Designing a Low-cost High-end Android-based Wireless Board for the EMULSION IoT Platform

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Abstract

This paper proposes an innovative generic wireless low-cost high-end Android-based board for use by the EMULSION IoT platform, which is being elaborated as IoT-service and IoT-system prototyping ready. Based on the AllWinner A33 quad core Cortex-A7 CPU with a Mali400MP2 GPU and 512MB RAM, the board supports a 5MP CMOS sensor camera, 1080p video, MIDP display, and Hi-Fi audio. The paper reveals the basics of the design of this proprietary board.

1. Introduction

The provision of Internet of Things (IoT) services requires suitable IoT platforms, allowing a transparent connection with different types of IoT devices and offering (value-added) functionalities, such as application enablement, remote device control and management, cloud/fog/dew/telco connectivity and storage management, 'big data' analytics and visualization, etc., with some sort of freedom of use by and customization to consumers [1], known as Platform as a Service (PaaS) in the cloud domain. A generic multi-service cloud-based IoT operational platform, EMULSION, serving as an architectural foundation for a 'smart city' development [2], has been proposed in [3], aiming to support heterogeneous-type communications and data exchange between different types of IoT applications and devices. Our goal is to develop this platform for future rapid roll-out of IoT systems of different types, whereby a single cluster can support up to 1,000,000 IoT devices.

There is a variety of IoT system solutions, for instance, for smart homes, smart metering, smart agriculture, smart environmental protection, ubiquitous health, etc. All these rely on different IoT devices, which for the most part are embedded systems and boards used to collect information from the physical world and deliver it through capillary communication networks to a cloud for further processing and taking corresponding actions. IoT devices could be broadly classified into three categories [4]: low-end, middle-end, and high-end devices. Low-end IoT devices, used for basic sensing and actuating in the physical world, are constrained in terms of resources (with RAM in the range of tens to hundreds kB and 8/16/32-bit CPU) to run traditional operating systems (OSs). Middle-end IoT devices have more features and greater processing capabilities (e.g., image recognition), and can support more than one standard for communication. High-end IoT devices, mostly in the form of single-board computers (SBCs), poses sufficient resources to run traditional OSs, can perform provisional computations (e.g., execution of machine learning algorithms), and could be equipped with multimedia I/O interfaces. They can be used also as intelligent communication gateways for facilitating heterogeneous communication with low-end IoT devices and/or performing 'big data' analytics at the edge [4].

Another classification divides the IoT devices into two categories [4]: (i) *microprocessor*-based (high-end) devices, which are in fact specialized (and expensive) computers with lots of processing resources allowing them to use a full OS and simultaneously run multiple programs (written in/by different languages/tools) with associated communication support but with high-power consumption; and (ii) *microcontroller unit* (*MCU*)-based (cheap) boards, utilizing a single integrated circuit with limited processing and communication abilities, which position them in the low-end and middle-end IoT device range.

So far, with the development of EMULSION, our efforts were focused on designing proprietary MCU-based boards [5]. However, the main principles of consumer freedom require the provision of greater flexibility of communication with variety of choices. In addition, in the IoT world, lots of application scenarios require the execution of machine learning algorithms, running object-oriented applications, supporting different types of databases, etc. For meeting all these requirements, high-end IoT devices are needed. This paper presents our design solution for a proprietary high-end IoT device, in the form of a microprocessor-based board, for utilization by the EMULSION platform.

An essential feature of the high-end IoT devices is the OS allowing their integration across heterogeneous communication networks. Most SBCs run Linux but offer also Android and Chrome compatibility [4]. Android became our OS choice for the designed high-end board.

In [6], the design of an Android-based wireless notice board is presented, based on a low-cost Arduino UNO microcontroller using Bluetooth or Wi-Fi (for extending the communication range at the expense of increasing the system cost and requiring the supply of more power). An Arduino UNO microcontroller is utilized also in [7] for Android-based control (by a smartphone via Bluetooth connectivity) of a prosthetic hand with five motors (one for each finger). In [8], an Android-based mobile application is presented which works with an API cloud service, ThingSpeak, for vehicles tracking by utilizing an Arduino UNO board with a GPS module. However, most Arduino boards are low-end and only few of these are middle-end IoT devices [4]. Among the middle-end and high-end IoT devices, which are compatible with Android, the most popular choices include: ODROID boards, Wandboards (utilizing a system-on-module approach), UDOO single board computers (SBCs) belonging to the family of open-source Arduino-powered mini-PCs, Cubieboards, Radxa Rock single boards, PandaBoard SBCs, Beagleboards, pcDuino mini-PCs, Banana Pi SBCs, and Orange Pi SBCs. However, the cost of these open-source devices ranges from 49 USD (for UDOO NEO) to 249 USD (for BeagleBoard-X15) [4].

Our aim was to design a cheaper high-end proprietary board, for utilization by the EMULSION IoT platform, whose performance is close to that of the open-source high-end boards available on the market. We succeeded in this task, having designed such a board with an overall 'PCB+BOM' cost coming to only 30 USD.

2. EMULSION

The EMULSION IoT platform is being developed by means of low-cost electronic devices and open-source software components, by utilizing the generic IoT system architecture depicted in 0The sensors (S), location trackers (T) [9], and monitoring stations (MS), deployed in the sensor tier for capturing the changes occuring in the physical world, communicate via corresponding data/remote transfer units (D/RTUs) [5], furnished with wireless communication modules of different types (e.g., 2G÷6G, LoRa, Wi-Fi, Bluetooth, etc.), with intelligent communication gateways (guaranteeing the seamless interconnection and interoperability of heterogeneous IoT devices accessible through different capillary networks) and through them with servers in the cloud tier. Additional wireless sensor networks (WSNs) are set, where needed, for extending the communication range and reaching the corresponding communication gateway(s). This way the cloud tier can collect and analyze the data coming from the sensor tier as to make relevant decisions and recommendations that are sent back to the actuators (A), controllers (C), and guards (G) in the sensor tier, e.g., as a configuration information and/or commands for enforcing control and management actions and implementing desired/necessary changes in the physical world.

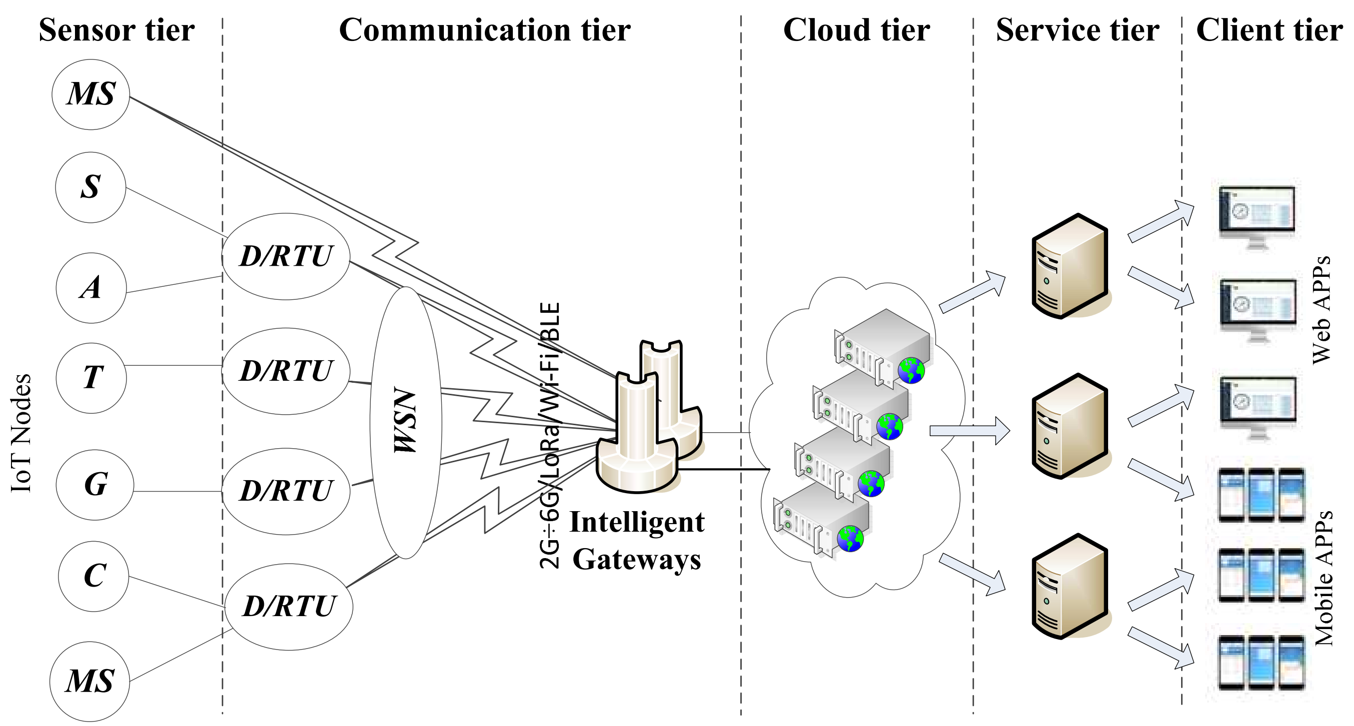

Figure 1. The generic IoT multi-tier architecture, utilized by EMULSION.

3. Board's Design

The board's hardware consists of a four-kernel smart A33 chipset, a 512MB DDR3 SDRAM, three serial ports (a RS-232 port and two RS-485 ports), two USB 2.0 ports, a SD card, and an audio interface. For communication with external world, it contains a RJ-45 100Mb/s LAN module, a 4G/Cat1 module, and a Wi-Fi module. The elaborated design of the board meets the requirements of most industrial IoT (IIoT) applications.

The main schematic of the board includes the following parts: (i) two SY8113BADC chipsets, providing a 3.5V supply for the 4G/Cat1 module and 5V supply for the A33 chipset; (ii) a small TSSOP-20 MCU (MM32F003TW) chipset, communicating with the A33 chipset and providing 4-20MA or 0-5V ADC and control via a SY8113BADC power enabled port (i.e., MM32F003TW can open/close A33 by employing a time logic or another business logic); (iii) a A33 kernel module, running the Android 7.0 OS on 512MB RAM, and providing LVDS and MIPI display interfaces; (iv) a SR9900A chipset providing a wired network support; (v) a EC600N CAT1 module for 4G communication; (vi) a GL850G-HHY22 chipset, used to clone one USB port to four USB ports; (vii) a ESP8089 chipset, supporting Wi-Fi communication; (viii) a SN74LVC1G08 chipset; (ix) a TP3232N-SR chipset and a YD3082E chipset, sharing one TTL port. Figure 2 shows the corresponding PCB layout design of the board.

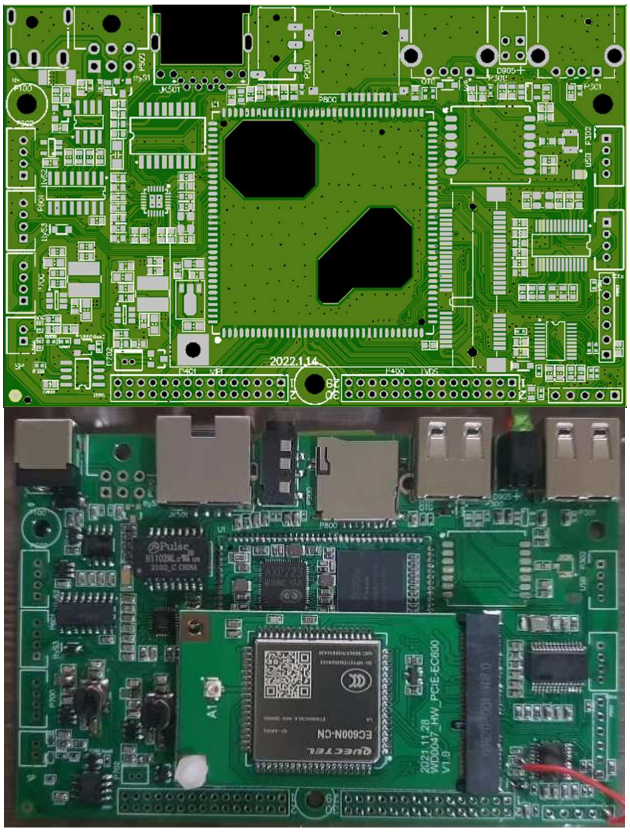

Figure 2. The PCB layout design of the board.

4. Conclusion

The design of a low-cost high-end Android-based board has been briefly presented in this paper for utilization by the EMULSION IoT platform. Its main hardware includes a four-kernel smart A33 chipset, a 512MB DDR3 SDRAM, Wi-Fi and 4G communication modules, three serial ports, two USB 2.0 ports, a SD card, and an audio interface. The overall 'PCB+BOM' cost of the board is only 30 USD.

5. Acknowledgements

This publication has emanated from joint research conducted with the financial support of the Bulgarian National Science Fund (BNSF) under the Grant No. КП-06-ИП-КИТАЙ/1 (KP-06-IP-CHINA/1) and the S&T Major Project of the Science and Technology Ministry of China, Grant No. 2017YFE0135700.

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