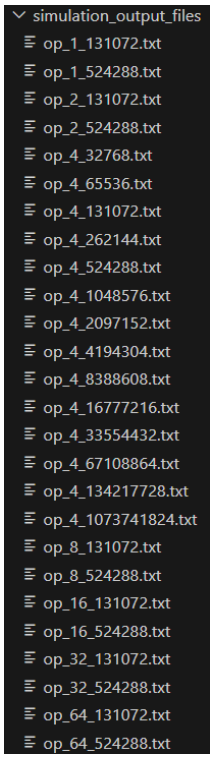
Assignment 2 - Cache Area, Access Time and Energy analysis

Assumptions and Procedure

- In the experiments conducted, the associativity of the cache is varied from 1 to 64 (1,2,4,8,16,32 and 64) for recording the values of the area of data array, total dynamic read energy per access and access time for fixed cache sizes.
- The cache sizes are varied from 32 KB to 128 MB to record the values of the area of the data array, total dynamic read energy per access at a constant associativity of 4. For the access time, the associativity is kept constant (4), cache size is varied from 64 KB to 2 MB.
- The results which are presented in the graphs are collated from the Cacti tool. For automating the data collection process, a Bash script was written which ran the simulator for the all combinations required and wrote the output for each simulation into an output text file.
- The graphs were plotted from the data in these output files using the matplotlib library in Python.
- All the log files have a certain nomenclature format as described in the next section.

Format of the Log Files



Directory structure of the logs folder -

Here, every log file has a specific nomenclature.

Each log file is labelled as –

op_associativity_cache_size.txt

- **associativity** – Associativity values are varied from 1 to 64 (1,2,4,8,16,32,64)
- **cache_size** – Cache sizes are varied from 32KB to 128 MB

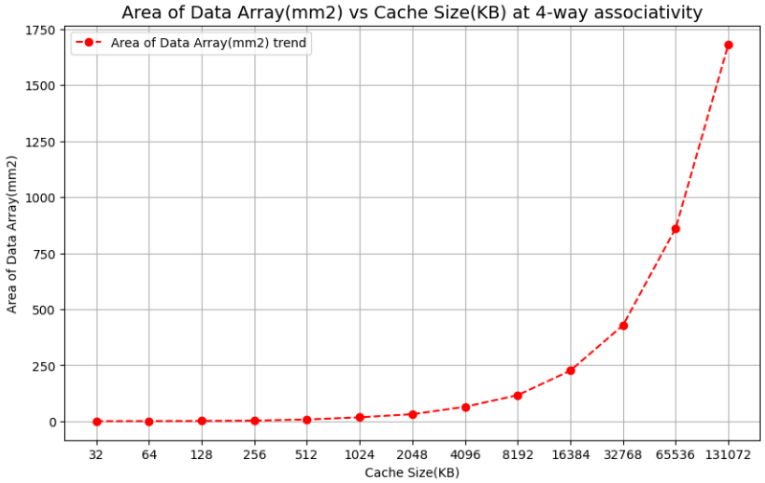
The simulation outputs are automatically written into these text files via a Bash script to reduce manual effort.

The following sections in this report contains the observations and detailed explanations of the trends observed in the experiments conducted.

Submitted By – Kapil Ravi Rathod
PSU ID - 973212163
Email – kvr5715@psu.edu

Experiment Results

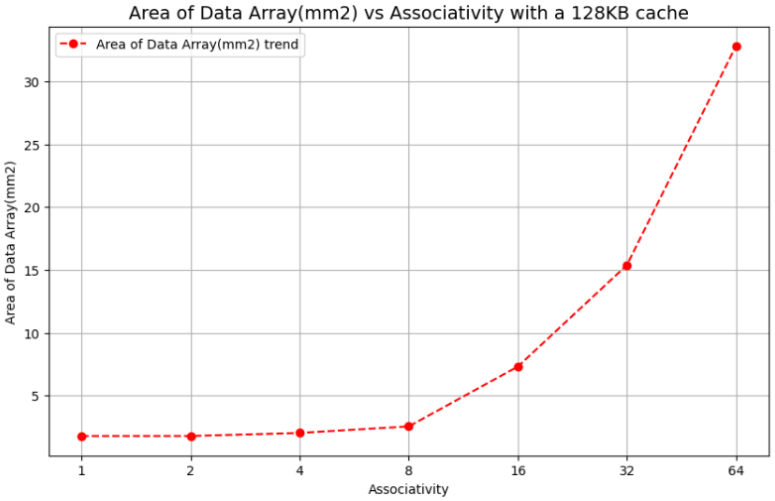
Area of Data Array(mm^2) vs Cache Size(KB) for a 4-way associative cache



- The amount of data that a cache can store is increases with the number of memory cells.
- Since memory cells take up space, increasing the cache size increases the physical area required to store the data.

Parameter	Trend Observed	Explanation/ Comments
Area of Data Array (mm^2)	The area increases in gradually with the cache size.	Larger cache sizes require more memory cells, leading to an increase in the physical area.

Area of Data Array(mm^2) vs Associativity for a 128 KB cache

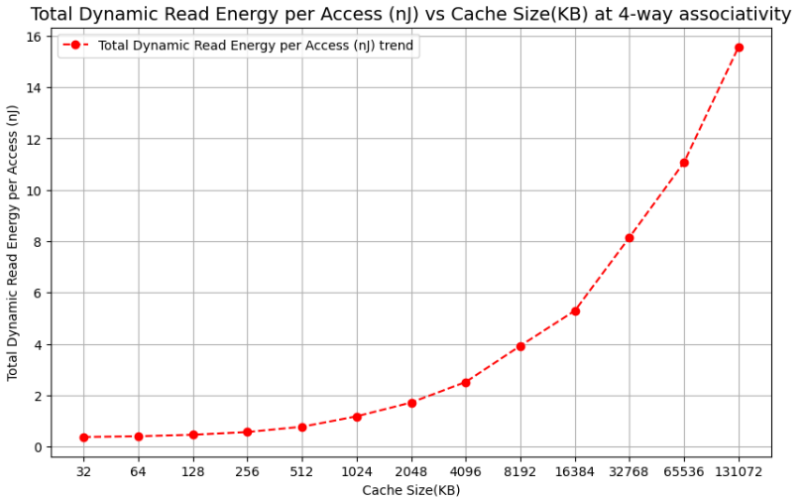


- Higher associativity needs more connections between data arrays and the control logic, requiring additional hardware which increases the area on the chip.
- At low associativity values (for example 2), the area grows slowly due to simpler hardware.
- As associativity rises (to 32 and 64 way), the area increases sharply due to more complex circuits.

Parameter	Trend Observed	Explanation/ Comments
Area of Data Array (mm^2)	Area of the data array grows slowly for low associativity, then more steeply as associativity increases due to complex hardware.	More associativity requires more hardware (complex circuits), which takes up more space on the chip.Large cache sizes need more memory cells, leading to an increase in the physical area.

Submitted By – Kapil Ravi Rathod
PSU ID - 973212163
Email – kvr5715@psu.edu

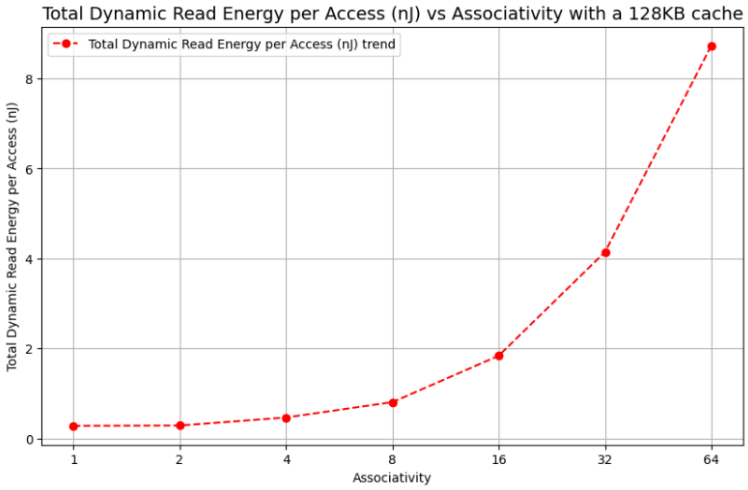
Total Dynamic Read Energy per Access for the Data Array (nJ) vs Cache Size(KB) for a 4-way associative cache



- Larger caches consist of more memory cells, and accessing data in larger caches means more cells need to be powered and read. This results in greater energy consumption.
- As cache size increases, the data buses may also widen to accommodate more data, leading to more energy being used per access. Larger caches also involve more complex structures, such as additional tag checks (for finding data locations) and longer bitlines (for reading/writing data), which consume more energy.

Parameter	Trend Observed	Explanation/ Comments
Dynamic Read Energy per Access (nJ)	Energy consumption increases as the cache size grows, starting off slowly and then increasing steeply.	Larger caches need more power to activate additional memory cells and handle more complex structures. Energy rises slowly for small caches and becomes more steep for larger ones, as more energy is needed.

Total Dynamic Read Energy per Access (nJ) vs Associativity for a 128 KB cache

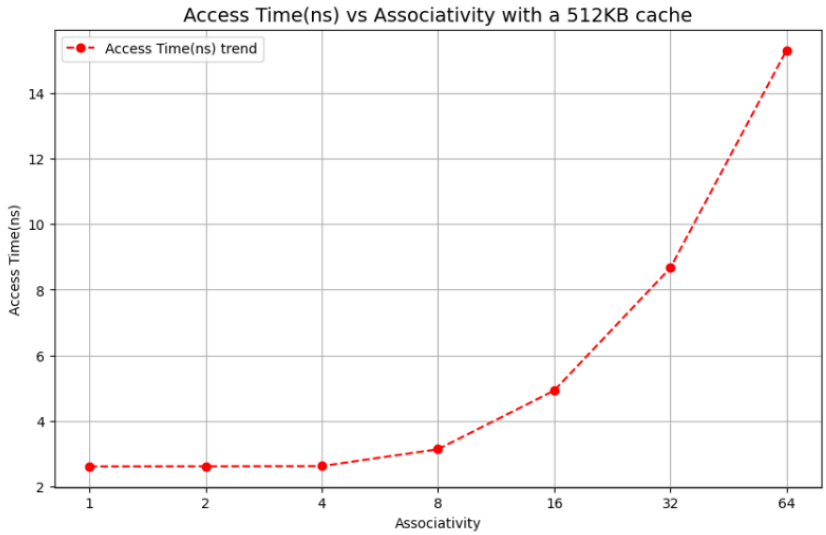


- As associativity increases, the total read energy per access also increases since more energy is needed to check multiple potential locations where the data could be stored. This increases the number of comparisons needed during a read operation, requiring more energy.
- Higher associativity involves more hardware circuits which require additional energy to operate.
- For lower associativity values, the increase in energy is gradual since fewer circuits are involved.

Parameter	Trend Observed	Explanation/ Comments
Dynamic Read Energy per Access (nJ)	Energy consumption rises slowly at first but increases more steeply as associativity increases.	Higher associativity needs more energy for comparisons and managing more complex hardware.

Submitted By – Kapil Ravi Rathod
PSU ID - 973212163
Email – kvr5715@psu.edu

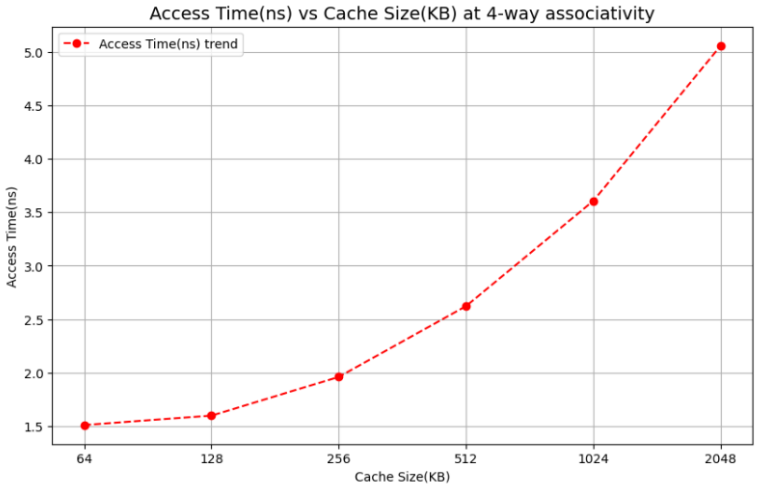
Access Time(ns) vs Associativity for a 512 KB cache



- As associativity increases in a cache, the cache has more ways to look for data. This makes the search for a specific piece of data more complex, which leads to longer access times.
- Higher associativity increases the complexity of cache hit/miss checks because the cache controller needs to check more locations to determine whether data is available. This complexity results in longer delays.
- The circuit which handles tag comparison becomes more complicated. Also, the logic circuit which takes care of way selection needs more multiplexers to pick the correct 'way'. As a result of these, the access time increases.

Parameter	Trend Observed	Explanation/ Comments
Access Time(ns)	As associativity increases, access time rises slowly for lower associativity values and then steeply for higher values due to the increasing complexity of searching through more cache locations.	As associativity increases, the cache has more locations to search for data, leading to more complex comparisons. This added complexity causes longer access times, as the cache controller must check more locations before determining whether data is available.

Access Time(ns) vs Cache Size(KB) for a 4-way associative cache



- As cache size increases, the number of cache blocks grows, requiring more time to search and retrieve data. The word and bit lines also get longer as a result of which the propagation delay increases.
- A larger cache needs more complex indexing and management systems to keep track of data locations, resulting in increased access time.
- Additionally, with more blocks to search through, the overall delay in data lookup rises because the cache controller must sift through more data entries before returning a result.

Submitted By – Kapil Ravi Rathod
PSU ID - 973212163
Email – kvr5715@psu.edu

Parameter	Trend Observed	Explanation/ Comments
Access Time(ns)	As cache size increases, access time rises steadily.	Large caches introduce overhead in data lookup and management causing noticeably slower access times due to the higher number of data blocks to search.

Log Files

All the log files for the experiment can be found in this One Drive link

973212163-Assignment2-CSE530-Cacti-Logs

Submitted By – Kapil Ravi Rathod
PSU ID - 973212163
Email – kvr5715@psu.edu