IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received October 13, 2017, accepted November 15, 2017, date of publication November 22, 2017,
date of current version February 28, 2018.

Digital Object Identifier 10.1109/ACCESS.2017.2776400

A Cloud-Based System for Improving Retention Marketing Loyalty Programs in Industry 4.0: A Study on Big Data Storage Implications

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This work was supported by Cloud for Europe Tender Project: Realization of a Research and Development Project (Pre-Commercial Procurement) on Cloud for Europe, Italy-Rome: Research and development services and related consultancy services under Grant 2014/S 241-424518.

ABSTRACT Nowadays, the growing global economy and demand for customized products are bringing the manufacturing industry from a sellers' market toward a buyers' market. In this context, the smart manufacturing enabled by Industry 4.0 is changing the whole production cycle of companies specialized on different kinds of products. On one hand, the advent of cloud computing and social media makes the customers' experience more and more inclusive, whereas on the other hand cyber-physical system technologies help industries to change in real time the cycle of production according to customers' needs. In this context, ''retention'' marketing strategies aimed not only at the acquisition of new customers but also at the profitability of existing ones allow industries to apply specific production strategies so as to maximize their revenues. This is possible by means of the analysis of various kinds of information coming from customers, products, purchases, and so on. In this paper, we focus on customer loyalty programs. In particular, we propose cloud-based software as a service architecture that store and analyses big data related to purchases and products' ranks in order to provide customers a list of recommended products. Experiments focus on a prototype of human to machine workflow for the pre-selection of customers deployed on both private and hybrid cloud scenarios.

INDEX TERMS Industry applications, product life cycle management, marketing and sales, clouds, data analysis.

I. INTRODUCTION

Nowadays, emerging technologies such as Internet of Things (IoT), Big Data Analytics, Artificial Intelligence, Advanced Robotics, and 3D printing are revolutionizing Industry 4.0 enabling a faster smart factory deployments globally. According to a recent market analysis, it is predicted that smart factories will deliver 500 billion dollars in value by 2022 [1].

Smart manufacturing involving interactions between humans, machines, and products is becoming a highly competitive area for market capitalization. Even though, smart manufacturing plays an important role in Industry 4.0, it faces many challenges including structural, operational, and managerial independence from shops and enterprise constituent systems, plug and play, self-adaptation, reliability, security, energy-awareness, high-level cross-layer integration and cooperation, event propagation and management, and industrial big data analysis.

In this context, the growing global economy and demand for customized products are bringing the manufacturing industry from a market of sellers to a market of buyers. In fact, smart manufacturing is changing the whole production cycle of industries specialized on different kinds of products. On one hand, the advent of social media makes the customers' experience more and more inclusive, whereas on the other hand Cyber-Physical System (CPS) technologies help industries to change, in real time, the cycle of production according to customers' needs and preferences.

This paper focuses on approach for improving one of the major retention marketing strategies, that is customer loyalty program. It is aimed not only at the acquisition of new customers but also at the profitability of existing ones. However, considering a multi-national company, a customer loyalty program raises two main challenges that are big data storage and analytics. In order to achieve such a goal we propose a Cloud-based Software as a Service (SaaS) architecture able to store and analyse raw big data (including customers, sales, and products information) in order to provide customers a list of potential recommended products that could be of interest so as to improve the profitability of existing customers. In particular, we focus on the big data storage issue considering an user-driven Human to Machine (H2M) workflow required to pre-select candidate customers destined to the loyalty program. Experiments performed by means of an event bus connected to a NoSQL database prove the goodness of our system considering both hybrid and private Cloud scenarios.

The rest of the paper is organized as follows. Section II presents background and related initiatives in Cloud computing and big data in the field of Industry 4.0. In Section III, we motivate our scientific work. A description of our Cloud-based SaaS system architecture for accomplish customer loyalty programs by means of the storage and analysis of big data related to products' purchases and ranks is provided in Section IV. Experiments specifically focused on a big data storage system based on MongoDB and deployed in both private and hybrid storage scenarios are discussed in Section V. Conclusion and lights to the future are summarized in Section VI.

II. BACKGROUND AND RELATED WORK

Industry 4.0 is a new trend that put together Cloud computing, Cyber Physical Systems (CPSs), Internet of Things (IoT), and big data analytics technologies in order to bring new opportunities in terms of the manufacturing automation and data exchange. Thanks to Industry 4.0 companies can produce new added-value products that can quickly reach the market for sale in various sectors [2]. Industry 4.0 is transforming companies and economy with a great impact in terms of design approaches in the areas of qualifications, leadership and demography-resistant work [3]. A strategical and operational approach for the implementation of industry 4.0, also discussing new opportunities, scenarios, and applications is discussed in [4]. The dynamics of Industry 4.0 revolution, also analyzing market, suppliers and customers as benchmark to identify current trends is discussed in [5]. In particular, the technical, economic, social and environmental elements of possible smart innovations are evaluated in terms of resource efficiency. The impact of Industry 4.0 digitalization and employment in manufacturing considering Italian companies is presented in [6], whereas, the application of advanced manufacturing technologies in industrial business-to-business contexts is discussed in [7]. The challenges of Product Lifecycle Management (PLM) in Industry 4.0 are discussed in [8]. The problem of Vendor lock-in considering sellers having different service interfaces is discussed in [9].

Up to now, apart from the aforementioned theoretical scientific works focusing on Industry 4.0, only a few concrete initiatives have been proposed so far. Regarding the application of Cloud computing strategies, a multi-cloud marketplace architecture leveraging various existing Cloud service level abstractions is presented. A real-time remote monitoring and operation of industrial devices using IoT and Cloud computing is discussed in [10]. An Advanced Industry 4.0 manufacturing system based on Cloud Computing and sensing network technologies is discussed in [11], motivating how a good share multinational resources can successfully improve the production efficiency and reduce the equipment downtime. A software defined networking (SDN) virtualization approach for industry 4.0 based on IoT and Cloud computing that allows to optimize production processes is discussed in [12]. A locality-aware least recently used (LLRU) replacement algorithm optimizing the use of Cloud computing for industry 4.0 smart factory [13]. The advantages of using big data analytics techniques to simplify the interconnectivity in a industry 4.0smart factory perspective is discussed in [14]. In this regards, a conceptual piece of framework which offers a higher level of abstraction to increase adoption of big data techniques as part of Industry 4.0 vision for future enterprises is discussed in [15]. The use of big data analytics for equipment production management is argued in [16]. A Cloud service platform for big data analytics is discussed in [17]. In particular, authors combine e-commerce with traditional business models so as to build an integrated cloud services platform for livestock marketing management, by using cloud computing, database, network and marketing management technologies.

In spite of both academic and industrial community have demonstrated their interest on the application of big data analytics in Industry 4.0, no work has been focused on retention marketing strategies. In this paper, we try to fulfill such a gap.

III. MOTIVATION

Customer retention marketing strategies enables companies to improve their revenues. They are aimed not only at the acquisition of new customers but also at the profitability of existing ones. Among these, popular strategies include Attrition Reducing, Sell and Then Sell Again, Bring Back the Lost Sheep, Frequent Communications Calendar, Extraordinary Customer Service, Courtesy System, Product or Service Integrity, Measure Lifetime Value, a Complaint is a Gift, Blogs, Customer Relationship Management (CRM) systems, Magic Moments, Overcome Buyers Remorse, Personal Touches, Premiums and Gifts, Questionnaires and Surveys, Regular Reviews, Social Media, Welcome Book and Loyalty Programs.

In this paper, we focus on the last one. A customer loyalty program is a rewards program offered by a company to customers who frequently make purchases. A loyalty program may give a customer free merchandise, coupons, rewards, or advance released products. As highlighted in Section II, even though several initiatives have been proposed so far in the field of Cloud Computing and Big Data Storage and Analytics for Industry 4.0 initiatives, for the best of our knowledge, no solution has been proposed so far aimed at retention marketing strategy and in particular focused on customer loyalty programs. Considering a multi-national company, this form of Customer retention marketing strategy raises two main issues: Big Data Storage and Analytics. The objective of this paper is to fulfill such a gap.

The main contributions of this paper are:

- proposing a Cloud-based SaaS architecture for customer loyalty programs;
- describing the main involved workflows;
- analysing a NoSQL Big Data Storage system for the pre-selection of candidate customers;
- discuss how deployment in private and hybrid scenarios affect the performance of the Big Data Storage system.

IV. ARCHITECTURAL DESIGN

In this section, we discuss the design of a Cloud-based SaaS for retention marketing aimed at performing customer loyalty program in order to improve the profitability of existing buyers. Customers are users of the e-commerce platform of a company who purchase products and rates them creating a customer experience. The SaaS system includes the following components: an eCommerce platform, a Dashboard for company's marketing operators, an Event Bus, a NoSQL database, a Streaming Manager, a Machine Learning Cluster, and an Email Marketing Microservice.

Figure 1 shows our reference Cloud-base architecture for retention marketing. Considering a multi-national company, once customers buy products by means of the e-commerce system front-end, big data related to customers' purchases and ranks are preliminary analysed by a marketing employ of the company in order to perform a pre-selection of the candidates destined to the loyalty program. In particular, the marketing operator can choose candidates according to different criteria such as amount of sold orders (e.g., total costs of the order, amount of product of the order) and cancelled orders (e.g., total costs of the cancelled order, amount of product of the cancelled order). The employee can also pre-select candidate customers according to other criteria such as products' ranks and geographical location. Figure 2 shows an example of dashboard for the pre-selection of customers of a multi-national company producing tea. The dashboard shows a list of candidate customers specifying for each one nationality, category tags, total purchases in 2016 and 2017 expressed in Euro or Kg, amount of the last purchase in Euro, link to a detailed report and a switch to manually select the customer as a candidate. A more accurate pre-selection can be performed analysing details about users, by means of the user interface showed in the Figure 3 that shows an example of customer report specifying, for each year, the amount of issued invoices in Euro, the amount of bought tea in Kg and the amount of cancelled order in terms of Euro and Kg. Moreover the pre-selection of customers candidates can be also done manually doing a query according to geolocation criteria, recent sales, ranks and products' category tags. The result of the query represents the pool of users that participate to the customer loyalty program.

Once an event related to purchases and ranks happens it is caught by the event bus. It plays a twofold role: from one side, it forwards unstructured information (including users' profiles, geolocation data, purchases, ranks, and so on) to the NoSQL database; whereas on the other hand, it forwards the same unstructured information to the Streaming manager to the Streaming Management, sending input data to the Machine Learning Cluster component running the "recommendation" algorithm used to associate to each customer candidate a list of suggested products. Both Streaming Manager and Machine Learning Cluster work as batch processes. Actually, a scalable asynchronous bus is required to transfer data among the SaaS components. Specifically, the Machine Learning Cluster uses a Collaborative Filtering (CF) with the Alternating Least Squares (ALS) method. Specifically, the CF predicts customers' interests, gathering behavior and preferences from other customers (who are named collaborators according to the Machine Learning terminology). The recommendation algorithm needs to be ran every time new entries are inserted. In this regards, using a Streaming Management is a good solution for training the model continuously.

Finally, the elaborated and aggregated data that consists of a list of recommended products for each user are stored inside the NoSQL database. Such results provide insight for the customer loyalty program and are used by the Email Marketing Microservice component to automatically send to target customers personalized emails with customized advertisements on suggested products. We underline that there is a continuous flow of information that are generated from customers in term of products' purchases and ranks and received from the customers in term of received email with suggested products. This enable companies using the SaaS system self-adapt their production cycle according to the evolution of the market and changes in the customers' needs and preferences.

The SaaS system works according to two workflows:

- **Users-driven Human-To-Machine (H2M)**. It involves the e-commerce platform, the dashboard, Event Bus and NoSql database. Its main objective is to gather data related to products' purchases and ranks in order to pre-select customer candidates for the loyalty program.
- **Users-driven Machine-To-Human (M2H)**. It involves the event bus, Streaming Manager, the Machine Learning Cluster and the Email Marketing Micro-service. Its main objective is to run recommendation algorithm on pre-selected customer candidates in order to choose the ones to whom send personalized advertisement emails with recommended products.

The two workflows raises two main complementary challenges, that are respectively big data storage and processing. Since the discussion of these two challenges require

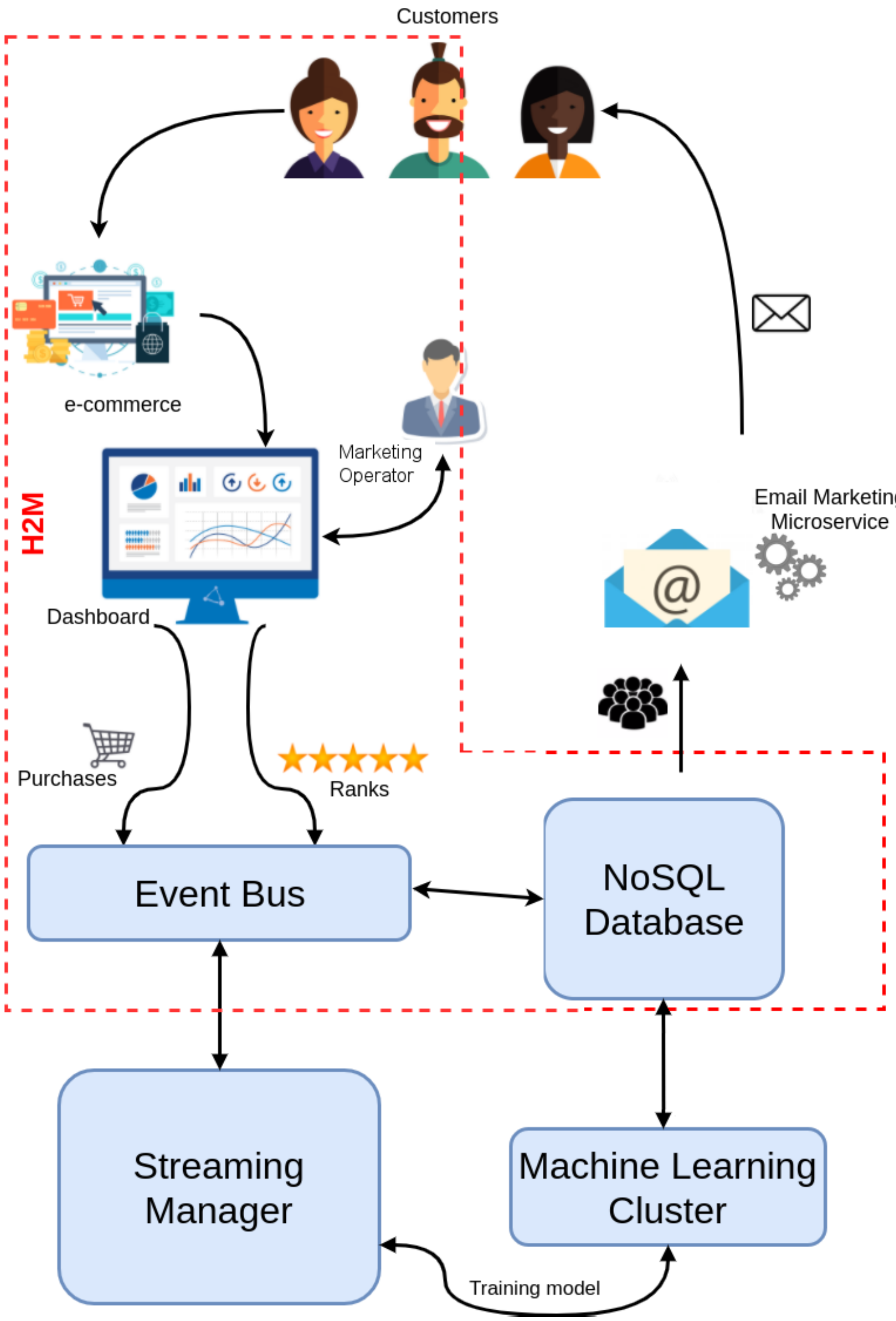

FIGURE 1. **Retention marketing SaaS architecture.**

separated detailed explanations, in this paper we will specifically deepen the Users-driven H2M workflow that is necessary because it provides data related to pre-selected candidate customers in input along with real-time events to the Machine Learning Cluster running the recommendation algorithm that is fundamental for the user-driven M2H workflow.

V. EXPERIMENTAL RESULTS

In this Section, we discuss experiments performed on a SaaS prototype specifically focusing on the big data storage. In particular, we focus our on the user-driven H2M workflow for the pre-selection of candidate customers. In particular starting from a variable number of category tags, we performed several queries in order to pre-select candidate customers who match particular marketing operator's conditions. In order to perform our performance analysis, we arranged a testbed implementing an event bus, a NoSQL database and a Machine Learning Custer interface-end. The Event bus component catches information generated by an even generator simulating events related to customers and products'

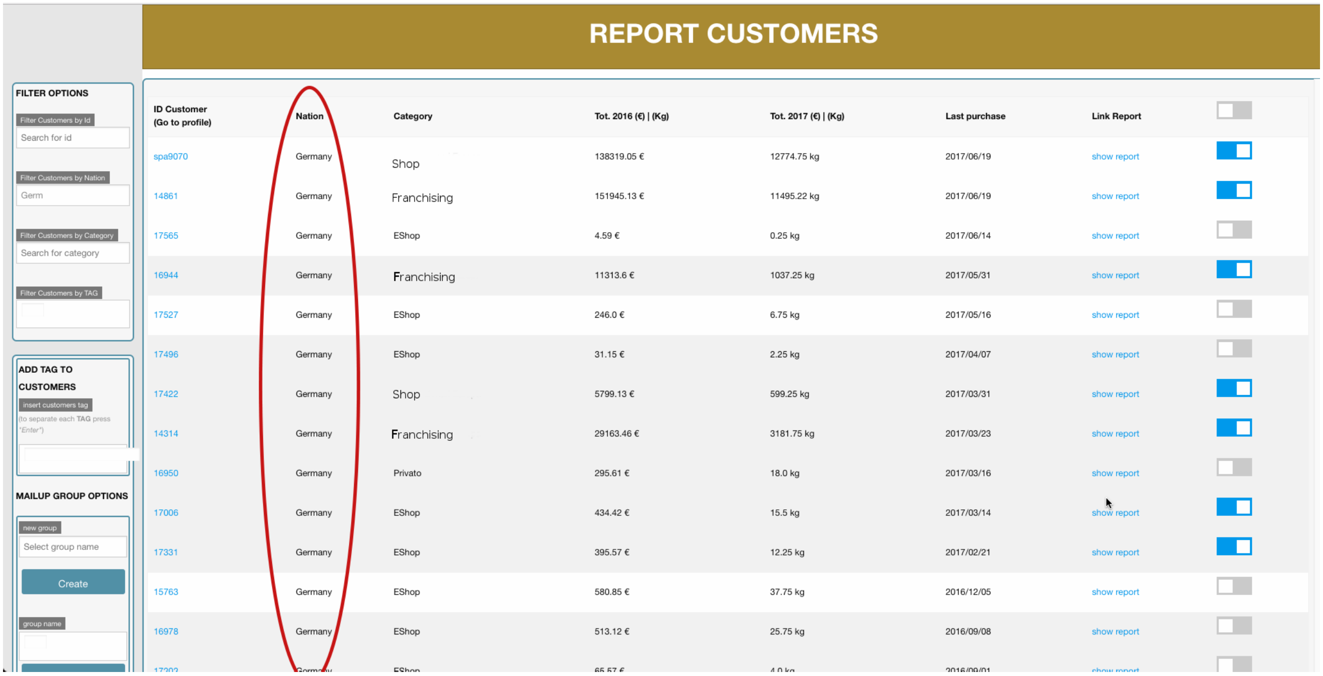

FIGURE 2. Example of dashboard.

FIGURE 3. Example of customer's purchases report.

purchases and rates. A NoSQL database that runs a replica-set instance of MongoDB v. 3.4 composed of four machines, three replica-set and one arbiter stores big data coming from the event bus. A Machine Learning Cluster interface performs queries on the NoSQL database.

In order to consider a concrete testing environment, inside a MongoDB collection we put 100.000 documents, each one representing a customer with corresponding products' purchases and ranks. We made different kinds of analysis, in different configurations. More specifically, we increased

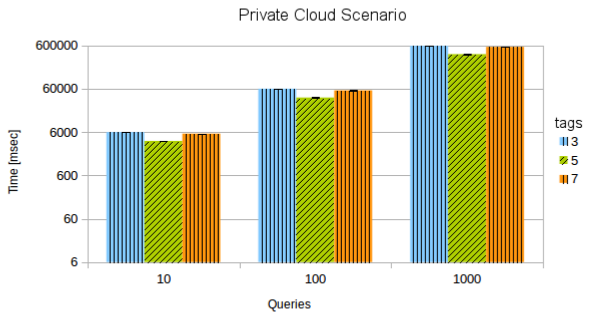

FIGURE 4. Summary of response times considering scenario 1: Private cloud.

the number of category tags that we considered in our queries, ranging from 3 to 7. Furthermore, in order to test if our prototype can be used in a real environment, we made a scalability analysis. In particular, we performed 10, 100, 1000 subsequent queries. Experiments were repeated 30 times. In order to have reliable data we calculated mean values and 95% confidence intervals. Unfortunately, until now, we have not found any similar solution that can be compared with our solution. Moreover, our performance analysis were performed considering two different scenarios, using two different Cloud paradigms:

1) **Scenario 1 - Private Cloud**. In this scenario both MongoDB and the Machine Learning Cluster are deployed in the same 1 Gbps network location. In particular both MongoDB and the Machine Learning Cluster interface are deployed in blade servers with the following hardware/software configurations: CPU Intel(R) Core(TM) I3 @ 3.20GHz, RAM 8GB, OS: Ubuntu server 16.04 LTS 64 BIT. The summary of time performance of this configuration is shown in Figure 4. For both 10, 100, and 1000 queries we observed the same behavior: queries with 3 category tags presented the worst response times, queries with 5 category tags presented the best behavior, whereas queries with 7 category tags presented intermediate response times. This kind of behavior is simply understandable. It is due to the huge amount of retrieve pre-selected candidate customers with only 3 category tags that must be transferred over the network to the Machine Learning Cluster component. Considering queries with 7 category tags, even though the number of pre-selected candidate customers is less than the previous case, the response time is due to the the complexity of the query in MongoDB. Instead, considering such a scenario the optimum case is represented by queries with 5 category tags because there is the right compromise between transfer over the network and processing time in MongoDB.
2) **Scenario 2 - Hybrid Cloud**. In this scenario the Machine Learning Cluster interface is deployed in the private Cloud, whereas MongoDB is deployed into a VM on Amazon EC2. In this case, the two components are interconnected by a DSL 7 Mbps connection. In this scenario, the adopted hardware configuration is the following. For the Machine Learning Cluster interface acting as MongoDB client, we used a blade Server with: CPU Intel(R) Core(TM) Xeon CPU @ 3.40GHz, RAM 32GB, OS: CentOS 7 server. For MongoDB we used a VM hosted in Amazon EC2 with the following software/virtual hardware configuration: Flavor large with 2 virtual CPU Intel Xeon E5-2676 v3 (Haswell) @ 2,4 GHz with 8 GB of RAM. The behavior is shown in Figure 5. Response times raise up with the number of executed queries presenting a linear trend. As we can see, the behavior is similar to the one experienced in scenario 1. In this case by exploiting better virtual hardware capabilities in Amazon EC2, in spite of the overhead introduced by the network latency we have better performances, saving roughly 1000, 10000 and 100000 msec respectively for 10, 100, and 1000 queries compared to scenario 1.

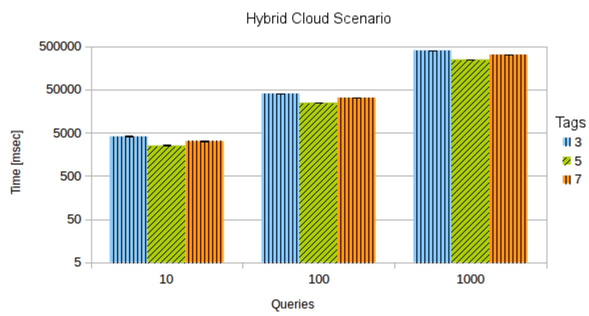

FIGURE 5. Summary of response times considering scenario 2 - Hybrid cloud.

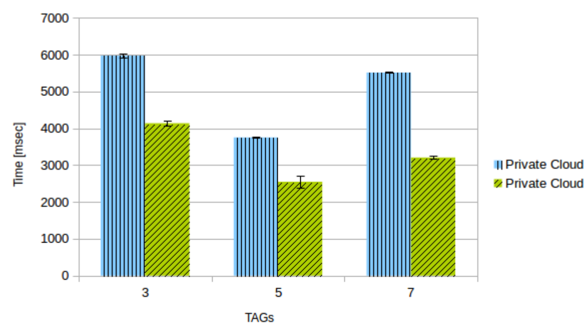

FIGURE 6. 10 queries.

Figures 6, 7 and 8, show a comparison among scenarios 1 and 2 considering queries with 3, 5 and 7 category tags respectively on 10, 100, and 1000 requests. How we can observe comparing 100, 1000 and 1000 queries in private and hybrid Cloud scenarios, for 3, 5 and 7 category tags we observed gaps respectively of 2000, 1300, 2300 msec proving that the system is stable. According to the aforementioned experiments, we can state that the user-driven H2M workflow can be deployed in both scenarios, but for security reasons

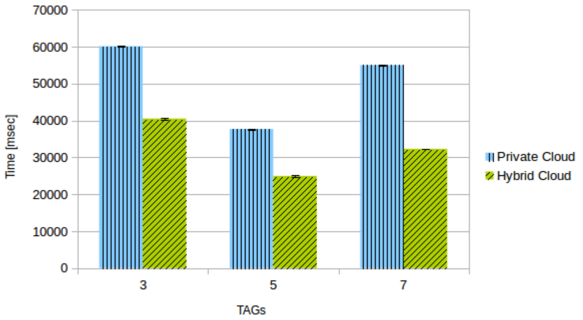

FIGURE 7. 100 queries.

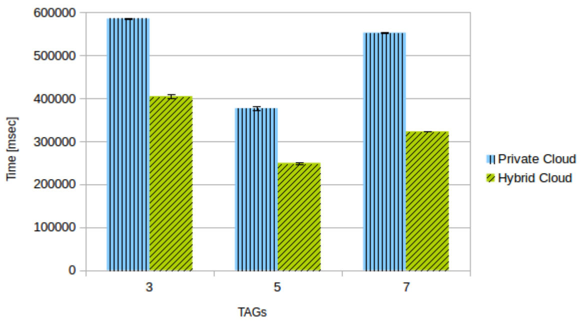

FIGURE 8. 1000 queries.

concerning data sniffing (in fact in our communication we are not considering data encryption) it is better to deploy the system according to Scenario 1. In fact in order to take the advantages of Amazon EC2 it is required to assess the impact of secure communications and encrypted big data storage over the Cloud. In this regards, an emerging and interesting solution is represented by the homomorphic encryption that allows companies to perform arithmetic and aggregation operation directly on encrypted data without the need to decrypt process and encrypt them again. The adoption of homomorphic encryption of MongoDB could improve the trust of companies regarding the possibility to move their data over public Cloud providers.

Once that data related to pre-selected candidate customers are extracted by MongoDB they are passed to the Machine Learning Cluster that processes them along with data continuously coming from the Streaming Manager in order to run the recommendation algorithm that extracts a list of suggested products customized for each customer selected for the loyalty program. The discussion of the recommendation algorithm implemented by the Machine Learning Cluster is out of the scope of this paper and will be discussed in future works along with the description of the user-driven M2H workflow.

VI. CONCLUSION AND FUTURE WORK

Smart manufacturing enabled by Industry 4.0 is changing the whole production cycle of companies specialised on different kinds of products. In this context, retention marketing strategies aimed not only at the acquisition of new customers but also at the profitability of existing ones allow industries to apply specific production strategies so as to maximize their revenues. In this paper, we focused on a Cloud-based SaaS aimed at customer loyalty programs. Such a system raises two main challenges that are storage and analytics of big data related customers and products' purchases/ranks. In particular, after presenting architectural components, and the two main involved workflows that are user-driven H2M and M2H, we specifically focused on the first one that involves the preselection of candidate customers, discussing a system prototype composed of an event bus, MongoDB and a Machine Learning Cluster interface. Experiments performed by means of an event generator prove the goodness of our system prototype in terms of response time considering two deployment scenarios that are private and hybrid Cloud.

Once tested the system components involved user-driven H2M workflow addressing the big data storage issue, in future work we plan to study the impact of the homomorphic encryption considering the hybrid Cloud scenario. Moreover, will focus on the development of the user-driven M2H workflow involving Streaming Manager, Machine Learning Cluster and the Email Marketing Microservice components. In particular we will develop a recommendation algorithm inside the Machine Learning Cluster taking as input the information coming from both the event bus and the NoSQL database in order to perform big data analytics so as to produce a list of customized products that will be sent to target customers by the Email Marketing Microservice component.

We remark that the continuous flow of information that are generated/received by customers enables companies adopting the proposed SaaS system to self-adapt their production cycle according to the evolution of the market and changes in the customers' needs and preferences as envisioned by Industry 4.0.

ACKNOWLEDGEMENT

Authors would like to thank Diego Busacca, Giovanni Parrino and Silvio Trotta, Senior Developers of Alma Digit S.R.L. for their support in development and testing of the system prototype discussed in this paper.

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