Pushing Sensor Network Computation to the Edge

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Abstract

Sensor Networks consist of multiple devices equipped with some sensing apparatus. The devices in the network may be homogeneous or heterogeneous, yet they coordinate in order to accomplish a pre-defined task. With the rising interest in the use of Sensor Networks in various applications, the sensor nodes need to subsist in a dynamic environment and react in a timely fashion to environmental stimuli. The current Sensor Network paradigm relies on static tasking of the nodes; which ultimately leads to the deployment of multiple sensor networks to cover a common area for different tasks. To improve hardware infrastructure re-usability, our work introduces a framework that enables nodes to support dynamic tasking in a dynamic environment by pushing computation to the edge through FPGA-based reconfigurable nodes.

Project Summary

Sensor nodes are generally low-power, low-memory devices with highly constrained computational capability. They are typically programmed prior to deployment with the ability to communicate with their peers. The data collected by the nodes are relayed to a base station or sink that does not suffer from the severe resource limitations. Sensor Networks have a wide range of applications, from environmental monitoring to video surveillance. For instance, the ability to track suspected terrorists in an airport using Sensor Networks is effective because humans cannot be expected to keep watch of all ongoing activities in various frames of video feeds [1, 2]. However, due to the limited computation capabilities of the nodes, video may need to be sent back to a centralized location for analysis. This incurs huge bandwidth consumption and long delays in target recognition.

Field Programmable Gate Arrays (FPGAs) allow a hardware chip to be reprogrammed to support a particular application. As the nodes are reconfigurable at the hardware layer, their reconfiguration can take advantage of possibly novel energy-efficient hardware implementations of algorithms. In addition, provision of hardware support for low-level tasks means that the amount of information that needs to be relayed to base stations can be significantly reduced.

Regardless of the application, the operations that can be supported by the camera will involve either detection or tracking of an object and as such we denote these tasks as Low-Level Tasks (LLT) for the camera. Providing hardware support for such tasks on the FPGA nodes can allow various applications to take advantage of the common tasks implemented in a manner that improves response time.

We propose to implement a reconfigurable tracking node by using the Xilinx development FPGA board ML405 [3] with a general-purpose processor to which an LLT tracker is attached. The board contains a hard-core version of the IBM PowerPC405 processor, which is used as our general-purpose processor. The LLT tracker implements the Mean-Shift tracking algorithm [4, 5], which tracks objects by applying monotonically decreasing kernels to determine the color probability distribution of target model and candidate locations of the object being tracked. The trajectory of an object is determined by minimizing the distance between the two probability distributions. The PowerPC405 core is connected to the LLT through the Processor Local Bus. The PowerPC405 core executes general instructions while tracking is provided by the LLT.

By pushing computation to the edge of a Sensor Network, our work intends to i) address the issue of dynamic tasking to improve the reusability of sensor networks and ii) improve the processing time of sensed data to satisfy timing constraints of applications. Experimental results indicate that the Bilkent tracker [6] has a processing rate of about 27.2633 seconds per frame. The LLT tracker, on the hand, accomplished the same task at 5.5379 seconds per frame, thereby providing a sizeable improvement in response time to any application that rely on the LLT. In addition, the LLT track generates accurate tracking results.

Our study has shown that the LLT is accurate and very responsive. The improved response time of the system can be crucial to time sensitive operations. Our future work, will attempt to address the issue from a broader spectrum by looking at the network as a whole.

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