUpObj:
    def __init__(self,  addr, n_tag, n_set, n_offset):
        self.addr = addr
        self.tag = int(addr) >> (n_set + n_offset) & ((1 << n_tag) - 1)
        self.set = int(addr) >> (n_offset) & ((1 << n_set) - 1)
        self.offset = int(addr) & ((1 << n_offset) - 1)
        self.data = 0
        self.line = -1
        self.hit = False

    def show(self):
        print("addr=", '{0: >10}'.format(self.addr),
              "TAG: ", '{0: >5}'.format(self.tag),
              "SET:", '{0: >5}'.format(self.set),
              "OFFSET:", '{0: >5}'.format(self.offset),
              " | data=", '{0: >5}'.format(self.data),
              "line=", '{0: >5}'.format(self.line),
              "hit:", '{0: >5}'.format(self.hit))

### Load Object: this object holds all the information about an instance of data to be loaded in a cache
class LoadObj:
    def __init__(self,  addr, dataList, n_tag, n_set, n_offset):
        self.addr = addr
        self.tag = int(addr) >> (n_set + n_offset) & ((1 << n_tag) - 1)
        self.set = int(addr) >> (n_offset) & ((1 << n_set) - 1)
        self.offset = int(addr) & ((1 << n_offset) - 1)
        self.dataList = dataList

    def show(self):
        print("addr=", '{0: >10}'.format(self.addr),
              "TAG: ", '{0: >5}'.format(self.tag),
              "SET:", '{0: >5}'.format(self.set),
              "OFFSET:", '{0: >5}'.format(self.offset),
              " | data=", *self.dataList)
```

Parameterized Cache Simulation Function

In [10]:
```python
### Main function to simulate the cache for given cache parameters:
#   1. cache size
#   2. block size.
#   3. associativity.
#   4. replacement policy

def simulateCache(cSize, bSize, assoc, pol):

    ############# set-up the cache parameters ##########
    CACHE_SIZE=cSize * 1024 #bytes
    BLOCK_SIZE=bSize #bytes
    ASSOCIATIVITY=assoc
    POLICY=pol
    print ("")
    print ("Cache Size: {0}K".format(cSize), "Block Size:", bSize, "Associativity:", assoc, "Policy:", POLICY.name)

    ## number of address bits, offset bits, set bits, tag bits
    ADDR_SIZE=32
    N_OFFSET=int(math.log2(BLOCK_SIZE))
    N_SET=int(math.log2(((CACHE_SIZE//BLOCK_SIZE)//ASSOCIATIVITY)))
    N_TAG=ADDR_SIZE - N_OFFSET - N_SET
    print ("TAG-bits:", N_TAG, "SET-bits:", N_SET, "OFFSET-bits:", N_OFFSET, )

    ############## create cache #############
    cache = Cache(CACHE_SIZE, BLOCK_SIZE, ASSOCIATIVITY, POLICY)
    #cache.show()

    ############## look for each addresses given in trace #############
    for idx in range(len(addr_trace)):
        lookupObj = LookUpObj(addr_trace[idx], N_TAG, N_SET, N_OFFSET)
        #lookupObj.show()
        cache.lookup(lookupObj)
        #lookupObj.show()

        # load data if you get a miss
        if(lookupObj.hit == False):
            loadDataLine = getRandDataLine(BLOCK_SIZE)
            loadObj = LoadObj(lookupObj.addr, loadDataLine, N_TAG, N_SET, N_OFFSET)
            #print("loading data line(to set {0}): {1}".format(loadObj.set, loadDataLine))
            cache.load(loadObj)

        # limited to first N address for testing
        if(idx >= (len(addr_trace) * trc_limit)):
            break

    # show cache again to see that the data loaded
    #cache.show()

    # show statistics
    cache.recorder.showRecord()
    #cache.recorder.showHistory()

    return cache.recorder.hitRate
```

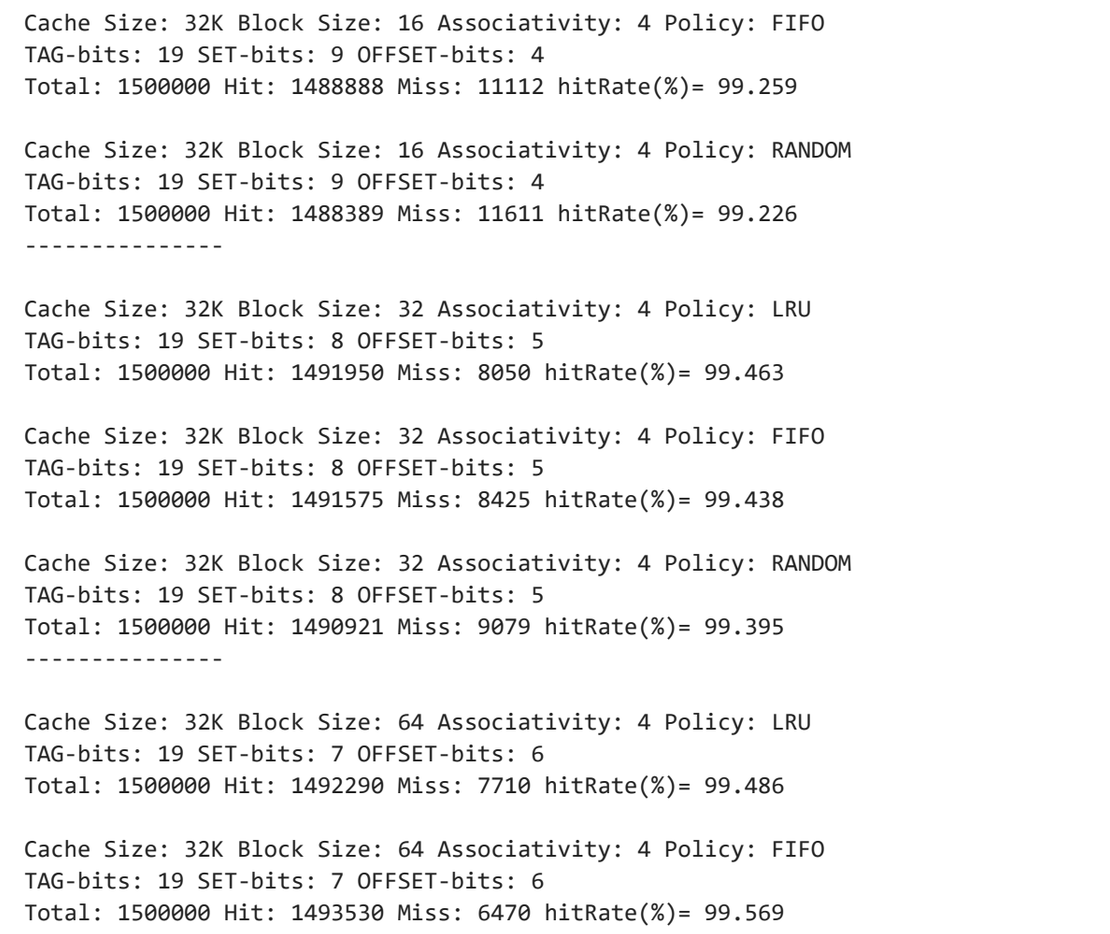
Simulate Cache for Different Combinations of: cache-size, block-size, associativity

In [11]:
```python
########## Simulate cache for different combinations of each parameters ##########

cache_size_KB = [16, 32, 64, 128]
block_size_B = [16, 32, 64, 128]
associativity_N=[1,4,8, 16, 32]
policies=[Policy.LRU, Policy.FIFO, Policy.RANDOM]

## function to plot a chart
def plotHits(ht, label, colName):
    df = pd.DataFrame(ht)
    df.set_index(colName, inplace=True)
    display(df)
    df.plot.bar(rot=0)
    plt.title("Miss Rates ({0})".format(label))
    plt.legend(loc='upper right')
    plt.show()

###########  Scenario 1  ###########
print("Scenario-1 : fixed(block-size=32-Bytes, Associativity:4) Varying(Cache-size: 16KB to 128KB)")
allHits = []
label = 'Scenario-1: Variable Cache Size with [Block=32B, Assoc=4])'
colName = 'Cache Size'
for cs in cache_size_KB:
    print ("--------------")
    hits = {}
    for pol in policies:
        hits[pol.name] = 100.0 - simulateCache(cs, 32, 4, pol)
    hits[colName] = cs
    allHits.append(hits)
plotHits(allHits, label, colName)

###########  Scenario 2  ###########
print ("Scenario-2 : fixed(cache-size=32KB, Associativity:4) Varying(Block-size: 16-Bytes to 128-Bytes)")
allHits = []
label = 'Scenario-2: Variable Block Size with [Cache=32KB, Assoc=4]'
colName = 'Block Size'
for bs in block_size_B:
    print ("--------------")
    hits = {}
    for pol in policies:
        hits[pol.name] = 100.0 - simulateCache(32, bs, 4, pol)
    hits[colName] = bs
    allHits.append(hits)
plotHits(allHits, label, colName)

###########  Scenario 3  ###########
print("Scenario-3 : fixed(block-size=32-Bytes, cache-size:8KB) Varying(Associativity: 1, 2,.. to fully-associative)")
allHits = []
label = 'Scenario-3: Variable Associativity with [Block=32B, Cache=8KB]'
colName = 'Associativity'
associativity_N.append((8 * 1024) // 32) #append full-assoc.: 8KB(cache-size)/32B[block-size]
for assoc in associativity_N:
    print ("--------------")
    hits = {}
    for pol in policies:
        hits[pol.name] = 100.0 - simulateCache(8, 32, assoc, pol)
    hits[colName] = assoc
    allHits.append(hits)
plotHits(allHits, label, colName)
```

```
Scenario-1 : fixed(block-size=32-Bytes, Associativity:4) Varying(Cache-size: 16KB to 128KB)
--------------

Cache Size: 16K Block Size: 32 Associativity: 4 Policy: LRU
TAG-bits: 20 SET-bits: 7 OFFSET-bits: 5
Total: 1500000 Hit: 1475924 Miss: 24076 hitRate(%)= 98.395

Cache Size: 16K Block Size: 32 Associativity: 4 Policy: FIFO
TAG-bits: 20 SET-bits: 7 OFFSET-bits: 5
Total: 1500000 Hit: 1483523 Miss: 16477 hitRate(%)= 98.902

Cache Size: 16K Block Size: 32 Associativity: 4 Policy: RANDOM
TAG-bits: 20 SET-bits: 7 OFFSET-bits: 5
Total: 1500000 Hit: 1481216 Miss: 18784 hitRate(%)= 98.748
--------------

Cache Size: 32K Block Size: 32 Associativity: 4 Policy: LRU
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1491950 Miss: 8050 hitRate(%)= 99.463

Cache Size: 32K Block Size: 32 Associativity: 4 Policy: FIFO
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1491575 Miss: 8425 hitRate(%)= 99.438

Cache Size: 32K Block Size: 32 Associativity: 4 Policy: RANDOM
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1490933 Miss: 9067 hitRate(%)= 99.396
--------------

Cache Size: 64K Block Size: 32 Associativity: 4 Policy: LRU
TAG-bits: 18 SET-bits: 9 OFFSET-bits: 5
Total: 1500000 Hit: 1496025 Miss: 3975 hitRate(%)= 99.735

Cache Size: 64K Block Size: 32 Associativity: 4 Policy: FIFO
TAG-bits: 18 SET-bits: 9 OFFSET-bits: 5
Total: 1500000 Hit: 1494378 Miss: 5622 hitRate(%)= 99.625

Cache Size: 64K Block Size: 32 Associativity: 4 Policy: RANDOM
TAG-bits: 18 SET-bits: 9 OFFSET-bits: 5
Total: 1500000 Hit: 1494194 Miss: 5806 hitRate(%)= 99.613
--------------

Cache Size: 128K Block Size: 32 Associativity: 4 Policy: LRU
TAG-bits: 17 SET-bits: 10 OFFSET-bits: 5
Total: 1500000 Hit: 1497038 Miss: 2962 hitRate(%)= 99.803

Cache Size: 128K Block Size: 32 Associativity: 4 Policy: FIFO
TAG-bits: 17 SET-bits: 10 OFFSET-bits: 5
Total: 1500000 Hit: 1496670 Miss: 3330 hitRate(%)= 99.778

Cache Size: 128K Block Size: 32 Associativity: 4 Policy: RANDOM
TAG-bits: 17 SET-bits: 10 OFFSET-bits: 5
Total: 1500000 Hit: 1495960 Miss: 4040 hitRate(%)= 99.731
```

Cache Size	LRU	FIFO	RANDOM
16	1.605067	1.098467	1.252267
32	0.536667	0.561667	0.604467
64	0.265000	0.374800	0.387067
128	0.197467	0.222000	0.269333

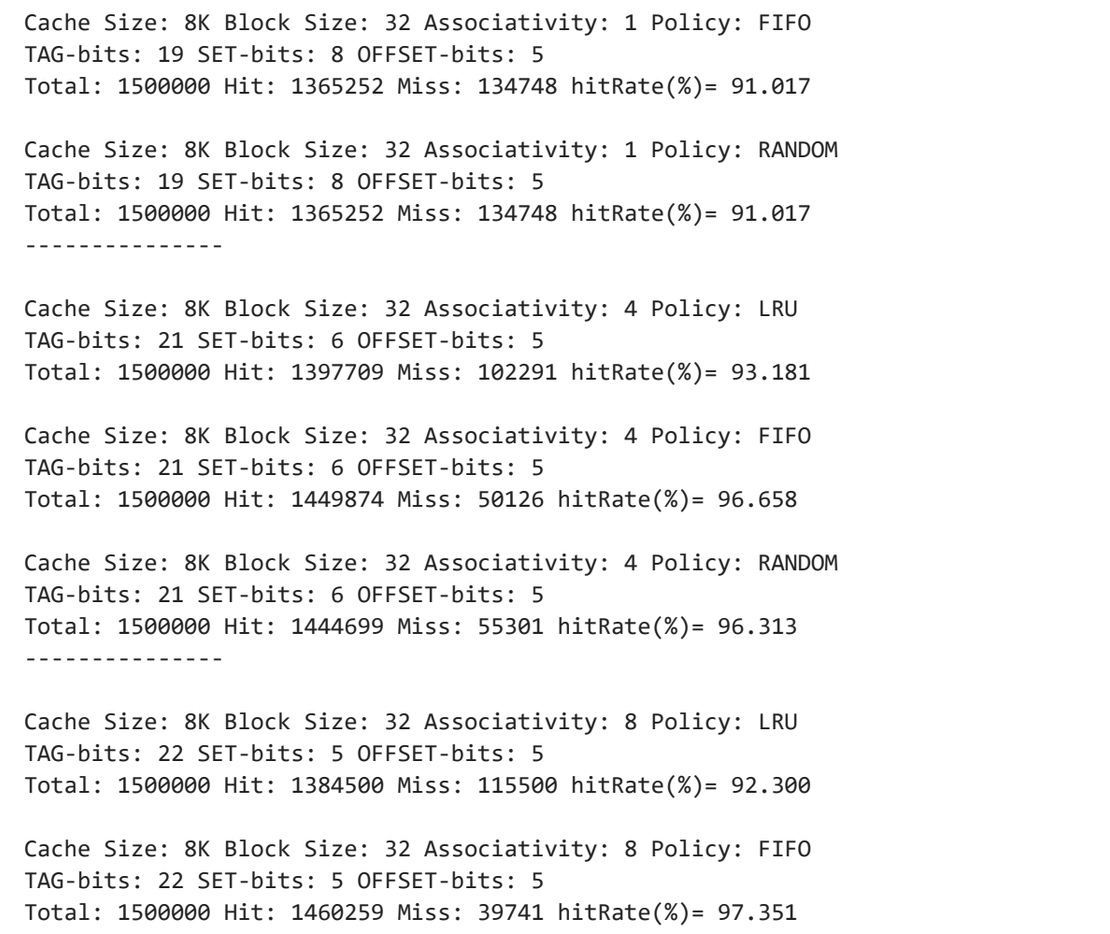
Miss Rates (Scenario-1: Variable Cache Size with [Block=32B, Assoc=4]))




```
Scenario-2 : fixed(cache-size=32KB, Associativity:4) Varying(Block-size: 16-Bytes to 128-Bytes)
--------------

Cache Size: 32K Block Size: 16 Associativity: 4 Policy: LRU
TAG-bits: 19 SET-bits: 9 OFFSET-bits: 4
Total: 1500000 Hit: 1490113 Miss: 9887 hitRate(%)= 99.341

Cache Size: 32K Block Size: 16 Associativity: 4 Policy: FIFO
TAG-bits: 19 SET-bits: 9 OFFSET-bits: 4
Total: 1500000 Hit: 1488888 Miss: 11112 hitRate(%)= 99.259

Cache Size: 32K Block Size: 16 Associativity: 4 Policy: RANDOM
TAG-bits: 19 SET-bits: 9 OFFSET-bits: 4
Total: 1500000 Hit: 1488389 Miss: 11611 hitRate(%)= 99.226
--------------

Cache Size: 32K Block Size: 32 Associativity: 4 Policy: LRU
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1491950 Miss: 8050 hitRate(%)= 99.463

Cache Size: 32K Block Size: 32 Associativity: 4 Policy: FIFO
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1491575 Miss: 8425 hitRate(%)= 99.438

Cache Size: 32K Block Size: 32 Associativity: 4 Policy: RANDOM
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1490921 Miss: 9079 hitRate(%)= 99.395
--------------

Cache Size: 32K Block Size: 64 Associativity: 4 Policy: LRU
TAG-bits: 19 SET-bits: 7 OFFSET-bits: 6
Total: 1500000 Hit: 1492290 Miss: 7710 hitRate(%)= 99.486

Cache Size: 32K Block Size: 64 Associativity: 4 Policy: FIFO
TAG-bits: 19 SET-bits: 7 OFFSET-bits: 6
Total: 1500000 Hit: 1493530 Miss: 6470 hitRate(%)= 99.569

Cache Size: 32K Block Size: 64 Associativity: 4 Policy: RANDOM
TAG-bits: 19 SET-bits: 7 OFFSET-bits: 6
Total: 1500000 Hit: 1492922 Miss: 7078 hitRate(%)= 99.528
--------------

Cache Size: 32K Block Size: 128 Associativity: 4 Policy: LRU
TAG-bits: 19 SET-bits: 6 OFFSET-bits: 7
Total: 1500000 Hit: 1492321 Miss: 7679 hitRate(%)= 99.488

Cache Size: 32K Block Size: 128 Associativity: 4 Policy: FIFO
TAG-bits: 19 SET-bits: 6 OFFSET-bits: 7
Total: 1500000 Hit: 1494564 Miss: 5436 hitRate(%)= 99.638

Cache Size: 32K Block Size: 128 Associativity: 4 Policy: RANDOM
TAG-bits: 19 SET-bits: 6 OFFSET-bits: 7
Total: 1500000 Hit: 1493952 Miss: 6048 hitRate(%)= 99.597
```

Block Size	LRU	FIFO	RANDOM
16	0.659133	0.740800	0.774067
32	0.536667	0.561667	0.605267
64	0.514000	0.431333	0.471867
128	0.511933	0.362400	0.403200

Miss Rates (Scenario-2: Variable Block Size with [Cache=32KB, Assoc=4])




```
Scenario-3 : fixed(block-size=32-Bytes, cache-size:8KB) Varying(Associativity: 1, 2,.. to fully-associative)
--------------

Cache Size: 8K Block Size: 32 Associativity: 1 Policy: LRU
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1365252 Miss: 134748 hitRate(%)= 91.017

Cache Size: 8K Block Size: 32 Associativity: 1 Policy: FIFO
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1365252 Miss: 134748 hitRate(%)= 91.017

Cache Size: 8K Block Size: 32 Associativity: 1 Policy: RANDOM
TAG-bits: 19 SET-bits: 8 OFFSET-bits: 5
Total: 1500000 Hit: 1365252 Miss: 134748 hitRate(%)= 91.017
--------------

Cache Size: 8K Block Size: 32 Associativity: 4 Policy: LRU
TAG-bits: 21 SET-bits: 6 OFFSET-bits: 5
Total: 1500000 Hit: 1397709 Miss: 102291 hitRate(%)= 93.181

Cache Size: 8K Block Size: 32 Associativity: 4 Policy: FIFO
TAG-bits: 21 SET-bits: 6 OFFSET-bits: 5
Total: 1500000 Hit: 1449874 Miss: 50126 hitRate(%)= 96.658

Cache Size: 8K Block Size: 32 Associativity: 4 Policy: RANDOM
TAG-bits: 21 SET-bits: 6 OFFSET-bits: 5
Total: 1500000 Hit: 1444699 Miss: 55301 hitRate(%)= 96.313
--------------

Cache Size: 8K Block Size: 32 Associativity: 8 Policy: LRU
TAG-bits: 22 SET-bits: 5 OFFSET-bits: 5
Total: 1500000 Hit: 1384500 Miss: 115500 hitRate(%)= 92.300

Cache Size: 8K Block Size: 32 Associativity: 8 Policy: FIFO
TAG-bits: 22 SET-bits: 5 OFFSET-bits: 5
Total: 1500000 Hit: 1460259 Miss: 39741 hitRate(%)= 97.351

Cache Size: 8K Block Size: 32 Associativity: 8 Policy: RANDOM
TAG-bits: 22 SET-bits: 5 OFFSET-bits: 5
Total: 1500000 Hit: 1454178 Miss: 45822 hitRate(%)= 96.945
--------------

Cache Size: 8K Block Size: 32 Associativity: 16 Policy: LRU
TAG-bits: 23 SET-bits: 4 OFFSET-bits: 5
Total: 1500000 Hit: 1371312 Miss: 128688 hitRate(%)= 91.421

Cache Size: 8K Block Size: 32 Associativity: 16 Policy: FIFO
TAG-bits: 23 SET-bits: 4 OFFSET-bits: 5
Total: 1500000 Hit: 1465142 Miss: 34858 hitRate(%)= 97.676

Cache Size: 8K Block Size: 32 Associativity: 16 Policy: RANDOM
TAG-bits: 23 SET-bits: 4 OFFSET-bits: 5
Total: 1500000 Hit: 1458713 Miss: 41287 hitRate(%)= 97.248
--------------

Cache Size: 8K Block Size: 32 Associativity: 32 Policy: LRU
TAG-bits: 24 SET-bits: 3 OFFSET-bits: 5
Total: 1500000 Hit: 1334866 Miss: 165134 hitRate(%)= 88.991

Cache Size: 8K Block Size: 32 Associativity: 32 Policy: FIFO
TAG-bits: 24 SET-bits: 3 OFFSET-bits: 5
Total: 1500000 Hit: 1465635 Miss: 34365 hitRate(%)= 97.709

Cache Size: 8K Block Size: 32 Associativity: 32 Policy: RANDOM
TAG-bits: 24 SET-bits: 3 OFFSET-bits: 5
Total: 1500000 Hit: 1459250 Miss: 40750 hitRate(%)= 97.283
--------------

Cache Size: 8K Block Size: 32 Associativity: 256 Policy: LRU
TAG-bits: 27 SET-bits: 0 OFFSET-bits: 5
Total: 1500000 Hit: 1228095 Miss: 271905 hitRate(%)= 81.873

Cache Size: 8K Block Size: 32 Associativity: 256 Policy: FIFO
TAG-bits: 27 SET-bits: 0 OFFSET-bits: 5
Total: 1500000 Hit: 1466447 Miss: 33553 hitRate(%)= 97.763

Cache Size: 8K Block Size: 32 Associativity: 256 Policy: RANDOM
TAG-bits: 27 SET-bits: 0 OFFSET-bits: 5
Total: 1500000 Hit: 1459773 Miss: 40227 hitRate(%)= 97.318
```

Associativity	LRU	FIFO	RANDOM
1	8.983200	8.983200	8.983200
4	6.819400	3.341733	3.686733
8	7.700000	2.649400	3.054800
16	8.579200	2.323867	2.752467
32	11.008933	2.291000	2.716667
256	18.127000	2.236867	2.681800

Miss Rates (Scenario 3: Variable Associativity with Blocks=320, Cache=8KB)