Time Based Multicore Scheduling System

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ABSTRACT: Introduces a novel multicore scheduling method that leverages a parameterized dataflow Model of Computation (MoC). FIFO digital processing algorithm have inefficient use of the CPU core that affects latency and energy consumption. Desired parallelism is not achieved instead of having sufficient CPU core. Objective of this paper is to design of multicore signal processing systems, is to distribute computational tasks efficiently onto the available CPU core while taking into account dynamic changes. Design a flexible scheduling method that determines scheduling decisions at run-time to optimize the mapping of an application onto multicore processing resources. The proposed method name is Time Based Multicore Scheduling (TB-MS), TB-MS denotes to efficiently schedule Parameterized and Interfaced Synchronous Dataflow (PiSDF) graphs on multicore architectures. TB-MS method exploits features of PiSDF to find locally static regions that exhibit predictable communications. For experimental purposes, uses a multicore signal processing benchmark to demonstrate that the TB-MS scheduler can exploit more parallelism than a conventional multicore task scheduler based on task creation and dispatch. These experimental results of the TB-MS on an 8-core Texas Instruments Keystone Digital Signal Processor (DSP) are compared with those obtained from the OpenMP implementation provided by Texas Instruments and also apply TB-MS method on Intel core i3 guard core processor using OpenMP Simulator. With the help of TB-MS algorithm approach latency improvements of up to 34% for multicore signal processing systems and also obtained result compare to conventional method.

Key Words: Processing Elements, Digital Signal Processor, Open MP and Time Based Multicore Scheduling.

I. INTRODUCTION

An important evolution in embedded processing is the integration of increasingly more Processing Elements (PEs) in the Multiprocessor Systems-on-Chip (MPSoC) devices [1], [2], [3], [4]. This trend is mainly due to limitations in the processing power of individual PEs as a result of power consumption considerations. Concurrently, signal processing applications are becoming increasingly dynamic in terms of hardware resource requirements. This tendency is due to the growing complexity of algorithms allowing higher levels of performance in aspects such as data compression, transmission efficiency, and precision of data analysis. For example, the Scalable High Efficiency Video Coding (SVC) video codec provides a mechanism to temporarily reduce the resolution of a transmitted video in order to match the instantaneous bandwidth of a network [5]. One of the main challenges of the design of multicore signal processing systems is to distribute computational tasks efficiently onto the available PEs while taking into account dynamic changes. The process of assigning, ordering and timing actors on PEs in this context is referred to as multicore scheduling. Inefficient use of the PEs affects latency and energy consumption making multicore scheduling a very important problem to solve [6]. Describes a novel method called TB-MS to address this challenge. TB-MS is a flexible scheduling method that determines scheduling decisions at run-time to optimize the mapping of an application onto multicore processing resources. In relation to the scheduling taxonomy defined by Lee and Ha [7], TB-MS is a fully dynamic scheduling strategy. Singh presents a survey on multi/many core mapping methodologies in [19]. In the context of the taxonomy used in Singh's survey, our methodology can be classified as "On-the-fly" mapping, targeting this work is supported by the ANR COMPA project. Heterogeneous platforms with a centralized resource management strategy. Applications managed by the TB-MS scheduler are described using the PiSDF dataflow Model of Computation (MoC), which is related to the general Dataflow Process Network (DPN) MoC. DPN MoCs are widely used in design of signal processing systems [8]. A distinguishing feature of PiSDF is the integration of a parameter tree to asynchronously transmit control values between actors [9]. The TB-MS scheduling method is embedded in the Synchronous Parameterized and Interfaced Dataflow Embedded Runtime (SPIDER) [10] organized as...
follows: Section II and Section III present related research, providing the context of current work, Section IV details our proposed new TB-MS scheduling method.

II. RELATED WORKS

Various frameworks based on OpenMP [11] and OpenCL [12] language extensions are currently proposed to address the multicore scheduling challenge. However, these extensions are based on imperative languages e.g., C, C++, FORTRAN that do not provide mechanisms to model specific signal flow graph topologies. On the contrary, signal processing oriented dataflow MoCs are widely used for specification of data-driven signal flow graphs in a wide range of application areas, including video decoding [13], telecommunication [14], [15], and computer vision [16]. The popularity of dataflow MoCs in design and implementation of signal processing systems is due largely to their analysability and their natural expressivity of the concurrency in signal processing algorithms, which makes them suitable for exploiting the parallelism offered by MPSoCs. Synchronous Dataflow (SDF) [17] is the most commonly used DPN MoC for signal processing systems. Production and consumption rates of actor' pieces of computation are set by firing rules. These rates are fixed scalars in an SDF graph. Data values, encapsulated by tokens, are passed along the edges first In, First in first out (FIFOs) of a dataflow graph as it executes. Initial tokens, called delays can be set on FIFOs. The PiSDF dataflow MoC [9] results from the addition of the Parameterized and Interfaced Meta Model (PiMM) to the SDF MoC. PiMM extends the semantics of a targeted dataflow MoC by introducing specific notions of hierarchy, interfaces, and parameters. Parameters in PiMM can influence, both statically and dynamically, different properties of a DPN, such as the firing rules of actors. The Meta model introduces configuration actors, i.e. specific actors that can modify parameter values.

Neuendorffer, et al. define quiescent points as points where parameters influencing an execution are allowed to change [18]. Between two quiescent points, the application can be considered static.

Authors decision are taken Just-In-Time, immediately after the quiescent points are reached, unveiling new application parallelism. TB-MS is an evolution of the work in [14] presenting an adaptive scheduler of parameterized dataflow MoC. However, this work did not consider application hierarchy and was focused only on 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) base stations. Our work on TB-MS goes beyond the methods of [14] to take application hierarchy into account and address a broad class of signal processing applications through generalized scheduling techniques.

III. ARCHITECTURE OF TB-MS

A. Runtime Architecture: The method developed is applicable to heterogeneous platforms. In such platform, optimized local decision to start an actor computation e.g., based on earliest availability of input data can be inefficient in a global sense. In order to take effective decisions globally, a Master/Slave execution scheme is chosen for the system. The TB-MS method requires multiple software or hardware components Figure 1. Processing Elements (PEs) are slave components that process actors. They can be of multiple types, such as General- Purpose Processors (GPPs), DSPs, or accelerators. The master of the TB-MS system is called Scheduling Element (SE). This is the only component that has access to the overall algorithm topology. Jobs are used to communicate between the SE and PEs. Each PE has a job queue from which it pops jobs out prior to their execution. Parameters influence dataflow graph topology or execution timing of actors. When a parameter value is set by a configuration actor, its value is sent to the SE via a parameter queue. Finally, Data FIFOs are used by the PEs to exchange data tokens. A data FIFO can be implemented for instance over a shared memory or a network-on chip.

B. Benchmark: Apply the TB-MS scheduling algorithm by the scheduling of a benchmark application. This benchmark is an extension of the MP-sched benchmark [20]. The MP-sched benchmark can be viewed as a two-dimensional grid involving N channels, where each branch consists of M cascaded Finite Impulse Response (FIR) filters of NbS samples. Here, in future will apply the MP-sched benchmark by allowing the M parameter to vary across different branches. Will apply to this extended version of the MP-sched benchmark as heterogeneous-chain-length MP-sched (HCLM-sched).
C. Notations: To describe TB-MS, the following notation is used. CA represents the set of configuration actors of the given PiSDF graph. Thus, CA represents all actors in the given PiSDF graph that are not configuration actors.

IV. WORKING OF TB-MS

A. Multicore Scheduling of Static Sub Graphs: TB-MS involves decomposing the scheduling of a given PiSDF graph into the scheduling of a sequence X1, X2 . . . of SDF graphs. Different executions with different sets of input data can result in different sequences of SDF graphs for the same PiSDF graph. For a given execution, author refer to each Xi as a step of the TB-MS scheduling process for that execution. On each step, resolved parameters enable the transformation of the PiSDF graph into an SDF graph, which can be scheduled by any of the numerous existing SDF scheduling heuristics that are relevant for multicore architectures [21]. For example, see [22] for a set of techniques that can be applied upon transforming the resulting SDF graph into a single rate SDF (srSDF) graph. A srSDF graph is an SDF graph in which the production rate on each edge is equal to the consumption rate on that edge. A consistent SDF graph can be transformed into an equivalent srSDF graph by applying techniques that were introduced by Lee and Messerschmitt [23]. The Time Based Multicore Scheduling (TB-MS) method is based on the static multicore scheduling method which is composed of the following sequence of phases:

1) Computing the Basis Repetition Vector (BRV) of the current graph the graph that is presently being scheduled. The BRV, also known as the SDF repetition vector, is a positive-integer vector and represents the number of firings of each actor in a minimal periodic scheduling iteration for the graph. Author note however, that certain technical details of PiSDF require adaptations to the conventional repetitions vector computation process from [17].

2) Converting the SDF graph into an equivalent srSDF graph, where each actor is instantiated a number of times equal to its corresponding BRV component.

3) Scheduling actors and communications from a derived acyclic srSDF graph onto the targeted heterogeneous platform. Any scheduling heuristic that is applicable to acyclic srSDFs graphs can be chosen here — e.g., the applied schedule can be a list scheduler, fast scheduler, flow-shop or genetic scheduler [19], [24], [22]. Upon completing the scheduling process described, the resulting schedule S is executed.

A complete TB-MS schedule of a PiSDF hierarchical graph consists of several of these phases, repeated as many times as needed (see Section IV-B).

In a PiSDF graph, some data FIFOs behave as Round Buffers (RBs) [9] — i.e., such FIFOs produce multiple copies of individual tokens as necessary to satisfy consumption demand. In particular, FIFOs at the interface of a hierarchical actor have RBs behaviour to help ensure composability in hierarchical specifications. FIFOs connecting configuration actors to other actors also behave as RBs to ensure that configuration actors fire only once per sub graph. Application designers using the PiSDF model of computation need to take such RB behaviour into account during the development process. Configuration Actors and such RBs are excluded
from the BRV computation as they are forced to fire only once.

B. Multicore Scheduling of Full Graphs: The TB-MS method is based on the PiSDF runtime operational semantic. As shown in [9], the TB-MS scheduler has to proceed in multiple steps, each one unveiling a new portion of srSDF graph for scheduling. In one step, configuration actors have to be fired first, they produce parameters needed to resolve the rest of the sub graph. When all parameters are solved at one hierarchy level, scheduling of other actors of this hierarchy level is made possible. In a multicore system, the SE has to extract the parallelism of the application to send jobs to multiple PEs. Contrary to static applications, the difficulty of this process is to schedule actors efficiently without knowing the complete graphs. The complete srSDF graph is only known when all configuration actors have been executed. Once a srSDF graph has been generated, it can be analysed to exploit the parallelism of the application (Section IV-A). The TB-MS runtime schedules the actors and communications and fires their execution on the platform. Newly instantiated hierarchical actors are added to a global srSDF graph, called execution graph, and the same process can be used until the whole graph has been processed. To keep track of actor’s execution, each actor of the execution graph is tagged with a flag representing its execution state. An actor can be Run (R), Not Executable (N) or Executable (E). An actor is Executable only when all its parameters are resolved and when all its predecessors are Executable or Run. The procedure of TB-MS scheduling is shown in Algorithm 1. After initialization, the algorithm enters in a main while loop which computes scheduling steps until there is no more hierarchical actor in the execution graph. A single scheduling step is made of the 3 stages: graph configuration, actor execution and graph resolution. The first stage line 3 to 13 replaces each executable hierarchical actor of the execution graph by its configuration actors. As they are only fired once, there is no need to compute the BRV and the graph transformation to srSDF becomes trivial. If there is no configuration actor in this hierarchical actor, all the sub graph parameters can be resolved using the 2 first phases presented in Section IV-A and the sub graph can replace the hierarchical actor in the execution graph. In this stage, it is also important to add RBs at the interfaces of the hierarchical actors and between CA and CA to respect PiSDF semantics.

The second stage line 14 to 15 assigns orders and fires executable actors. It corresponds to phase 3 of Section IV-A. The third stage line 16 to 20 corresponds to the graph resolution. At this stage, the parameters resolved by configuration actors of the previous stages are used to solve the graph of each hierarchical step. The 2 first phases of Section IV-A can then be applied to fully replace the hierarchical actor in the execution graph with the corresponding child actors. At the end of the algorithm line 21 to 22, when no more
A hierarchical actor is present in the execution graph, a last phase of assignment, ordering and firing of executable actors has to be done to execute all non-executed actors.

VII. RESULT

Describes a method called Time Based Multicore Scheduling used to parallelize applications at runtime. In this context, results focus on the comparison between the JIT-MS approach and the OpenMP framework. Results have been acquired by studying the latency of single and multiple iterations of the HCLM-sched benchmark on the Texas Instruments 5478 multicore DSP [1].

OpenMP is a framework designed for shared memory multiprocessing. It provides mechanisms for launching parallel teams of threads to execute efficiently an algorithm on a multicore architecture. OpenMP applications are designed with a succession of sequential code, executed by a master thread, and parallel code, distributed in a team of threads dispatched onto multiple cores [11].

The platform used for the current experiments is the Texas Instruments Keystone I architecture (EVM TMS320C6678). This multicore DSP platform is composed of 8 c66x DSP cores interconnected by a Network on Chip (NoC) called TeraNet with access to an internal shared memory. To perform synchronization between cores, hardware queues provided by the Multicore Navigator [25] have been used. The OpenMP framework cannot implement the HCLM-sched as a double nested loop since FIRs are cascaded on each channel. So, OpenMP is used to parallelize channels by using a “parallel for”. For the first experiment, for calculate of amplitude to fix the M value to 8 for all stages, FIR of 2781 samples and latency measured of one graph iteration. Results on execution time are displayed in Figure 7.3.

Figure 7.1 Signaling Processing on Multicore Processing

Figure 7.2 Decomposed Signals on Multicore Processing
Figure 7.3 Four Time Execution of Signal on Multicore Processor

With the TB-MS implementation, the transformation and scheduling phases introduce a visible overhead but the execution efficiency over varying parameters is smoother. The overhead can be observed when N equals to 4 or 6 as the resulting scheduling is the same as OpenMP. The transformation to srSDF extracts more parallelism than OpenMP from the subdivision of channels into multiple FIRs. These choices make TB-MS suitable for unbalanced applications. In the HCLM-sched benchmark with 12 channels, the overall latency is reduced of up to 34%.

For the TB-MS implementation, the latency remains constant over iterations. By having prior knowledge on how the application will behave, the Scheduling Element can start an execution on processing elements which have already finished the previous execution. It can then start the following iteration as soon as the next period tick occurs. With a better knowledge of the application execution, the TB-MS can pipeline graph iterations.

VIII. CONCLUSION

A novel multicore scheduling method referred to as Time Based Multicore Scheduling (TB-MS). Presented TB-MS splits the scheduling of a PiSDF dataflow graph into steps to identify locally static regions. It enables efficient assignment and ordering of actors into PEs with a better knowledge of actor interactions. Experiments conducted on an 8-core Texas Instruments DSP demonstrate on a benchmark that the TB-MS scheduler provides more parallelism to the execution than the job posting system based on pragmas, task creation and task dispatch of OpenMP. Results have shown that TB-MS can reduce the execution latency up to 26% and can allow handling multiple executions.

REFERENCES


