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IOT RESOURCES MANAGEMENT: A COMPREHENSIVE STUDY SUPPORTED BY THE TOP PROVIDERS OF THINGS MANAGEMENT

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ABSTRACT

Internet of Things (IoT) became an essential tool nowadays in every practical or scientific field. IoT connects intelligently fixed or mobile devices, moving objects or even animals in one network. These devices may need physical resources or services over the cloud. IoT defined as a network that connects physical objects to interact with each other for to perform information sharing and to take an action. IoT offers services as well. Connected objects over IoT are identified by unique address on the network and supported with the ability to transfer data over a network without human or computer interaction. IoT has wide and growing scope of applications starts from smart home passing all the way to smart city, smart grids, intelligent fire-fighting, government, environment ending with smart farming. In this paper, a comprehensive study is done for resources management process done by researchers with a detailed explanation for IoT top providers like IBM Watson, Google and Amazon platforms. The study encompasses IoT things management for these three providers then concluded that the three providers have different design principles, algorithm modeling, data location requirements and type of services. However, they have almost the same pricing per service.

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INTRODUCTION

Internet of Things (IoT) became an essential tool nowadays in every practical or scientific field. A better definition to IoT is the networking system that is connecting fixed or mobile devices computing machines, moving objects, people or even animals (Atzori, Iera., and Morabito, 2010) (Matter and Floerkemeier, 2010). These connected objects identified by unique address on the network and supported with the ability to transfer data over a network without human or computer interaction (Libelium Distribuidas, 2014). IoT has wide and growing scope of applications starts from smart home passing all the way to smart city, smart grids, intelligent firefighting, government, and environment ending with smart farming (López, Brintrup, Isenberg Ma and Mansfeld, 2011).
Good literature can be found on IoT in divert fields, however our main concentration is on the part of IoT resource management.

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In (Yan, Sheng and He, 2011), authors tried to solve the complexity that is facing resource management by proposing new layer to share the resources among various numbers of users while they are using heterogeneous systems. In (Anuj, Perelman, Kuryla, and Schönwälder, 2012), the authors stand on the limitations of the hardware Rosh Hashanah that may be used as IoT resources, so they developed a new environment to implement SNMP and NETCONF management protocols considering their security mechanisms as well. In (Chen, Liang and Chen, 2014), authors worked on minimizing the total energy consumption for the uplink and power resources used in the IoT networks while maintaining high QoS. The authors solved the problem by presuming that the problem is an NP-complete problem rank and developed and energy conserving with power allocation method to the IoT resources. In (Takalo, Kiljander, Pramudianto and Ferrera, 2014), authors tried to solve the problem of IoT resources access, which is shared by different application with different complexity, level each. Authors developed resource management architecture with system level and local level. The system level took care of allocating resources according to their critical privilege and based on the need as well.

However, the local level assigned a local manager device to grant the resources using a careful schedule which is not affecting the critical applications. As a result, the performance of the critical applications will be optimized well. In (Kliem and Kao, 2015), authors solved resources management challenges by applying the cloud computing concepts into IoT domain. The idea was to provide a cloud device to allocate the resources to the users based on their demand. The prosed device or model consists of three components. Data End Point (DEP), Data Integrated Point (DIP) and Machine Communication Network (MCN) are the three components for the proposed model. Authors concluded that the model had mitigated the problem of static assignment to the resources between user and physical deceives and meet user's requirement. In (Caglar, Shekhar, Gokhale and Koutsoukos, 2016), authors tried to solve IoT resource management challenge by designing an intelligent middleware interface called iSensitive using backpropagation neural network. The proposed interface works based on virtual machines historic usage. The virtual machines those are considered in iSensitive interface are CPU, memory, and network features. The paradigm encompasses two steps; the first step works in an offline mode and it's mainly dedicated to pick out the workload pattern for clustering decision and key insights into performance interference caused due to VM collocation. The second step is to find the most suitable host machine to minimize the degradation effect in loud-hosted IoT applications. In (Kanti and Bonnet, 2016), authors tried to integrate Named Data Networking (NDN) in to IoT architecture.

The authors stand on the advantages of using NDN in IoT by explaining the full utilization of NDN mechanism for distributing high level knowledge derived from raw sensor data to the interested consumers through operational phases of the architecture. In (Margelis, Piechocki, Kaleshi and Thomas, 2015), authors focused on LoraWan, Sigfox and OnRamp wireless new emerging technologies. LoRaWan which provides a technology that lets other companies enable a global Internet of Things, while Sigfox is considered as the global Internet of Things operator, however, OnRamp which is systems provider for low-power wide area scalable sensor networking and location tracking. Authors novel work was by initiating the study to LoraWan, Sigfox and OnRamp technologies. Moreover, authors mainly focused on Low Throughput Network (LTN) in terms of comparing them to CDMA and stands on the trademarks for using the two models. Finally, they discussed some attacking vulnerabilities to these models. In (Renner, Medau and Kliem, 2016), authors tried to manage IoT resources and the increasingly traffic problem by creating a container-based resource allocation scheme for the connected and embedded IoT devices. Authors made advantage of the virtual level of the underlying Operating Systems virtualization level. The reason behind using OS virtualization level is the less overhead when compared to user level paradigm. Authors used Docker because it's an open-source program that enables a Linux application and its dependencies to be packaged as a container. Using Docker supported the authors work as it provided good segregation between user code and the dynamic allocation for the resources that is offered for the smart devices those are working under IoT environment. In (Xiong, Hou, Zheng, Hossain, and Rahman, 2016), authors tried to combine Software Defined Network (SDN) with IoT in order to solve the IoT resources management problem. Authors proposed and SDN based on Third Generation Partnership Project (3GPP) architecture for the Machine Type Communication (MTC). Then they codified the radio resource allocation for the SDN as Semi-Markov Decision Process (SMDP). SMDP is promising because it provides mathematical modeling forms and its method in optimization problem. Authors showed results of improving in the resource allocating and management problems as a comparison to the other techniques. In (Zhengguo, Hao, Changchuan, Xiping, Shusen, and Victor, 2015), authors tried to overcome resource management problem by developing a web service to manage devices in the wireless sensor devices. Authors achieved the final results by designing an open platform gateway and implemented it in IPV6 then they designed a framework to manage devices for the proposed platform. Results showed an improvement in packet length and loss rate.

In (Rao, Chendanda, Deshpande and Lakkundi, 2015), authors worked on improving Light Weight Machine to Machine (LWMTM) constrained devices on Open Mobile Alliance (OMA) at the client side IoT. Authors defined the protocol stack for the LWMTM devices and deployed the design on real world application scenarios to come out with a result on the memory overhead not more than 6-9%. In (Ghodsi, Matei, Hindman, Konwinski, Shenker, Stoica, 2011), authors worked on fair allocation of multiple resources. The authors worked on Dominant Resource Fairness (DRF) algorithm. Authors showed that DRF is one of the best mechanisms to manage resources over edge cloud. DRF features ensures that all resources shared fairly between users with better throughput.

IoT Architecture

Figure (1) shows IOT architecture, the general architecture includes 4 layers. Theas layers are, Application, Management service, Gateway and network and sensors connectivity and network layers respectively. Application layer provide services and determines a set of protocols for message passing at the application level in different sectors like retail, healthcare, transportation and supply chain. Management service layer function is to capture the sensor data in addition to analyzing it by extracting the proper information from the huge amount of data insuring data privacy and security. Gateway and network layer function is to support communication requirements including latency, bandwidth and security. Sensor layer is the bottom layer that handles interfacing between physical and digital components in addition to collect with processing real time information (Pipara, July 2014).

IoT Resources

Connecting things in IoT makes it more valuable, automated and efficient. The other issues are how we are building the network to find customer solutions and finally how multiple industries use the same data by building large platform. IOT service providers should follow certain steps starting from developing scalable platform then passing all the way through select platform, define a partnership, decide when to partner by purchasing or producing services, then provide security along with privacy, apps, analytics and underlying big data capabilities. Finally influence their supplier relationships to deliver on a joint go to market where supplier and service provider have common customers (Cisco, 2015).

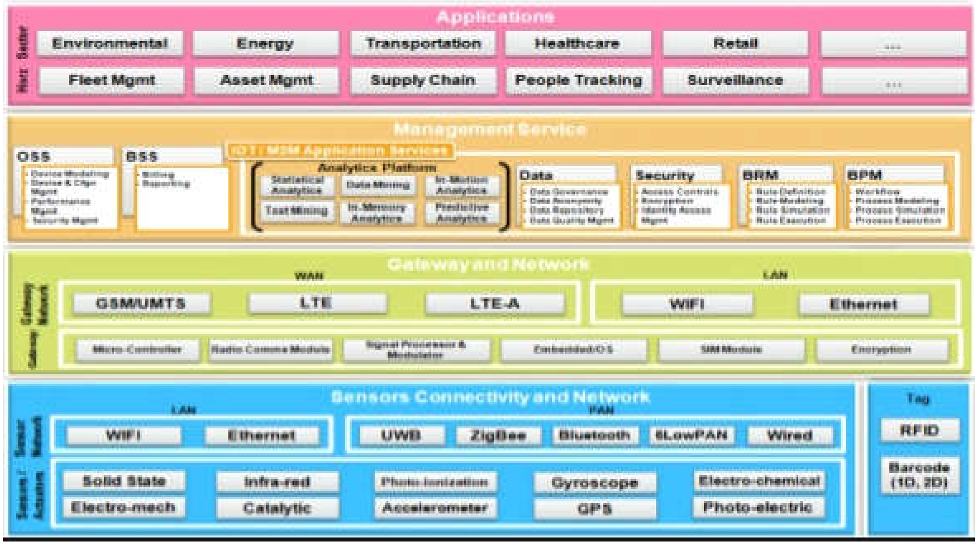

Figure 1. IoT Architecture

Table 1. a comparison of Amazon, Google and IBM Watson Platforms

	Amazon	Google	IBM Watson
Description	Deploys machine learning algorithms on the data stored in Amazon Web Services platform	Applies state of art industry algorithms. Industry leading applications and state-of-art algorithms.	Model production through REST (Representation State Transfer) API connectors.
Interface	Amazon Machine Learning CONSOL and Amazon Command Line Interface	Command Line Interface using gcloud ml-engine to control tensor Flow process	IBM graphical analysis software can be used as a front end. API connectors enable users to build models in third party data science applications
Algorithms and modeling methods	Users are able to bring their data to prebuilt algorithms including: Regression Binary classification Multiclass classification	User can build their own models from scratch or use retrained models supporting these applications: Video analysis Speech analysis Text analysis Translation	Users can build their own algorithms in any language through REST API. Links Apache Sparks MLib library of machine learning algorithms planned via IBM data science experience workbench platform.
Atomic algorithm suggestion	Yes	Yes	No
Data location requirements	Data must be stored in AWS store before using	Data must be stored in google cloud storage	Data must be stored in IBM Bluemix.
Pricing	For data analysis and model building:$0.42	For model training $.0.49 in the U.S. and $.54 in Europe and Asia	$10.00 per service instant (running 20 models)

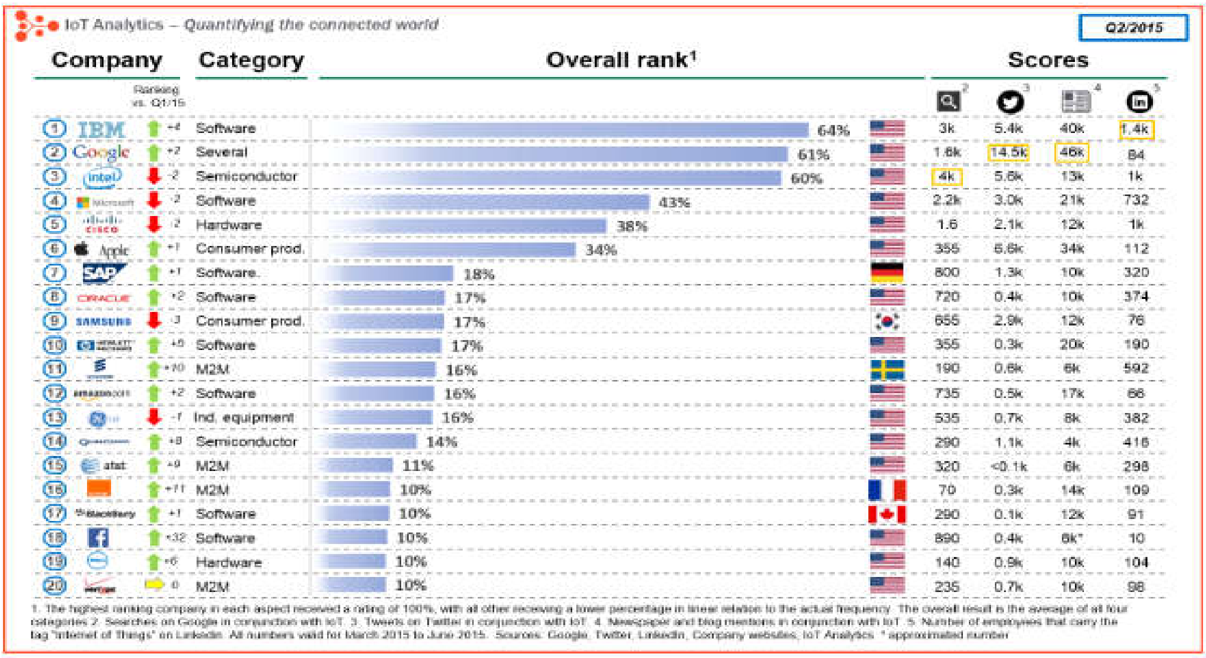

Figure 2. Top Twenty IoT Providers

IoT Top Providers

In this section, an explanation to the top IoT providers for the latest world classification. Figure (2) shows top twenty IoT providers over the world. This section explains IoT platform for IBM Watson, Google as the top two providers and Amazon as the most popular IoT providers (Lasse, 2015). The literature showed that two significant companies are taking different approaches, which obviously leaded to different business. IBM for example targeted health care and facilitated the technology for others while google opened source its technology. IBM and Google are strengthen their systems and competing now higher expansion. Of course, the future competition will be on getting customers. Amazon also took significant fast steps toward IoT grow and table (1) shows comparison among these three venders ((Lasse, 2015).

IBM Watson IoT Platform

IBM has two issues that reader should know about it. IBM platform and edge cloud design.

IBM Watson IoT platform

Figure (3) shows IBM Watson platform. It includes the flowing sub-modules.

Connect: Connecting a device to Watson IoT Platform involves registering the device with Watson IoT Platform and then using the registration information to configure the device to connect to Watson IoT Platform. Before a user starts the connection process, he/she must ensure that the devices must be able to communicate using HTTP or MQTT protocols and the device messages must conform Watson IOT platform message payload requirements: Connect sub-platform performs attach, organize, device management, secure connectivity and visualization.

Information management: figure (4) shows how IBM platform manages data. This sub-platform performs storage and archive, metadata management, reporting, streaming data, parsing and transformation, manage unstructured data. Using management feature user doesn't need to write his/her application. The application receives the signal then normalize it then connect to a consistent property which is called temperature in this case.

Analysis: This part starts analyzing data quickly to monitor conditions. The analysis steps are predictive, cognitive, real time and contextual.

Figure 3: IBM Watson Platform

Risk management: This sub-platform visualizes critical risks and enables creation of policy-driven mitigation actions. It also provides security analysis, data protection, auditing/logging, firmware updates, key certification management and organizing specific security (Dave, 2016).

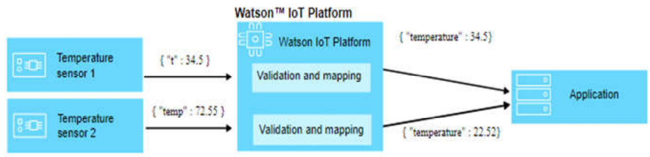

Figure 4. IBM Management Information Sub-Platform

IBM Watson Edge Cloud

Figures (5) shows IBM Watson IOT edge cloud. Edge cloud includes four sub-modules (Dave, 2016).

Ingest: the tool that is used to collect data to be processed online from the other submodules.

Profile: After collecting data that needs to be feed to the IOT devices, data may be sent to the profile sub-module to be converted into a form of PMQ (Predictive Maintenance and Quality).

Analyze: Analyzer sub module assists in realizing data value immediately then add the analysis to this data.

Report and recommend: This sub-module reports any error or mistake in the data.

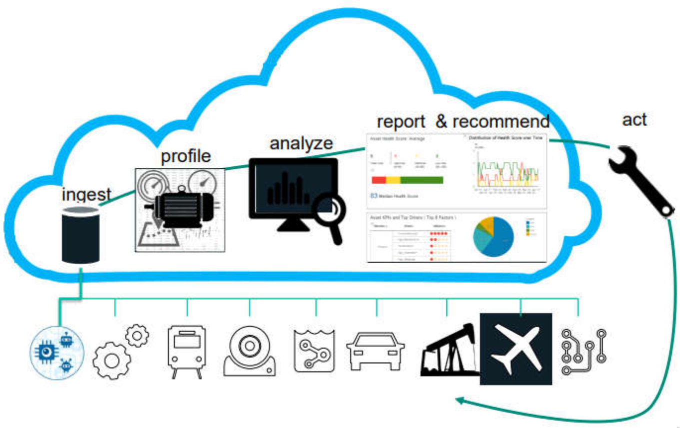

Figure 5. IBM Watson IoT edge cloud

Google IoT Platform

Figure (6) shows google cloud platform. Google connect millions of intelligent devices in its ITO platform. The devices those can be connected to google IOT are constrained devices that work on non-TCP protocol and the standard devices that works on HTTPS protocol. Below is a description for the google IOT platform (Google Cloud 2017).

Ingest

The role of ingest sub-module is to ship the information from device to cloud platform. Ingest can pass the information to either pipeline or analytics module according to the type of data (Google Cloud 2017).

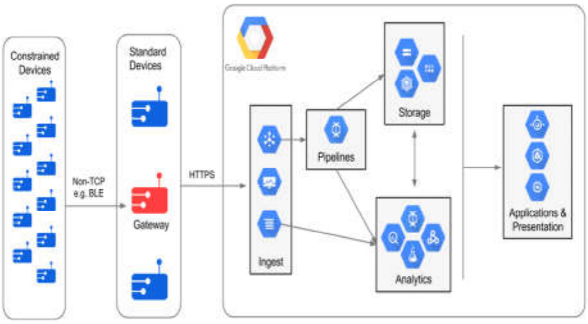

Figure 6. Google IoT Platform

Pipelines

Pipeline sub-module processes data on the cloud by applying four important steps similar to industry line. These steps are transform data, aggregate and compute data, enrich data and move data. Using transform data submodule converts data into another proper format, for example capturing the device signal to an image.

Aggregate and compute data module works by combining data to extract new data out of the aggregated data such as calculating average value across multiple devices. Computation allows data analytics even if it's in the pipeline process module. Enrich data submodule works on devices metadata as a subsequent analysis. However, move data submodule role is to store processed data into its final location (Google Cloud 2017).

Storage

Storage sub-module offers solutions to unstructured data such as images or videos to a structured storage completely (Google Cloud 2017).

Analytics

Analytics sub-module extract the information from the other raw data. Analysis can be on dataflow pipeline or over the accumulated data in various storage systems (Google Cloud 2017).

Applications and presentation

Applications sub-module offers different application, platforms with the maximum flexibility to user data (Google Cloud 2017).

Amazon

Amazon provides huge number of cloud service to customers over the world. Millions of customers are currently receiving amazon cloud products and solutions to build their own sophisticated applications with reliability, flexibility and scalability. The services in Amazon usually called Amazon Web Services (AWS). AWS according to Whatis.com" Amazon Web Services (AWS) is a comprehensive, evolving cloud computing platform provided by Amazon.com.

Web services are sometimes called cloud services or remote computing services" (Amazon AWS 2017). AWS offers compute power, database storage, content delivery and other functionality to help businesses scale and grow. Figure (6) shows AWS features. Some description to these features are provided below (Amazon AWS 2017).

AWS IoT Platform

AWS IoT Device SDK

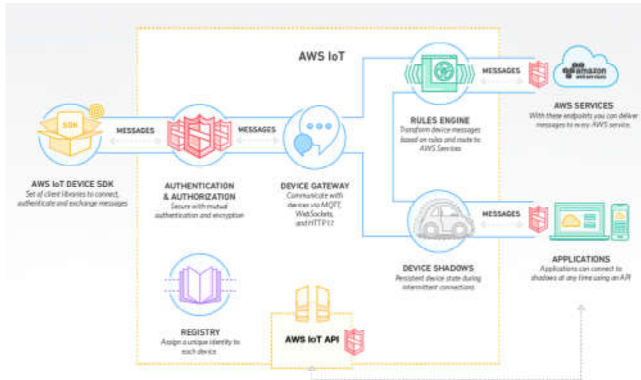

Figure 6. Amazon Web Services Infrastructure Design

Software Development Kit (SDK) under AWS is a connecting platform for the hardware or mobile applications. SDK provides authentication beside message exchanging (Amazon AWS 2017).

Device Gateway

Through gateway device, devices can communicate securely and efficiently. Gateway device can exchange messages using one-to-one and one-to-many communication models by unicasting or broadcasting respectively. It's worth to mention that gateway device supports over billion devices (Amazon AWS 2017).

Authentication and Authorization

To prove data identity, AWS provides both authentication and authorization in addition to encryption at all of the connection points. AWS uses X.509 and SigV4 protocols to secure the connection tunnels (Amazon AWS 2017).

Registry

AWS registry assigned unique identity to each device that is properly formatted regardless of the device type. Registry established device identity to track devices metadata like attributes and capabilities (Amazon AWS 2017).

Device Shadows

AWS device shadow or virtual version can store the device latest state in order to let other devices interact with it. Device shadow keeps record of each device current state and the future state even if its offline. Device shadow uses API or rules engine to detect current or future device states (Amazon AWS 2017). The Device Shadows persist the last reported state and desired future state of each device even when the device is offline. You can retrieve the last reported state of a device or set a desired future state through the API or using the rules engine (Amazon AWS 2017).

Rules Engine

Rules engine process and analyses data after gathering it. The gathered data builds the rules engine and hence connecting devices generate the data and use it globally without the need to manage any infrastructure.

After evaluating published data by rules engine, AWS delivers them into another device or cloud service based on user defined business rules. It's worth to mention that a rule can take many actions in parallel and could be requested from one or many devices. Rules engine endpoints may include including AWS Lambda, Amazon Kinesis, Amazon S3, Amazon Machine Learning, Amazon DynamoDB, Amazon CloudWatch, and Amazon Elasticsearch Service with built-in Kibana integration. External endpoints can be reached using AWS Lambda, Amazon Kinesis, and Amazon Simple Notification Service (SNS). Finally, rules engine offers dozens of user functions that can be used to transfer user data and it is possible to create infinitely more via AWS Lambda (Amazon AWS 2017).

How amazon manage things with AWS

Things in AWS may represent a specific device or logical entity and it could be defined by a name. If the user wishes to take logical service, then he/she can reach AWS database directly. While if the thing is a physical device an airplane control panel or a sensor, then AWS should connect to the related device. Things information can be stored in a thing registry and the following example shows how a thing can be defined and stored.

```
{
  "version": 7,
  "thingName": "MyIphone",
  "defaultClientId": " MyIphone7s ",
  "thingTypeName": "Mobile",
  "attributes": {
    "model": "7s",
    "price": "800$"
  }
}
```

As shown above, things can be identified by name or attributes. AWS uses or Message Queuing Telemetry Transport (MQTT) protocol to collect devices data and communicate with servers. AWS do not force mapping between things registry name and its use but they recommend users to choose things name then use it as MQTT client ID for thing registry and thing shadow (Amazon AWS 2017).

Conclusion

Internet of Things (IoT) became an essential tool nowadays in every practical or scientific field. A better definition to IoT is the networking system that is connecting fixed or mobile devices computing machines, moving objects, people or even animals. These connected objects identified by unique address on the network and supported with the ability to transfer data over a network without human or computer interaction. IoT has wide growing scope of applications starts from smart home passing all the way to smart city, smart grids, intelligent firefighting, government, environment ending with smart farming. IoT offers services and resources and the paper gave a comprehensive study on many resources management schemes. However, this paper gives an elaborated study for the top three providers for different resources or things. These providers are Amazon AWS, IBW Watson and Google. The study encompasses IoT things management for these three providers then concluded that the three providers have different design principles, algorithm modeling, data location requirements and type of services. However, they have almost the same pricing per service. The study does not find high competition among these providers since they are working on different services and still building their strong platforms.

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