Temperature-driven task migration to balance energy efficiency and thermal noise of sensor processing workloads

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ABSTRACT

Many researchers propose dedicated hardware [1, 2] to process sensor data on mobile systems, reducing the burden on general-purpose computing units and increasing a system's energy efficiency. However, these hardware units are placed at a distance from sensors, thermally isolated to avoid an increase in thermal noise of sensors that can degrade the fidelity of the sensor output signal. In this poster, we propose an investigation towards a system that places hardware units close to the sensor for additional gains in energy efficiency, while providing runtime temperature-driven task migration mechanisms to mitigate thermal noise issues.

1 EFFICIENCY THROUGH PROXIMITY

Processing sensor data on general-purpose computing units e.g., application processors, on smartphones is energy expensive due to long interconnects as the sensor is located physically farther from the processing unit. Also, high bandwidth applications need more DRAM transactions which are energy expensive and consume 550 mW of average power during read/write transfers [3].

Shifting the processing unit closer to the sensor through dedicated hardware [4] can reduce the inefficiency of I/O and memory by lowering the communication burden and reducing the bandwidth. This strategy also reduces the system stalls of I/O bound processes, leading to increased efficiency and performance.

However, while shifting processing closer to the sensor reduces the energy consumption of the system, it will increase the temperature of the sensor due to thermal coupling. That is, when a processing unit's power consumption increases, it will raise the temperature of the nearby thermally coupled sensor. Components can be thermally isolated by placing them on different boards, but this prevents tight integration, increases I/O overhead, and reduces system efficiency and performance.

To characterize the thermal implications of component proximity, we use Therminator [5] to estimate the steady state temperature of an image sensor with various placement configurations and power consumptions. As shown in Figure 1, at the power consumptions of 0.36 W and 1.25 W for image sensor and processing unit respectively, with the processing unit and image sensor thermally coupled, the steady state temperature of the image sensor crosses 60 °C, which is the hard limit for guaranteed operation for most image sensors. As these power consumptions are common for ubiquitous sensing applications, e.g., face recognition, such processing can significantly degrade the fidelity of sensor readings.

Thus, shifting processing unit closer to the sensor makes the system more energy efficient but it can lead to serious thermal issues if the processing happens on it continuously.

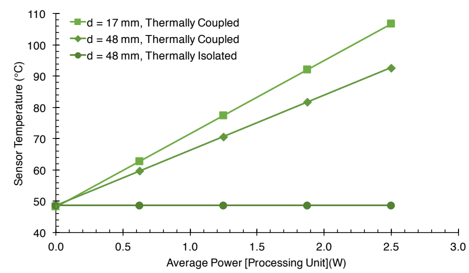

Figure 1: Steady-state sensor temperature with varying power consumption of processing unit, various distances (d) between sensor and processing unit, and with/without thermal isolation, with fixed sensor power of 0.36 W

2 TEMPERATURE MITIGATION THROUGH TASK MIGRATION

To leverage the gain in energy efficiency of the system while avoiding thermal issues, we propose temperature-driven task migration between the processing unit near to the sensor and the general-purpose processing unit, thermally isolated from the sensor. In doing so, we plan to investigate the following challenges:

- Characterizing transient thermal simulations and constructing thermal models covering realistic scenarios.
- Characterizing thermal noise for different sensors under different workload conditions.
- Constructing hardware for various sensor processing unit placement configurations.
- Designing mobile operating systems runtime strategies, guided by thermal and noise models.

The proposed work will lead towards a solution that dynamically migrates processing state towards and away from the sensor to mitigate thermal issues. Moving forward, we plan to evaluate the solution in the context of different continuous sensing use cases.

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