A Technical Overview of Embedded Platforms in Internet of Things

Introduction

From vending machines to cocktail dispensers, embedded systems are being utilized throughout the food delivery industry to ease the creation and delivery of consumables. The choices for both hardware and software must be carefully weighed against the cost of production and maintenance, the required performance needed, as well as issues such as power and energy consumption [1, 2]. Because the amount of Internet of Things (IoT) devices is expected to reach in the billions within the next 10 years, the next generation of food platforms will be expected to be connected to the internet [3]. This technical review summarizes various aspects of embedded platforms with the goal of processing spices in a connected environment.

Commercial Implementations

A large deciding factor in choosing a platform is the computer architecture used [2]. ARM processors have taken over the market for mobile and embedded devices, with a high market share in IoT applications [4]. Of the four ARM cores variants, the A-series cores have the highest performance and are meant for applications which require a robust OS and networking support, without the need for real-time applications as found in the M-series [5].

The Raspberry Pi is a $35 board with a Quad-core ARM Cortex A7, 1 GB RAM, a Broadcom VideoCore IV GPU, and basic peripheral support with a camera port [6]. There has been success using this platform for controlling a robotic arm with the Android OS over a network, and given its strong GPU, it can process video well [7].

For $45, the Beagleboard Black is has an ARM-A8 core, 500 MB RAM, a PowerVR SGX530 GPU, and many IO features [8]. Benchmarks have shown that Beagleboard Black is not only faster than the original Beagleboard, but it is faster than the Raspberry Pi in both processor performance and network response latency, however, the GPU of the Raspberry Pi has superior performance [9].

The Qualcomm DragonBoard 410c is a development board based off the Snapdragon processor. The board has a 64-bit Quad-core ARM cortex A53 and 1GB of 533 MHz LPDDR3 RAM, and a Qualcomm Adreno 306 GPU. The $75 product comes with Wifi, Bluetooth, GPS, and multiple expansion slots with robust IO support [10]. According to ARM product descriptions, the DragonBoard has the most powerful processor, followed by the Beagleboard Black, and Raspberry Pi [5]. Overall, considering costs, energy use, features, and product maturity, the Raspberry Pi has the best value for video processing and graphics, the BeagleBone has the best value as a controller due to its peripheral support, and the Qualcomm board has the best CPU, GPU, and peripheral features, but at a high cost.

Embedded System Design

Embedded systems typically have all needed functionality on the system board, or even on chip, unlike servers which can have hard disks and memory components as discrete components [2]. With area, cost, and power being as important as performance, embedded platforms have reduced pipelining and speculative execution compared to servers [2]. Due to their application-specific nature and high constraints, embedded devices are sometimes equipped with digital signal processors (DSPs) or media extensions to accelerate the processing of electrical signals or media applications [2]. For applications dealing with computer vision or machine learning, a GPU has been shown to provide substantial speed improvements. [11]

Software Architecture

With devices growing more intelligent, especially in the face of IoT, devices are less likely to be running bare metal applications. Rather, an operating system is utilized to manage device drivers and multi-program scheduling [12]. Device drivers allow the user to abstract away the hardware details of the specific device the user is controlling. Using the device abstraction allows networking and motor control to be accessed by multiple programs, without duplicating code [12]. Additionally, peripherals such as cameras may be required to use a provided driver.

The supported operating systems consisted of Linux (Android, Ubuntu, or Arch Linux) and Windows 10 [6, 8, 10]. Real time operating systems are not available because these platforms (A series ARM cores) are targeting applications which do not have real time constraints [5]. Windows 10 drivers for various peripherals are missing, and certain hardware configurations are not supported [13]. The Linux operating systems have had longer lifetimes on these devices and currently has more hardware support [6, 8, 10]. Using these software features in combination with the mentioned hardware will allow for faster and more powerful software engineering.

[1] P. Koopman, "Embedded system design issues (the rest of the story)," in *Computer Design: VLSI in Computers and Processors, 1996. ICCD '96. Proceedings., 1996 IEEE International Conference on*, 1996, pp. 310-317.

[2] J. L. Hennessy and D. A. Patterson, *Computer Architecture, Fifth Edition: A Quantitative Approach*: Morgan Kaufmann Publishers Inc., 2011, pp. E1-E25.

[3] K. Vandikas and V. Tsiatsis, "Performance Evaluation of an IoT Platform," in *Next Generation Mobile Apps, Services and Technologies (NGMAST), 2014 Eighth International Conference on*, 2014, pp. 141-146.

[4] ARM Holdings, Inc., "Embedded intelligence – connecting billions of smart sensors into the Internet of Things." [Online]. Available: http://ir.arm.com/phoenix.zhtml?c=197211&p=irol-embeddedintelligence. [Accessed: Oct. 25, 2015].

[5] ARM Holdings, Inc., "Cortex-A Series," [Online]. Available: http://www.arm.com/products/processors/cortex-a/index.php. [Accessed: Oct. 25, 2015].

[6] Adafruit, Inc. "Raspberry Pi," [Online]. Available: http://www.adafruit.com/category/105?gclid=COXVhbTO4MgCFdgUgQod5EwDbg. [Accessed: Oct. 25, 2015].

[7] K. Premkumar and K. G. J. Nigel, "Smart phone based robotic arm control using raspberry pi, android and Wi-Fi," in *Innovations in Information, Embedded and Communication Systems (ICIIECS), 2015 International Conference on*, 2015, pp. 1-3.

[8] BeagleBone, Inc., "BeagleBone Black," [Online]. Available: http://beagleboard.org/BLACK. [Accessed: Oct. 25, 2015].

[9] C. P. Kruger and G. P. Hancke, "Benchmarking Internet of things devices," in *Industrial Informatics (INDIN), 2014 12th IEEE International Conference on*, 2014, pp. 611-616.

[10] Qualcomm Inc., Dragonboard 410C Manual. [Online]. Available: https://www.96boards.org/products/ce/dragonboard410c/.

[11] N. Sundaram, "Making computer vision computationally efficient." M.S. thesis, EECS Department, University of California, Berkeley, 2012.

[12] J. Corbet, A. Rubini, and G. Kroah-Hartman, *Linux Device Drivers. 3rd Edition*: O'Reilly Media, Inc., 2005, pp. 1-14.

[13] Microsoft, Corp., "Ecosystem Compatibility List." [Online]. Available: http://ms-iot.github.io/content/en-US/win10/SupportedInterfaces.htm. [Accessed: Oct. 25, 2015].