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Evaluation of Docker for IoT Application

Ruchika
M. Tech (HPCS)
Vel Tech Dr. RR & Dr. SR Technical University, India
National Ilan University, Taiwan
vyas.ruchika02@gmail.com

Abstract: The Internet of Things (IoT) is highly connected smart devices through the internet network, the number of connecting devices is increasing day by day. So this will have a major impact on industry standard, security, business model and entire IT ecosystem. However, developers are facing multiple barriers while developing, creating and scaling IoT application. Docker is an open source container based virtualization technology which can help to develop and scale IoT application easy and fast. This paper introduces various container based virtualization technologies and Docker for IoT application requirement. In this paper, an IoT application is developed and run inside the container and over the host. Benchmark tools are used to analyse the performance of host and docker.

Keywords: *Internet of Things (IoT), Container Technologies, Docker, Performance measurement*

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1. INTRODUCTION

The invention of IPv6 in the year 2000 and later in 2007 wireless networking extension 6LoWPAN invention which enables devices to connect physical environment to real-world applications e.g., wireless sensor, Such technologies introduced a new hype in the internet world, known as "Internet of Things". The Internet of Things (IoT) is an idea to make physical objects intelligent, sharing information, and taking a decision in real time. The IoT provides automatic interaction between smart systems for exchanging data for meaningful time-sensitive analytics. Internet of thing (IoT) is the one of the biggest developing technology, IoT will give a new direction to the internet world and, unpredictable business development and profit. For example, Manufacturing and Industrial automation sectors are attaching the advanced sensor to several objects for sending and receiving data, which leads to the vast amount of useful information [1]. Before completely adopting this technology some important questions should be considered to solve, for example, How to utilize the tremendous amount of data using standard application of organization? What are the most specific barriers for industries to adopt this technology? What will be a risk and positive or negative consequences with Industrial-IoT? What is the standard architecture to follow?

Virtualization technology works as an abstraction layer for hardware which allows multiple sets of workloads to share a common set of resources while the workloads fulfil the property of isolation from each other. IoT applications tend to gain significant operational efficiencies through virtualization technology, as this could provide a resource (Hardware/Software) utilization, dynamic resource allocation and management, load balancing, and security. The features like on-demand self-provisioning and on-premise or off-premise and scaling can move IoT Industries market to business profit.

2. BACKGROUND: VIRTUALIZATION (CONTAINER) TECHNOLOGIES

Virtualization provides various benefits like resource utilization, Higher system availability, less failover time, improve load balancing, Isolation between running application, less administration/maintenance cost. Virtualization further can be divided depending upon the type of resources going to be virtualized example like hardware virtualization and operating system level virtualization.

Hardware level virtualization is hypervisor based virtualization. In this type of virtualization, the guest OS runs over host OS with their own kernel. The communication of the guest system with the actual hardware is done through an abstract layer of the hypervisor. This type of virtualization provides security and isolation but it has high overhead due to Hardware emulation (Communication overhead between guest OS to host's hardware). To reduce this overhead another type of virtualization can be used i.e.operating system level virtualization, this is also known as container based virtualization [2].

The container is lightweight virtual environment approach which isolates resources and host to any other containers. Containers use the same kernel of the host system, which enables almost zero performance overhead and provides better resource computing performance. Containers allow sharing of binaries and libraries access with other containers, whereas hardware virtualization restricts the scope within one VM environment[2,3]. IoT devices are often resource-poor, so container technology will help to utilize the resources as its share the binaries and libraries which help to save storage space. All container technologies do not meet IoTapplication's requirements, table 1 shows the comparison between different container vendors [2, 11].

Table 1. Container technologies and properties

Property	LXC	OpenVZ	Free BSD Jails	Solaries	Docker	Rocket(rkt)
Development lead	Canonical Ltd.	OpenVz Org.	Free BSD Org	Oracle and illumos	Docker Inc.	CoreOs Inc.
Platform(OS) Support	Linux	Linux	FreeBSD	Illumos (open solaries)	Linux	Linux
Resources/IO reduction limitation	Partial	Yes	Yes	partial	Yes	partially
File system Isolation	Yes	Yes	Yes	Yes	Yes	Yes
Portability & Live migration	Restricted	Yes	Yes	Yes	Yes	Yes
Interoperability and standardization	No	No	No	No	Yes	No
Manageability via remote access	No	Yes	Yes	Partial	Yes	No
Root Privilege or security	Yes	Yes	Yes	Yes	Yes	Yes
Nested virtualization	Yes	Partial	Yes	Partial	Yes	Partial

3. DOCKER FOR IOT APPLICATION REQUIREMENTS

Docker provides an easy to use service oriented architecture (SOA) of container technologies. This SOA architecture can handle composite applications where each service can be independently deployable and isolated with each other [4]. Docker is basically a lightweight open source containerization technology which gives a platform to develop, run and scale the application[10]. Now the question is that How Docker container will help in therapidly development of IoT application?

IoT application development is bit complex and there are lots of challenges still exist like interoperability, security, power, network connectivity and standard protocols. Docker can give Platform as a Service And!Or Software as a Service solution for easy development of IoT application [5]. Below are some points explains the docker for IoT application's requirements.

1. Easy and faster deployment for applications: Docker container can run on any modern Linux system or windows system. It has less launch time as run time overhead is almost zero, this also reduces the cycle time of developing and testing and deploying an application [4-5].

2. Cluster scheduler and service discovery: Cluster scheduler feature of docker allows the management of a cluster of docker host which provides automatic failover and migration of container in case of resource bottlenecks. Service discovery features help to store the IP addresses and ports of running theapplication in distributed key-value pair manner. Docker has container linking mechanism in which it passes environment variable and IP address to only linking container [4-7].

3. Security and privacy: IoT applications are amachine to machine communication in distributed or decentralized environment, so security is one of the measure challenges. Docker provides agood security mechanism. It enables the kernel or host operating system's level security to protect from thethreat. It also provides TLS/SSL certification for repository server/client verification. Docker allows only root access to anapplication running inside thecontainer[4-10].

4. Interoperability: In IoT, the interoperability is a big challenge, integration of IoT device with container will lead to a better solution. Dockeroffers remote management capability and portability amongst different devices. Docker provides scalability and easy to handle the large volume of data [7-10].

5. Management solution: The cost of managing, monitoring and developing of IoT application is high. IoT industries are looking for asolution to reduce the cost (money + manpower) forthedevelopment of IoT application. Docker could provide a low cost; low maintenance service for developer and admin to develop an IoT application [4].

4. IMPLEMENTATION: EXPERIMENT, EVALUATION

Docker enables a common architecture for developer and IT teams to deploy and development of an IoT application. In the section2 the benefits of using docker for IoT applications is explained which clarify that docker provides agility and portability which gives developers to create and deploy an application without complexity. Here in this part, I have explained the analysis steps and evaluation done over docker for IoT application.

Fig1. Shows the equipment setup for the experiment. The latest version of Raspbian Jessie operating system is used for host, the network connection is established using LAN with static IP and appropriate IoT Gateway. The experiment is done for an IoT application which collects and analyze the sensor data. Docker engine has been installed on the host machine (raspberry pi).

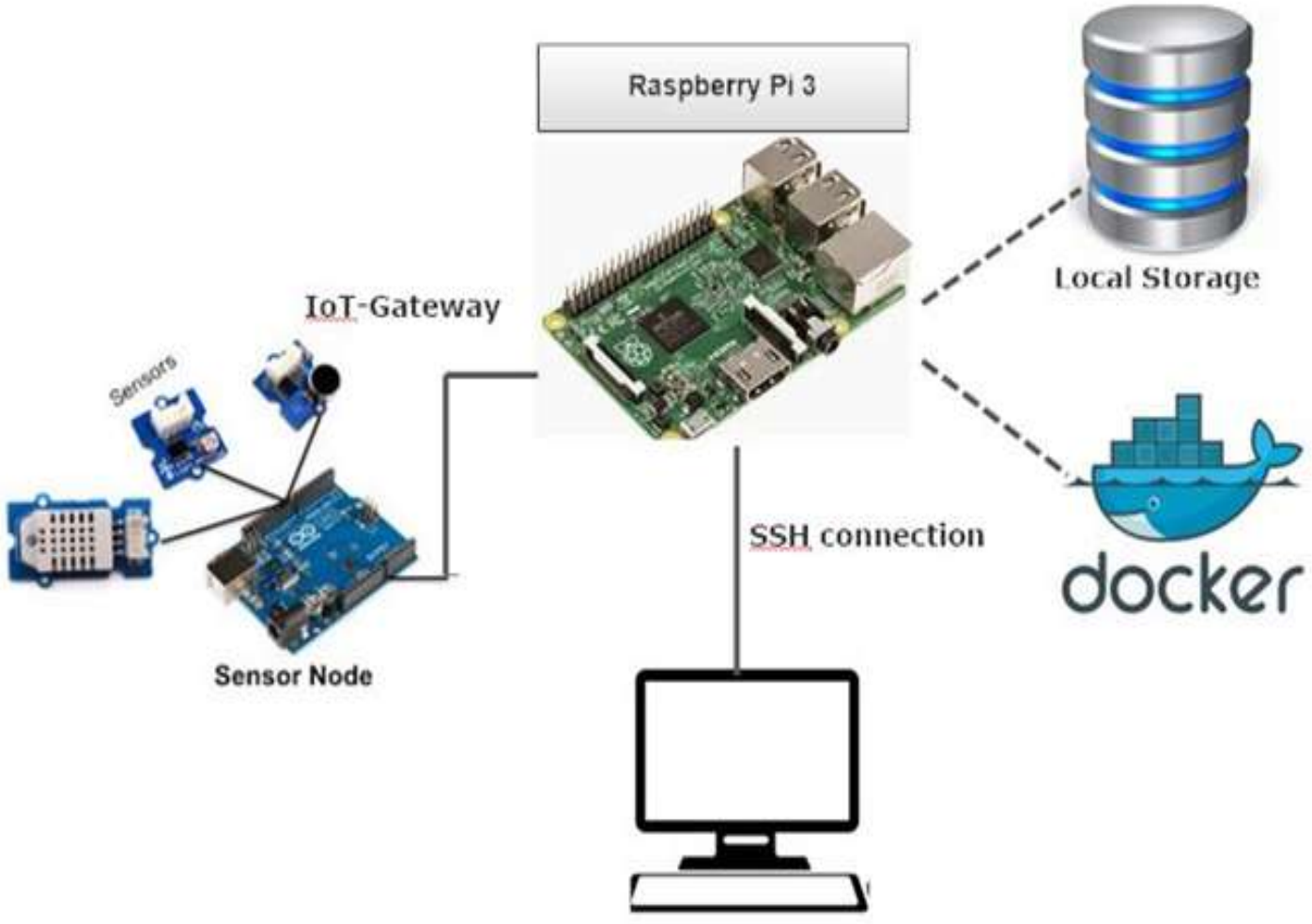

Fig 1. Equipment setup for experiment

Fig2 shows the flowchart of the experiment. The Raspberry pi is a good platform to connect devices and it is easy to install docker over pi, below are the steps followed for completingthe experiment.

Step1. Installation of Docker over Pi: As Linux, containers are built on x86 architecture and Pi uses ARM professor, so it will not work directly. It needs to be done manually compiled and for this software from an open source Hypriot is used for easy work on Pi [12].

Step2. Installation of GPIO access library: For this WiringPi is used which enable the access and setup of GPIO pins of RaspberryPi [13]. This library can be used for read, write and control the pins using scripts. After this connection between sensor nodes and the host is established with using appropriate IoT gateway.

Step3. Run an IoT application to collect/read the sensor data over the host.

Step4. Use of R for sensor data analysis.

Step5. Generate a Dockerfile which holds the layers of all the required software and library packages.

Step6. Build a docker image fromDockerfile. Docker tells host os to run docker program which will create a container and runs over the host.

Step7. Run the IoT application inside the container and analyze the data. While running this application measure the performance of CPU, Memory and Disk I/O performance over the host and inside docker. Run another container to analyze the load balance of web service.

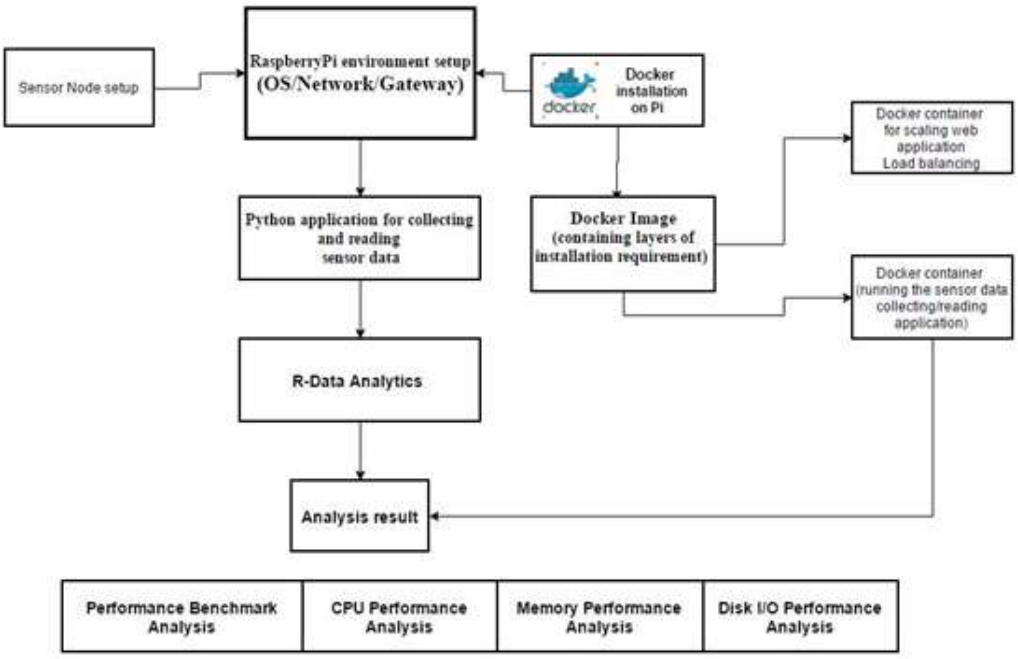

Fig2. Flowchart of the experiment

Performance Measurement: The main goal of this experiment is to evaluate docker for IoT application environment, and for this, some benchmark tools are used [8]. Table 2 shows the result of the benchmark, the results are average over 5 times run.

CPU. To test CPU performance sysbench tool is used the result shown in the table is the difference between the host case and docker case, the container engine introduce a little impact on the CPU performance [15].

Memory I/O. To test memory performance mbw tool is used [14],which determines the available memory bandwidth by copying alarge array of data in memory and provide better configurability by performing three different test(memcpy, dumb, mcblock). The average compared result is shown in the table.

Disk I/O. To evaluate Disk I/O sysbench tool is used [15]. This benchmark is used to get system's I/O performance. This benchmark creates a random file larger than RAM and RUN over the system.

Table 2: Benchmark result on host and Docker

CPU Benchmark			
	total time(sec)		execution time (sec)
Host	5.5831		5.5796
Docker	2.9436		2.9385
MEMORY Benchmark (Average speed (MiB/sec))			
memcpy		dumb	mcblock
Host	1035.0826	1235.0402	1682.8682
Docker	1021.812	1233.7074	1680.1522
DISK IO Benchmark (operation performed in KB)			
	read	write	total transferred time (KB/sec)
Host	960 KB	640 KB	43.9425
Docker	960KB	640KB	33.1966

5. CONCLUSION AND FUTURE WORK

The objective of this paper was to analyse and evaluate, whether container technology satisfies the requirement for IoT application. The successful development and run of IoT application were performed inside docker container. The result of benchmark tools for performance measurement comparison between host and docker shows the positive impact of using the container. My future work is to more explore docker for IoT real time application like cluster scheduling and real-time decision making for IoT applications.

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