Maximum Throughput Period Identification for SoC Performance Analysis

SHRAVYA PEDDIREDDY
ECE Department
JNTU, Kakinada

VIJAYA RAM SREENI
AMD R&D Center India Pvt. Ltd.
Hyderabad, India

E.V.NARAYANA
Assistant Professor
ECE Department
JNTU, Kakinada

Abstract—Performance projections are very important for any System on Chip (SoC) design. How fast these projections are verified and with what accuracy lies in the quality of the workloads and test bench. Given the variety and the nature of workloads, which also evolve based on the architectural changes, identification of the right throughput period is a unique challenge, as it determines the achieved bandwidth of a workload. This paper presents the design of a standard algorithm which will determine the valid throughput period for any kind of workload, which will work independent of the architectural changes.

Index Terms—SoC Performance Verification, Throughput Period, Bandwidth

I. INTRODUCTION

The objective of SoC Performance Verification is to validate the key performance metrics at pre-silicon level to ensure that the system performance specifications are met. During this process, the performance metrics such as Bandwidth (BW) calculated during Register Transfer Level (RTL) based simulations are compared with the theoretical expectations. This analysis helps in identifying bottlenecks and architectural drawbacks of the design which limit the overall system performance.

The RTL based simulations use Directed tests which target a particular BW intensive data path and present synthetic traffic which mimics workload from various Functional blocks (or clients) to the memory i.e. Dynamic Random Access Memory (DRAM). Finding the right time interval (which is a part of workload time) for measuring the workload BW (in GB/s) is important for reliable performance projections. This time interval is called Throughput (TP) Period.

During TP period, the workload demand for a Memory Bound case (when workload BW demand exceeds the BW supplied by DRAM) would be true to its nature. Also, the true nature of a memory bound workload will come to a reliable state when all the clients have started interacting with the memory. Figure 1 depicts a scenario where multiple clients (C1, C2, C3 and C4) are trying to access DRAM via the Memory Controller (MC) at certain times based on the workload demand. The individual client graphs show whether a client is active (requests to DRAM) or not. Figure 2 illustrates how the DRAM activity looks like with this client traffic.

Modern SoC architectures have removed the Command Processor (CP) interface to MC and instead enabled the clients to directly fetch the PM4 commands (Non-Workload transactions). These Non-workload transactions will also appear as the client transactions along with the actual workload transactions, which would mislead the TP period calculation. Figure 3 below shows the Non-workload & workload transactions per client and the idle periods (No activity intervals). These idle periods should not be considered for the performance measurements.
Fig. 3. Client Transactions

Virtual Memory (VM) or Address Translation Cache (ATC) enabled workload performance measurement is one of the key performance evaluations of the SoC designs. VM/ATC performance measurements are done for both the cold (L2 Cache Miss) and warm (L2 Cache Hit) periods to understand the impact independently. We run the same workload two times to have a cold and warm scenario. Figure 4 below shows the cold and warm scenario.

Fig. 4. VM/ATC Scenario

In order to determine valid TP period for any kind of workload, there is a need to implement a standard algorithm which would work irrespective of SoC architectural changes. The following sections describe algorithms which would estimate the right TP period for accurate performance projections.

II. LEGACY THROUGHPUT PERIOD ALGORITHM

In this approach, the TP period is calculated by choosing the time interval between the Latest Starting Client and the Earliest Ending Client, accessing the DRAM. Figure 5 depicts Ideal DRAM access scenario of different clients i.e. C1, C2, C3, C4, C5 and C6 (Y-axis) and their activity (X-axis). Client C4 is the latest starting client (at Ts Simulation Time), whereas Client C2 is the earliest ending client (at Te Simulation Time). As described in Equation 1 below, the legacy algorithm would interpret the TP period as the difference of these simulation times.

Legacy TP period = Te – Ts  

Fig. 5. Ideal Case

Figure 6 below shows the expected DRAM activity over time. The peak activity occurs during the TP period.

Fig. 6. DRAM Activity

But as mentioned earlier, the workload presented by the clients may not be continuous and would constitute both workload/non-workload transactions along with idle periods. The drawback of Legacy algorithm is that it would include idle periods in the calculated TP period because of the presence of Non-workload transactions. Figure 7 depicts the Legacy TP period with idle period included, leading to inaccurate BW calculation. Client C2 is the latest starting client whereas client C5 is the earliest ending client.

Fig. 7. Legacy TP period

Moreover, in VM/ATC enabled scenario, the algorithm fails to identify the cold and warm periods separately and the calculated TP period includes non-workload transactions along with idle periods as illustrated in Figure 8 below.
III. MAXIMUM (MAX) THROUGHPUT PERIOD ALGORITHM

In this approach, the workload is interpreted as a combination of multiple valid activity regions that are separated by No-Activity regions (Idle periods). The potential activity regions are identified and the Maximum active region is chosen as the recommended TP period for the workload.

Outstanding requests to DRAM per each client are calculated and used as the basis for identifying the idle periods. When all the clients involved in the workload have become idle, then we mark that as an end of the current activity period. The next request on any of the clients would trigger the next activity period. Once the activity period is identified, we choose the “Latest start” and the “Earliest end” time as the start and end times of the activity period. The maximum period out of all the activity periods is chosen as the throughput period. In case of VM/ATC tests, the MAX TP period is chosen as the cold period and the second best MAX TP period is chosen as the warm period. Warm period should be less than Cold period on the basis that warm period won’t have L2 Miss requests. Figure 9 shows the MAX TP period with non-workload transactions and idle periods truncated. As described in Equation 2 below, the MAX TP period would be,

\[
\text{MAX TP period} = \text{Tme} - \text{Tms}
\]

In case of VM/ATC tests, the MAX algorithm identifies cold and warm intervals separately as illustrated in Figure 10.

Equation 3 and Equation 4 show the calculated cold and warm MAX TP periods respectively.

\[
\text{MAX TP period (Cold)} = \text{Tmec} - \text{Tmsc} \quad (3)
\]

\[
\text{MAX TP period (Warm)} = \text{Tnew} - \text{Tmsw} \quad (4)
\]

IV. EXPERIMENTAL RESULTS AND ANALYSIS

Once we obtain the desired TP period, the BW Utilization is computed by taking into account the number of requests within the TP period and the request size as shown in Equation 5 below.

\[
\text{BW} = \frac{\text{Number of Requests in the TP period} \times \text{Request Size}}{\text{TP period}}
\]

As shown in Fig. 11 below, the Legacy algorithm is considering the Non-workload transactions and hence the No Activity regions will become part of the calculated throughput period resulting in wrong performance numbers.

Even though the MAX algorithm considers the Non-workload transactions, Non-workload activity will be considered as a standalone activity period, due to the idle period between the Non-workload and workload transactions. Since the Workload activity period is much larger than the Non-workload activity period, Non-workload activity period won’t be considered as the throughput period. Table I shows the comparison between the TP periods identified by the Legacy and MAX algorithms respectively for Non-VM test. The BW utilization significantly improves in case of MAX algorithm as compared to Legacy.
TABLE I. LEGACY V/S MAX FOR NON-VM TEST

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Algorithm</td>
</tr>
<tr>
<td>Textured Read/Write (or) SDM A Read/Write</td>
<td>Legacy</td>
</tr>
<tr>
<td>SDM A Read/Write</td>
<td>Max</td>
</tr>
</tbody>
</table>

* The traffic type corresponds to when a Texture client is performing memory Read/Write operation.

Figure 12 depicts the TP periods identified by Legacy and MAX algorithm for VM/ATC test. MAX will identify both warm and cold periods as opposed to Legacy considering it as a one single period.

![Fig. 12. Legacy v/s MAX TP period (VM Test)](image)

Table II shows enhancement in BW utilization when MAX algorithm is used for VM/ATC test.

TABLE II. LEGACY V/S MAX FOR VM TEST

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Algorithm</td>
</tr>
<tr>
<td>VM test:</td>
<td>Legacy</td>
</tr>
</tbody>
</table>

The traffic type corresponds to when a Texture client is performing memory Read or a Color client is performing memory Write.

V. CONCLUSION

In this paper, we have described various algorithms to identify the right TP period for accurate workload BW measurement. The MAX algorithm proves to be more efficient as compared to the Legacy algorithm in identifying the TP period, which is evident from the experimental results shown above. The MAX algorithm greatly helps in eliminating false alarms raised due to lower BW numbers as a result of inaccurate TP period calculation. Moreover, MAX algorithm can be used irrespective of SoC architectural changes.

VI. ACKNOWLEDGMENT

The authors would like to thank their manager, Kalyan Kumar Goje for his technical guidance and support.

VII. REFERENCES


