**CPS: Small: RUI: CPS Foundations in Computation and Communication**

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Modern processor architectures sacrifice timing predictability for increased average computational throughput. Branch prediction, multi-level memory hierarchies, out-of-order execution, and data forwarding all make exact execution timing prediction impossible. As accurate runtime predictions are required for task scheduling, our goal is the development of a Precision Timed (PRET) processor, along with the inter-process communication methods and operating system services, which remove many of the sources of timing indeterminacy.

Our architecture follows the approach described by Edward Lee of Berkeley. The deep pipelines of existing architectures are retained, but the data hazards resulting from these pipelines are removed by interleaving instructions from multiple threads. This approach is being implemented in a variant of the OpenFire soft processor, itself an open source clone of the MicroBlaze architecture popular in programmable logic devices. Preliminary implementation of the architecture indicates that the PRET modifications double the clock frequency, and thus the overall throughput, compared to the generic OpenFire. The increase in area of these modifications is minimal (~7% increase in slices, a basic component of Field Programmable Gate Arrays); though additional dedicated memory resources are required for the enlarged register file. This architecture permits up to 16 threads to time share the processor with scheduling possible on a cycle-by-cycle basis. Being released open source, it is envisioned that once completed the processor and associated tools will be used by the CPS community in a variant of applications.

CPS applications will require a network consisting of multiple computational-sensing nodes scattered throughout an area of interest. The lack of tools and techniques for an efficient communication scheme in CPS networks is a major research challenge that must be resolved before CPS can become practical. As such, the investigation of secure, power efficient, and latency-limited communication schemes is an integral part of our work.

We have devised a multicast algorithm for CPS considering the constraints of these networks. This multicasting algorithm is different from the existing multicasting algorithm, as it is not tree-based nor mesh based. This algorithm was designed with simplicity, energy efficiency, and reliability in mind. Our algorithm combines the best of multicasting, which we have based on multi-path MAODV, with the best of distributed source coding (DSC) which incorporates and uses ideas from rateless coding. By adding DSC using rateless codes on top of multi-path MAODV, the transmission load is distributed more evenly among the CPS nodes and the communication is more robust against link losses. Unlike existing algorithms, receiving any subset of the encoded packets will help the destination nodes for full recovery of the original information. Our algorithm has impact on theory and practice of multicasting in any application that requires a communication scheme with low computational complexity, energy efficiency, and reliability.

We implemented our algorithm in MATLAB to determine its energy efficiency by means of comparing the total number of required transmissions per transmitted packet. The simulation results calculate the number of packets needed to transmit a set of data when a channel experiences loss. The simulation results show that our algorithm’s performance is very similar to other multicasting methods with the added benefits of reliability, longevity, rate optimality, and higher adaptability. It also shows how, with increasing channel loss, our algorithms performance begins to rapidly increase when compared to other multipath multicast algorithms.