Investigating Operational Costs of IoT Cloud Applications

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Abstract. With the appearance of things of the Internet of Things (IoT) area, IoT Cloud systems have been formed that are supported by cloud technologies, but still needs a significant amount of research. Data users produce with IoT devices are continuously posted to online services, which require the use of cloud providers to efficiently handle, and meaningfully visualize these data. In this paper we analyze the pricing schemes of four corresponding providers, and perform usage cost calculations for a concrete IoT scenario to help users to better understand their operation. We also compare these IoT Cloud providers by estimating service costs for operating an application of a smart city use case. We also validate our cost estimation by simulating the smart city scenario in the IBM Bluemix Platform.

Keywords: Cloud computing · Internet of Things · Cost estimation

1 Introduction

The Cluster of European Research Projects on the Internet of Things [1] defined the Internet of Things (IoT) as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols. Things in this network interact and communicate among themselves and with the environment by exchanging data and information sensed, and react autonomously to events and influence them by triggering actions with or without direct human intervention. Recent trends and estimations call for an ecosystem that provides means to interconnect and control these devices. With the help of cloud solutions, user data can be stored in a remote location, and can be accessed from anywhere. There are more and more PaaS cloud providers offering IoT specific services (e.g. Amazon AWS IoT Platform, Azure IoT Suite). Some of these IoT features are unique, but every PaaS provider addressing IoT has the basic capability to connect to and store data from devices.

In this paper first we analyze the pricing schemes of four corresponding providers: the Microsoft Azure IoT Hub, the IBM Bluemix platform, the Amazon AWS IoT and the Oracle's IoT platform. We compare their pricing methods, and perform cost-efficient calculations for a concrete IoT application of a smart city use case to help users to better understand their operation. We also compare

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these selected IoT Cloud providers by estimating service costs for operating an application of a smart city use case. We also validate our cost estimation by simulating the smart city scenario in the IBM Bluemix Platform.

The remainder of this paper is as follows: Sect. 2 introduces related approaches in the field of IoT Clouds. Section 3 presents the pricing schemes of four providers, and Section Sect. 4 details our method to estimate resource usage costs and its results. Section 5 presents real cost usage validations for a concrete provider, and the contributions are summarized in Sect. 6.

2 Related Works

The integration of IoT and clouds has been envisioned by Botta et al. [2] by summarizing their main properties, features, underlying technologies, and open issues. A solution for merging IoT and clouds is proposed by Nastic et al. [3]. They argue that system designers and operations managers face numerous challenges to realize IoT Cloud systems in practice, due to the complexity and diversity of their requirements in terms of IoT resources consumption, customization and runtime governance. They propose a novel approach to IoT Cloud that encapsulates fine-grained IoT resources and capabilities in well-defined APIs in order to provide a unified view on accessing, configuring and operating IoT Cloud systems, and demonstrate the framework for managing electric fleet vehicles.

Atzori et al. [4] examined IoT systems in a survey. They identified many application scenarios, and classified them to five application domains: transportation and logistics, healthcare, smart environments (home, office, plant), personal and social, finally futuristic domains. They described these domains in detail, and defined open issues and challenges to all of them. Concerning privacy, they stated that a lot of information about a person can be collected without the person being aware, and control on all such information is impossible with current techniques.

Based on these works we selected the smart city environment to investigate further, and to provide operational cost estimations at different providers. The following section define our model of cost calculations based on publicly available pricing information.

3 Calculating IoT Cloud Operation Costs of Four Providers

In this section, we introduce and compare pricing models of IoT Cloud providers. We considered the following, most popular providers: (i) Microsoft and its IoT platform called Azure IoT Hub [5], (ii) IBM's Bluemix IoT platform [7], the services of (iii) Amazon (AWS IoT) [9], and (iv) Oracle's IoT platform [8]. We took into account the prices publicly available on the websites of the providers and when we found it necessary we asked for further information or clarifications via email from the providers. The calculation of the prices depends on different

methods. Some providers bill only according to the number of messages sent, while others also charge for the number of devices used. The situation is very similar if we consider the virtual machine renting or application service prices. One can be charged after GigaByte-hour (GB-hour) (uptime) or according to a fix monthly service price. This price also depends on the configuration of the virtual machine or the selected application service, especially the mount of RAM used or the number of CPU cores or their clock signal.

	MS Azure IoT	IBM Bluemix IoT	Amazon IoT	Oracle IoT
IoT fix prices and device side				
Pay as you go	+	+	+	+
Extras at start	+	+	+	-
In tiers	+	-	-	+
Device price / month	-	-	-	+
"Price / message" pricing	-	-	+	-
"X messages / month" pricing (tears)	+	-	-	+
Data exchanged (in MegaBytes)	-	+	-	-
Message size limit	+	-	+	-
Cloud side				
Instance price (VM, App/Compute service)	+	+	-	+
GB-hour price	-	+	+	(+)

Fig. 1. Pricing information of the considered providers

In our model we consider a real world smart city use case for cost estimations with following parameters: total number of sent messages in a certain period of time, the number of devices used, and the capacity of the virtual machine used to provide gateway services. We estimated how our application would be charged after a whole month of uptime running in the cloud of the providers mentioned before. In our model, the total cost of executing an application consists of two price categories: (1) IoT and device prices and (2) cloud side prices. In case (1), we may be charged after the tier (a package) used or only after the resources used. The latter is also called "pay as you go" billing method, it means that we only pay for what we really use. At some particular providers, we need to pay for both of these two methods. Moreover, there are message prices as well. If we pay for a tier (if it is possible at the particular provider) then the price of a message is not so important because the tier includes prices of a fix number of messages. However, the price of the tier depends on the number of messages we want to send; more messages are covered by bigger tiers. If we use a provider with a "pay as you go" category, then the price of a message becomes more important. In some cases, we are charged after data exchanged not the number of messages sent but the data used can also be covered by a tier. Finally, it may occur that we need to pay for the number of devices used. To run an IoT application we also need to pay for a virtual machine or application/compute service or runtime to operate a gateway service – covered by case (2). There can be a fix monthly price for a service but GB-hour price can be charged as well. In

our investigation, we considered the most popular cloud providers, the pricing categories and their availability at different providers are depicted in Fig. 1. Our investigation estimates prices for executing the smart city application for traffic light control to compare the pricing methodology of the providers.

Azure IoT Hub [5] charges one after the chosen edition/tier. Figure 2 details the available Tiers and also shows the size restriction for messages. This means that there are intervals for the number of messages used in a month. Azure also comes with some extras when we start to use its services, as well as some of the providers do so, but we do not take extras into consideration because we investigate general situations. There is a restriction for message sizes which depends on the chosen tiers. One can choose from four tiers, Free, S1, S2, S3. Each of them vary in price and the total messages allowed per day. Message size of the Free tier also differs from the other tiers. In the Free edition, devices can only send a lot smaller messages than in the other editions. Regarding to the cloud side prices we need to count with an application service price and there is no GB-hour price because the service is in full uptime. We have the opportunity to choose from a wide variety of configurations, selecting the number of processor cores, RAM used and storage capacity, affecting the price of the application service.

Tier	Tier price / month (€)	Total messages / day	Message size / unit (KB)
Free	0	8 000	0.5
S1	42.17	400 000	4
S2	421.65	6 000 000	4
S3	4215.5	300 000 000	4

Fig. 2. Tier prices of MS Azure

As depicted in Fig. 3, the IBM Bluemix IoT platform's pricing method follows completely the "pay as you go" method, and it can be read in Bluemix's pricing sheet under the Internet of Things section and at Internet of Things platform [7]. Bluemix only charges after the MegaBytes (MB) exchanged. We differentiate three categories and each of them comes with a different price per MB. There are three categories for the data used in MegaBytes and each category has its own price per the MBs exchanged. The more MBs we use and thus select a bigger category, the less price per MB we get. Working with Bluemix we need to pay for the runtime as well to run our applications. It is configurable, depends on the number of instances and the RAM used, and has a fix monthly price. On the top of that, we will be charged for GB-hour price, too.

Amazon's IoT platform can also be classified as a "pay as you go" service. Its billing method [9] works out incredibly easily. Prices are based on publishing cost (the number of messages published to AWS IoT) and delivery cost (the number of messages delivered by AWS IoT to devices or applications). A message is a 512-byte block of data and the pricing in EU and US regions denotes $5 per

million messages. In addition, there is no charge for deliveries to some other AWS Services. So, there is only price per message billing which can be affected by the size of messages because there is a limit for message size. Using Amazon's IoT solution we also need a virtual machine for the gateway service. We can choose from a wide range of virtual machine configuration affecting its price and GB-hour price will be charged as well. In our calculations 1 USD converts to 0.914039185 €.

From (MB)	-	To (MB)	Price / MB
1	-	499 999	0.00097
450 000	-	6 999 999	0.00068
7 000 000	-		0.00014

Fig. 3. Pricing for data exchange in IBM Bluemix

Finally, we investigated how prices can be calculated at Oracle's IoT solution. Its pricing can be seen in Fig. 4. The pricing method is slightly different from the three providers described before. We can say that its rather similar to Azure's tiers than a completely "pay as you go" billing like in Bluemix. The information was gathered from [8] and we calculated with the so-called Metered Services. There are four product type categories regarding the used devices (wearable, consumer, telematic, commercial/industrial). Each category type has a price per used device type. The four device/product type category determine the monthly device price and the number of messages that can be sent by that particular type of device. In addition, there is a restriction on how many messages can a particular type of device deliver per month. In case, the number of messages sent by a device is more than the device's category permits, an additional price will be charged according to a predefined price per thousand of messages. Concerning the cloud side, in Oracle we should also pay for a compute service and daily uptime of our application. The number of CPU cores also affect the price of this service.

Product type	Device price / month (€)	Messages / Month / Device
Wearable	0.46015	1 500
Consumer	0.93	15 000
Telematic	2.32	100 000
Commercial / Industrial	3.47	100 000
Additional messages	0.02344	1 000

Fig. 4. Device pricing in Oracle

Concerning cloud-based cost requirements of our smart city use case, we estimated that about 2–4 GBs of RAM and 2 CPU cores could run our application smoothly. We also collected pricing information for these cloud gateway services from the providers' official sites. The pricing of Azure's application service can be found at [10], Bluemix's runtime is in its pricing sheet under the Runtimes section [7], Amazon EC2 On-Demand prices are described at [11] and we can find the pricing of Oracle's compute service at [12]. We used the prices of the Metered Services. By clicking on the Buy Now button next to Metered Services sign we can navigate to a detailed pricing calculator [13].

Scenario II	MS Azure IoT	IBM Bluemix IoT	Amazon IoT	Oracle IoT
VM / Service / Engine / Runtime	app service	runtime	VM (US East) linux	compute service
Instances	1	1	1	1
Category name	Basic B2	Liberty for Java	EC2 t2.medium	compute service
RAM (GB)	3.5	3.5	4	?
CPU Cores	2	?	2	2
GB-hour price	0	0.0526	0.0475300376	+
Fix price	**94.11**	**112.83**	**0**	**139**

Fig. 5. Virtual machine related configuration and prices for our use case

In Fig. 5 we can see the detailed cloud-side parameters. We decided to take 3.5 GBs of RAM for this scenario in the case of Azure and Bluemix, and 4 for the virtual machine at Amazon. For Oracle we could not manage to find out the exact amount of RAM used by the compute service, it is probably 7.5 GBs as defined for the provided OCPU. The number of CPU cores of Bluemix's runtime is not clear (denoted by "?"). GB-hour price is used by Bluemix and Amazon but Azure does not charge for GB-hour. The price of the compute service used for Oracle IoT is also affected by the uptime, we illustrate this with the "+" sign in the column of Oracle. Amazon is the cheapest in the cloud-side, and Oracle is the most expensive.

4 Estimating Operational Costs for a Traffic Light System Use Case of a Smart City

To perform our cost estimation we chose a use case of a traffic light control system in a smart city. This scenario represents a relatively large system, its detailed information concerning a monthly operation period is depicted in Table 1. We use 128 devices referring to a study and implementation of a smart city in Messina [14]. We perform the estimation for running the application for a whole month (744 h mean 31 days). We worked with message sizes up to a maximum of 0.05 KiloBytes (KB). Devices send messages in every 20 s which means 180 messages in an hour. From the previously mentioned value we can assume that

Table 1. Basic configuration information

Devices	128
Device type	Telematic
Message size	0.05
Messages/month/device	133920
Total messages/day	552960
Total messages/month	17141760
MB exchanged/month	837
Messages transferred/device/hour	180
Test duration (days)	31
Full uptime (hours)	744

to get the total number of messages per device for the whole month we need to determine the messages sent by a device during a day (180 * 24) and then multiply it by the number of days (31) while we run this scenario resulting in 133920 messages per month per device. The total messages per day is counted by the number of the messages sent by a device during a day (180 * 24) multiplied by the number of devices (128), so the result is 552960. Furthermore, we can count out the total messages per month including all the devices by just easily multiply the number of devices by the number of messages per month per device which means 128 * 133920 = 17141760. We can estimate the exchanged Megabytes if we multiply the number of total messages per month by the message size given in KBs so we then divide with 1024 and then we get the result of 837 MBs.

Our estimated calculations are shown in Table 2. In our investigation Azure seemed to be really expensive compared to the other providers. Bluemix and Amazon cost less than a half of the price of Azure, and Oracle is just a little cheaper than Azure.

Table 2. Cost estimation for the smart city use case

Provider/Cost	Azure	Cost	Bluemix	Cost	Amazon	Cost	Oracle	Cost
IoT fix prices and device side								
Device price/month	–		–		–		+	296.96
"Price/message" pricing	–		–		+	78.19	+	
"X messages/month" pricing	+	421.65	–		–		+	0.79
Data exchange (in MegaBytes)	–		+	0.81	–		–	
Message size limit	4		–		0.512		–	
Total messages/day with size limit	552960				552960			
Cloud side								
Instance prices	+	94.11	+	112.83	–		+	139
GB-hour prices	–		0.0526	39.134	0.04	35.36	(+)	
TOTAL PRICE/MONTH		515.76		152.77		113.55		436.75

5 Validating the Cost Estimations with IBM Bluemix

As the next step, we performed experimental measurement of the defined IoT scenarios to confirm our former investigation. To accomplish this goal, we used IBM's Bluemix IoT Platform [6]. After registration for Bluemix, we created a Cloud Foundary Application runtime for a Node.JS application with 1 GB RAM and 1 instance. We also needed an IoT Service to handle the messages between the application and the devices; it lets our application communicate with and consume data collected by our connected devices, sensors and gateways. Finally, we created a device-side program to connect to the IoT service. We developed special scripts to simulate the 128 devices and their messages sent in every 20 s, with the message size of 0.053 KBs. A sample message we used is the following:

{"d":{"id":"1uz6","s":"1","t":"2016-12-01 09:00:00"}}

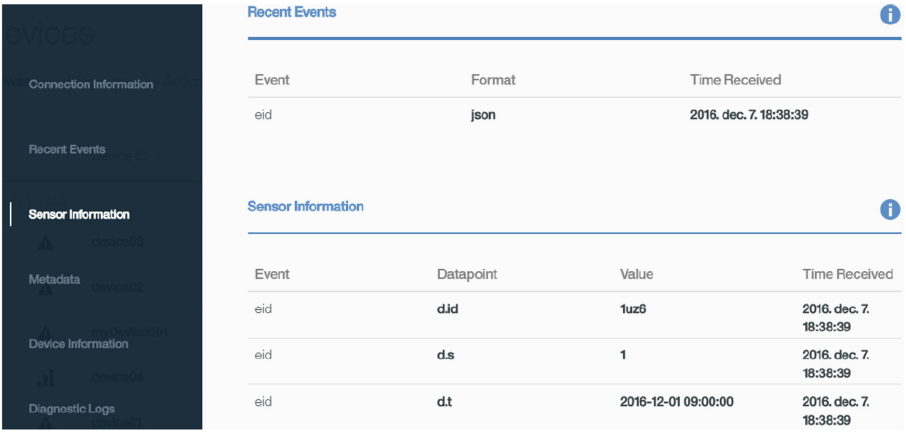

Fig. 6. Live event log of Bluemix devices

Bluemix provides a live event log for devices where we can trace the actual incoming messages from them. Figure 6 shows an example event log for a message received. In our simulated case, each device sends 180 messages in an hour to the IoT gateway service. The data usage of 180 messages was 61.44 KBs according to the Bluemix metering. This means that 0.3412 KB (i.e. 61.44/180) was logged by Bluemix for a message in contrast to the originally created text file with size of 0.053 KB. From this point, we can count that using 128 devices we have 17141760 messages for the whole month. We can calculate the total data exchanged by multiplying the number of the total messages with the size of one message which gives 5711.688 MBs. This is significantly larger than the estimated amount because of the additional information added to messages by Bluemix (that we found out later). Bluemix charges up 0.00097€ for each MB exchanged, so it means 5.54€ after that nearly 6 thousand MBs exchanged. This price is also larger than the estimated one (∼0.81€) as well as the amount

of data exchanged. The cloud side prices are the same as we estimated. The conclusion is that we need to pay some more Euros than estimated due to the larger message size the Bluemix system introduces, otherwise our prior calculations were right.

6 Conclusions

Data users produce with IoT devices are continuously posted to online services, which require the use of cloud providers to efficiently handle, and meaningfully visualize these data. Users also need to be aware of corresponding cost introduced by service providers, which can be very diverse.

In this work, we investigated pricing schemes of four popular IoT Cloud providers to help users to better understand their operation. We also performed usage cost calculations for a concrete IoT use case of a smart city, and compared them by estimating service costs for operating this application. Finally, we validated our cost estimation by simulating the smart city scenario in the IBM Bluemix Platform.

In general, we can conclude that Bluemix and Amazon is the cheapest due to the cheap message prices of Bluemix and the cheap virtual machine-related prices in case of Amazon. If we want to use a large number of devices, Oracle should be avoided, because of its expensive device prices. Nevertheless, for small systems Azure can be a good choice.

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References

1. Sundmaeker, H., Guillemin, P., Friess, P., Woelffle, S.: Vision, challenges for realising the Internet of Things. CERP IoT - Cluster of European Research Projects on the Internet of Things, CN: KK-31-10-323-EN-C, March 2010
2. Botta, A., de Donato, W., Persico, V., Pescape, A.: On the integration of cloud computing and Internet of Things. In: The 2nd International Conference on Future Internet of Things and Cloud (FiCloud-2014), August 2014
3. Nastic, S., Sehic, S., Le, D., Truong, H., Dustdar, S.: Provisioning software-defined IoT cloud systems. In: The 2nd International Conference on Future Internet of Things and Cloud (FiCloud-2014), August 2014
4. Atzori, L., Iera, A., Morabito, G.: The Internet of Things: a survey. Comput. Netw. **54**(15), 2787–2805 (2010)
5. Pricing of Microsoft Azure IoT Hub, December 2016. https://azure.microsoft.com/en-gb/pricing/details/iot-hub/
6. IBM Bluemix IoT Platform, December 2016. https://www.ibm.com/cloud-computing/bluemix/internet-of-things
7. Pricing of IBM Bluemix IoT Platform, December 2016. https://console.ng.bluemix.net/?direct=classic/#/pricing/cloudOEPaneId=pricing&paneId=pricingSheet

8. Pricing of Oracle's IoT Platform, December 2016. https://cloud.oracle.com/en_US/opc/iot/pricing
9. Pricing of Amazon IoT, December 2016. https://aws.amazon.com/iot/pricing/
10. Pricing Calculator of Microsoft Azure, December 2016. https://azure.microsoft.com/en-gb/pricing/calculator/
11. Pricing of Amazon EC2 Instance, December 2016. https://aws.amazon.com/ec2/pricing/on-demand/
12. Pricing of Oracle's Compute Service, December 2016. https://cloud.oracle.com/en_US/opc/compute/compute/pricing
13. Pricing Calculator of Oracle's Compute Service, December 2016. https://shop.oracle.com/cloudstore/index.html?product=compute
14. Smart city of Messina, December 2016. http://smartme.unime.it/