Integration of Cloud with Embedded Systems for IoT devices

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Abstract- Embedded Systems face performance challenges like memory, CPU, speed, size and power consumption. Considering the exponential growth in the use of these systems due to a boom in IoT solutions, these challenges need immediate attention. This paper discusses integrating cloud with embedded systems as a solution to these performance challenges. Cloud provider AWS's solution of embedded and cloud integration: AWS IoT is discussed to support the idea.
Keywords – Embedded Systems, Cloud Computing, AWS IoT, Internet of Things

I. INTRODUCTION

Embedded System is a combination of hardware and software that delivers an information based and context aware application [2]. They range from miniature health care capsule to industry applications and more. These devices serve a wide range of purpose. Therefore, all these devices have different hardware, software and communication needs and are highly constrained by their resource capacity [5]. Embedded devices are also called "edge" devices [4]. There are three terms that rule embedded system's field: Wireless Sensor Networks (WSN), Internet of Things(IoT) and Cloud Computing.

Wireless Sensor Network is an example of networked embedded system. It contains a large number of low power low cost sensor devices called nodes that wirelessly communicate with each other or a central node. Internet of Things is a heterogenous network of devices that have connectivity to the internet. These devices can be your phone, a refrigerator, etc. Cloud Computing is a managed resource pool that is scalable and elastic based on your needs. It works on demand and you pay for what you use, which makes it a cheap and provides a hassle-free computing solution.

This paper discusses the idea of integrating cloud with embedded devices, that comprise of an IoT solution, to solve the challenges faced in embedded device performance. The first section talks about performance issues that exist in an embedded system. The second section talks about cloud and its actual integration with these devices by taking an example of the work done by Furuichi et al. [1]. The third section explains AWS IoT as a cloud provider and its features that can be used for the integration with embedded devices. Concluding remarks are given in last section IV.

II. PERFORMANCE CHALLENGES IN EMBEDDED SYSTEMS

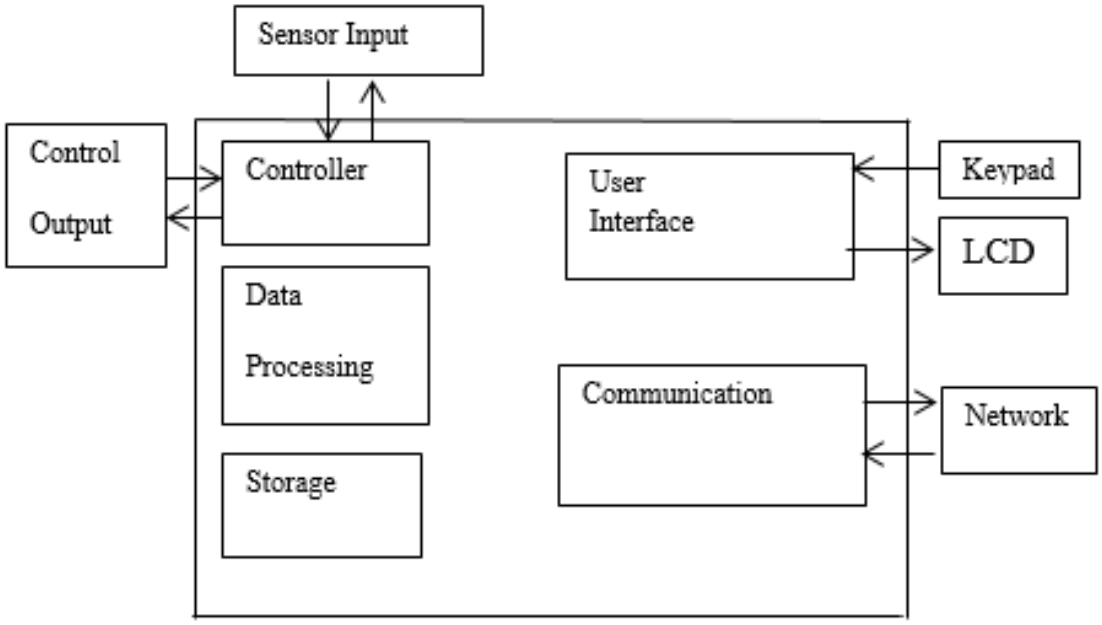
The number of embedded devices are growing exponentially, and is said to outnumber the global human population by the year 2050[5]. Real Time application is the major use case here. With the advent of IoT, considering the performance issues of these devices is of utmost importance. Below is a mention of the major expectations of an ideal embedded system and are also the areas of focus for performance optimization:

Low Power Consumption
Small Device Size
High Processing Capacity (Processing Speed and CPU Capacity, OS)
High Memory Size
Truly Real Time – Quick Response Time
Light Weight and Reliable Communication Protocols with ability to connect to the internet
Highly Secure
User Friendly Interface

III. EMBEDDED SYSTEMS AND CLOUD COMPUTING

A Cloud a cluster or pool of resources. These resources can be processing power like Virtual Machines(VM), storage, and many more. Cloud computing involves on-demand and ubiquitous use of these configurable shared resources. Cloud providers provide 3 types of cloud service models:

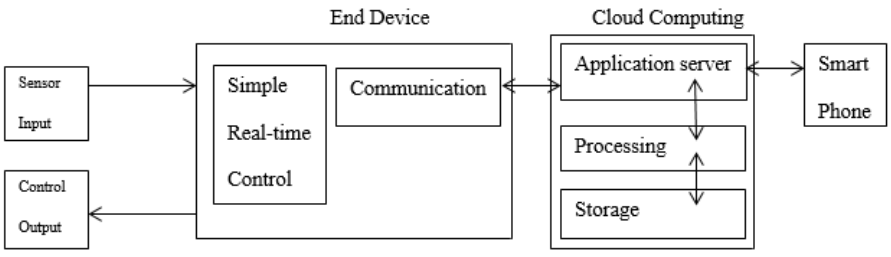
Infrastructure as a Service(IaaS) – This model provides the users with control over the VMs, storage, OS
Platform as a Service(PaaS) – This model provides software deployment options with most of the infrastructure taken care of by the cloud provider.
Software as a Service(SaaS) - This model provides ready to use, full features solution software like emails.



3.1 Embedded System Design without Cloud

Figure 1 shows a modern embedded system. The input and output devices can be sensors and/or actuators. The controller is brain and is responsible for the functioning of the external IO, data processor, storage, communication and user interface. The data processor is the unit where the actual program is executed. The storage section is a memory which can be RAM/ROM/Flash memory can hold the program, data, logs, etc. The user interface can be a small LCD screen for the user to see the output. A key board is also present to interact with the system directly. The communication system can be wireless or wired, based on the system and its needs. In this paper, it is considered that the communication system has access to the Internet. The power unit can contain a battery or harvest energy from a power source [1].

Integration of Cloud and Embedded Systems is possible when embedded system has the ability connect to the Internet directly or indirectly and utilize cloud computing resources [5]. Multiple approaches have been proposed on how to integrate embedded system with Cloud. They include approaches like sharing hardware device as a virtual server, separating out the display over the network, directly moving the application processing to cloud [1]. The solution proposed by Furuichi et al. [1] is a promising approach. The approach is to move all the possible functionality to cloud and keep only the communication system, external IO and immediate and important control functions on the device. User interface processing is moved to the cloud which interacts with mobile phones, making it as a user interface. The device's data is directly transmitted to cloud, where it is processed. The application's main algorithm is deployed on cloud. Cloud provides data bases and storage options to store this data received from the device and can analysis can be carried out on this data. Figure 2 shows a block diagram of such a system



3.2 Embedded System Design with Cloud

All embedded devices generate increasing volumes of data. These devices can be heterogenous or homogenous, leading to variety of data formats. The management, storage, retrieval and analysis of this data comes under "Big Data" section [1]. Deriving useful outcomes of this data, as real time as possible, is base of IoT. Processing of such data needs high CPU capacity, speed and memory, which is very limited in an embedded system.

For Embedded Systems, IaaS and PaaS are the most suitable models for cloud integration. They provide a means to decouple software and hardware needs. This integration addresses many of the performance challenges in embedded systems in a very efficient manner. Below is the impact of it:

By offloading most of the processing, storage and user interface controls to cloud, power consumption is reduced

Smaller device size.

Taking advantage of cloud's scalability and elastic nature based on demand, it provides high processing capacity and speed.

Since Cloud is considered to have virtually unlimited storage, memory size is not an issue

Being real time depends on the speed of communications between the device and cloud, and with cloud processing fast enough, real time processing is not far away.

Communication need to happen over the internet to access the cloud resources.

Cloud providers provide secure modes of communication and data storage

With the user interface being controlled by cloud, mobile phones can be used as a UI.

Other advantages include:

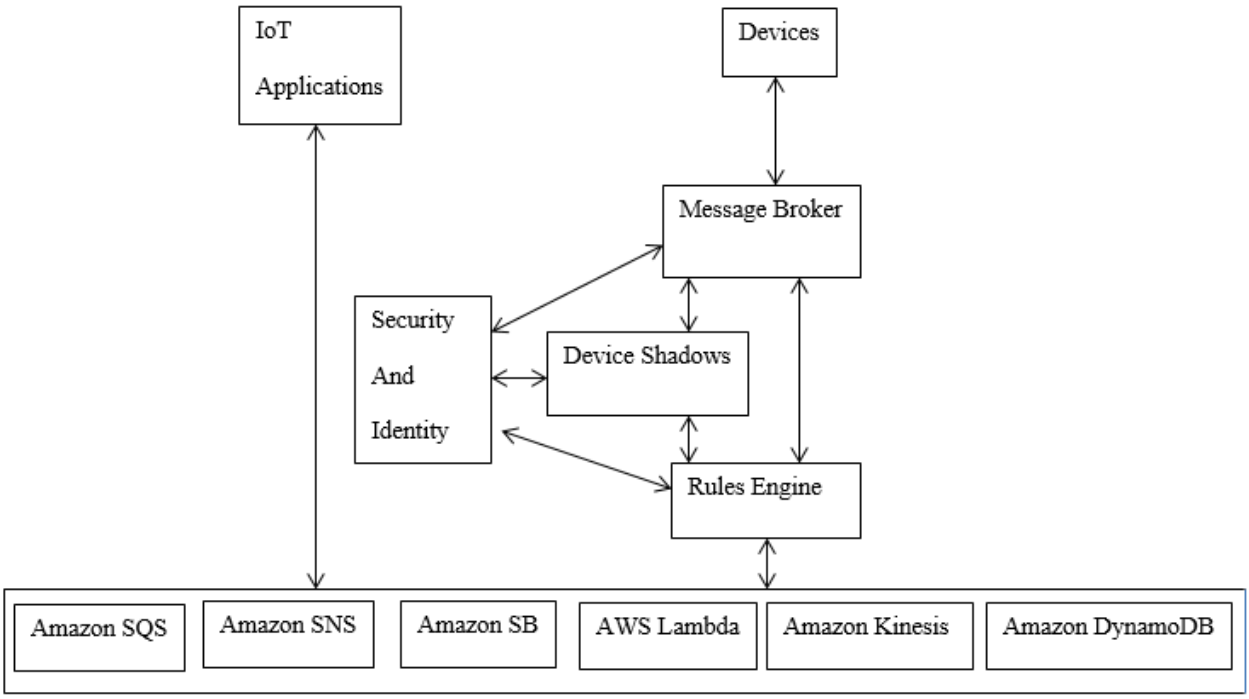
Remote Monitoring and Management

Firmware upgrade (bulk or standalone)

Broadened application scope

IV.CLOUD PROVIDER : AMAZON WEB SERVICES (AWS)

This paper discusses AWS as a Cloud provider for IoT applications. AWS IoT service encapsulates security, device management, SDKs for development and many more features. Figure 3 is the block diagram of how the AWS IoT works:



4.1 AWS IoT Basic Architecture

The device gateway connects the internet enabled devices to AWS. Communication is bidirectional and is in MQTT protocol and JSON objects. The message broker passes on these messages to or from the devices and AWS. Device

Shadows contain the state of the devices. Rules Engine identifies what next action is to be performed on data received in the messages. It can be sent to AWS Lambda, DB, S3, etc. Security and Identity services take care of authentication. It also contains a registry that register devices and associates authentication to them [6].
AWS provides device SDKs for Embedded C, Python, Java and many more. It also has API and CLI command integration. It provides AWS FreeRTOS and AWS Greengrass as operating systems that work with a large variety of devices. These features of AWS IoT make it very developer friendly [6].
AWS IoT provides solutions that include devices, local data collection and analysis, and cloud services to store and analyze device data [6]. With such solutions available, performance enhancements of embedded systems is much more realizable.

V. CONCLUSION

Considering the impact of IoT devices on our lives and our future, optimizing these devices is the main focus of research. Cloud integration of an embedded system not only takes us a step ahead of the performance optimization game, but also opens up new avenues of applications and third-party integrations. Cloud providers like AWS have already provided broad solutions for this integration, which makes the integration process much more simple, modular and smoother.

VI. REFERENCE

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