From IoT to Cloud: Research Platform for IoT/Cloud Experiments

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1 INTRODUCTION

In this study, We aim to build a testbed, Chameleon IoT (CHIoT), that can provide general support for IoT to Cloud experiments. IoT/Cloud research covers a range of topics. To understand the specifics of research projects we conducted a literature review that included 65 IoT projects from 5 IoT conferences/journals. We summarize the topics of the projects in Tab.1.

Based on the observed IoT research, we determined that an IoT/Cloud testbed should provide the following functionalities in order to support experimentation: IoT to cloud communication, computation deployment, and hardware management. This platform should enable researchers to 1) physically connect devices to a network and enable Machine-to-Machine (M2M) communication, 2) deploy computation on the edges and cloud, 3) manage the membership of the device fleet, and 4) ensure security for the devices and data. We depict the functionality of CHIoT in Fig1. CHIoT automates logistics in order to reduce manual effort during experiment preparation.

2 LIMITATIONS OF COMMERCIAL IOT SOLUTIONS

Cloud providers such as Google Cloud, Amazon Web Service (AWS), and Azure all provide IoT/Cloud services but these solutions are intended for IoT application development and are not directly designed to support IoT research. Therefore, they are subject to the following limitations:

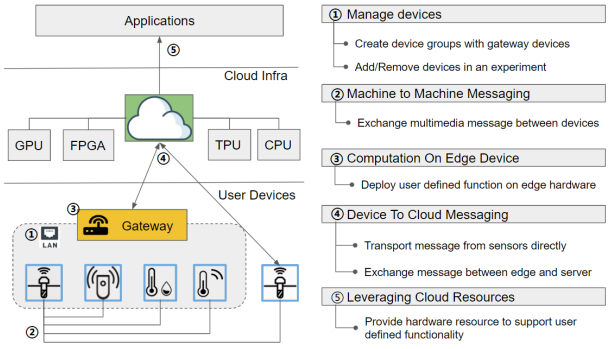


Figure 1: IoT testbed functionality to support IoT to cloud experiments

- Flexibility: Researchers may leverage a desktop/workstation as an alternative to the cloud in the early stages of study for rapid prototyping. The commercial IoT model assumes users work directly on the cloud during development.
- Portability: Device network created through one cloud provider is incompatible with other providers' IoT infrastructure. Researchers, who have a high demand for data privacy cannot integrate commercial IoT solutions with their private cloud.
- Observability: Commercial IoT provides a service-oriented solution for IoT data consumption. Result analysis and observation may be obstructed as researchers do not have direct access to execution details.
- Reproducibility:For VM cloud, performance-related experiment results can be influenced by the "noisy neighbor" phenomenon, i.e., other VM tenants residing on the same machine.

3 ARCHITECTURE

We developed CHIoT as a three-layered architecture containing a cloud system, gateway system, and an SDK. The cloud system is a service hosted on Chameleon to enable communication between devices and servers, while the gateway system manages devices at the edge. The SDK provides interfaces for communication between

Table 1: Observed research categories

IoT Category	Description
Application	Develop IoT based applications to address a specific type of challenge
Sensor sample strategy	Control sensor behaviors to improve efficiency and save energy
Network protocol	Improve network efficiency and reduce energy consumption
Security	Address security challenge for devices and networking
Edge computing	IoT devices as computation resources for leveraging data locality
Cloud service	Develop services on cloud to support IoT activities
Architecture	Designs new interaction patterns among devices
Other	Not belong to the above categories

servers and devices. Users need to download and install a gateway system. Devices can join cloud or edge groups by downloading credentials either from the cloud or the local PKI system. The registered device then can send data upstream, e.g., to a gateway system or cloud servers, for further processing.

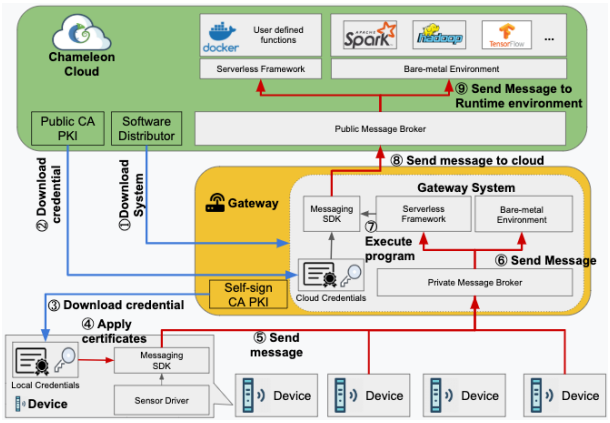


Figure 2: CHIoT architecture

4 USE CASE STUDY

We now demonstrate how CHIoT can be used by different projects.

4.1 Scaling Experiments With Cloud Resources

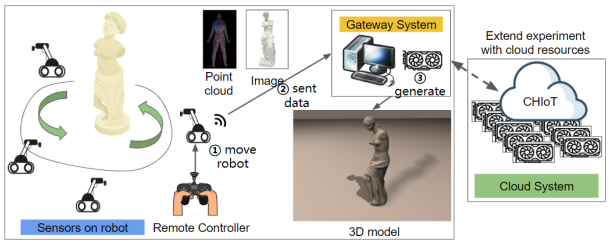
In this experiment[2], a robot equipped with image sensors moves around an object and sends image data to a local GPU workstation to generate 3D graphic models. To scale this experiment to a cloud-based GPU cluster researchers could leverage CHIoT by deploying a data proxy function on the gateway and by migrating 3D model generation algorithms to the Chameleon GPU cluster. The gateway system will redirect sensor data to the cloud so that no modification within the edge system is required to scale.

4.2 Enhance Portability for IoT Projects

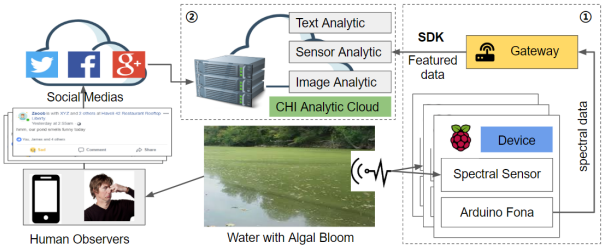
Experiment in Fig 3b [1] combines IoT with social media to predict the algae bloom in water bodies. Researchers distribute a group of sensor systems and register them to a gateway system to collect water quality data. By identifying suspicious peak values at the edge and sending them back to analytic applications on the cloud through the SDK, the algorithm will process sensor data, social media text and images to make a prediction. By replacing the CHIoT SDK with existing commercial IoT SDK, our gateway system can be transplanted to any commercial cloud platform for production.

4.3 Support Privacy-sensitive Research

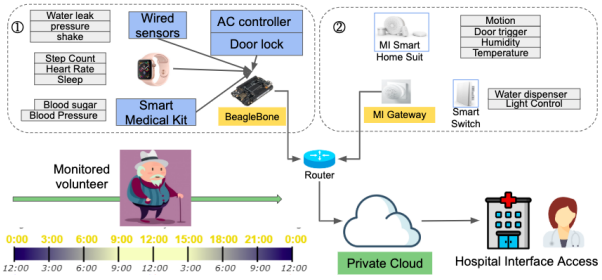
This project[3] is privacy-sensitive as the researchers monitor volunteers' daily activities 24/7. In this case, two smart home subsystems are created, shown as system 1 and 2 in Fig 3c, which can both be managed by the CHIoT gateway system. For privacy consideration, researchers prefer private clusters instead of public clouds. The gateway system of CHIoT is adaptable for this scenario as users can connect device groups to the private cloud by offering a customized SDK.



(a) Generate 3D graphic models with mobile image sensors



(b) Monitor algal bloom with multimedia data



(c) Activity prediction with smart home

Figure 3: IoT research projects in real world

5 CONCLUSION

We identified common IoT/Cloud research requirements by conducting a literature review. Guided by these observations, we designed CHIoT as a three component system to satisfy the requirements specified through our study. We expect this system to overcome the limitations of existing commercial IoT solutions and to be more applicable for research purposes. However, as CHIoT adopts standard communication and security protocols as the default implementation, studies which aim to improve or replace those mechanisms are not supported by CHIoT for the current implementation.

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