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Towards Marketing 4.0: Vision and Survey on the Role of IoT and Data Science

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Abstract: According to KPMG, Internet of Things (IoT) technology was among the top 10 technologies of 2019. It has been growing at a significant pace, influencing and disrupting several application domains. It is expected that by 2025, 75.44 billion devices will be connected to the Internet. These devices generate massive amounts of data which, when harnessed using the power of data science (DS) techniques and approaches such as artificial intelligence (AI) and machine learning (ML), can provide significant benefits to economy, society, and people. Examples of areas that are being disrupted are digital marketing and retail commerce services in smart cities. This paper presents a vision for Marketing 4.0 that is underpinned by disruptive digital technologies such as IoT and DS. We present an analysis of the current state of the art in IoT and DS via the three pillars of marketing: namely, people, products, and places. We propose a blueprint architecture for developing a Marketing 4.0 solution that is underpinned by IoT and DS. We conclude the paper by highlighting the open challenges that need to be addressed in order to realise the Marketing 4.0 blueprint architecture, including supporting the integration of IoT data concerning people, products, and places and using DS to make efficient and effective recommendations.

Keywords: IoT; digital marketing; Marketing 4.0

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1. Introduction

The term "smart city" is coined with the promise of using ICT technologies such as Internet of Things (IoT) and data science techniques and methods of processing and extracting high-value information from data generated by IoT to solve unprecedented challenges in contemporary urban management for sustainable and social cities. Internet of things (IoT) relates to an interconnected set of computing devices, mechanical or digital machines, objects, or animals and people, and they are identified by their own unique identifier, having the ability to transfer data over a network without requiring any human intervention. The massive machine-type communication of IoT can revolutionise applications and services in various domains, e.g., e-health services, smart cities, e-farms, intelligent transportation system (ITS), etc. [1]. IoT technology is also estimated to have a huge impact on the retail sector, with a global forecast for the retail market size having estimated it to reach around USD 35.5 billion by 2025; furthermore, it is expected to have an even bigger or similar influence on other domains such as hospitality, tourism, aviation, legislation, etc. [2]. For most of these domains, if not for all, marketing is one of the backbones that increase sales and revenue by creating product awareness among customers. The impact of IoT on digital marketing will imply greater data control for consumers, with them being digital natives or digital refugees, and marketers must make efforts to collect the data from devices [3] to gain insights into client behaviour [4].

Smart city environments provide the necessary infrastructure for transforming and making retail operations smarter and more efficient; these environments allow for new opportunities to reshape the decision-making process (making it more agile and real-time) to meet the need of consumers [5]. With the recent trend of webrooming and showrooming, it has become a necessity for brick and mortar retailers that are part of smart cities (e.g., shopping malls) to adopt digital technologies. In webrooming, customers go online to research products and then head to a brick-and-mortar store to complete their purchase. In contrast, showrooming refers to the situation where a shopper visits a store to check out a product but then purchases the product online from home [6]. On top of these features, online retailers are bringing different cost structures and business profitability models while comparing them with the in-store operations. To overcome these circumstances, physical retailers are turning to information technology and new business models to devise omnichannel strategies that cater to their customers for online, in-store, and mobile shopping [7]. With the high competitiveness of the retail industry coupled with changing consumer behaviour driven by the COVID-19 pandemic, the sustainability of business operations rely on adapting omnichannel strategies to closely match consumer expectations [8].

A large amount of business establishments use the digital marketing platform for the branding and marketing of various products and services because of its diverse offerings. It includes platforms such as social marketing, word ads, banner ads, video advertisement, etc., to promote or market products and services to targeted consumers and businesses [3]. Digital tools have provided people with a new way of browsing products and offerings and it provides benefits to both consumers and marketers. Consumers benefit from stress-free purchases, invariable choices, payment options, cash on delivery, discounts on online purchases (cheaper than brick-and-mortar stores), social reviews, etc. [9]; marketers benefit from building customer relationships, targeting specific demographics in advertising, reduced costs and increased efficiency, access to global markets, etc. [10]. The interconnected nature of infrastructure networks enables opportunities for reshaping the decision-making process by leveraging new sites of experimentation and stimulating sustainable and inclusive urban infrastructure. In [11], the authors argue that enhanced customer centricity and effective decision making are key shifts that are driving digitization in omnichannel retail.

Philip Kotler [12] stated that a marketing mix is the mixture of controllable marketing variables that the firm uses to pursue the desired level of sales in the target market. Marketing refers to the set of actions or strategies that an organisation uses to promote its outcome to the market; more precisely, it can be defined as the elements an organisation controls that can be used to satisfy or communicate with customers. So, traditional marketing, also known as the product marketing mix, is composed of four Ps (product, price, place, and promotion), whereas expanded marketing, also known as the service marketing mix, includes people, physical evidence, and processes. Focusing on the traditional marketing mix, a product refers to the physical goods or total products that exceed customers' expectations and that are ready to be purchased or paid for depending on the quality, design, features, packaging, sizes, and variety. Pricing depends upon the cost of the product, the affordability, and the ability and willingness of the customer to pay for it. Discounts, allowances, cost price, and selling price play important roles in the pricing strategy of a product. The third P, places, refers to the platform where the finished product is to be delivered from the service provider, producer, or manufacturer to the customer. Planning has to be performed to reach the customers through various channels, locations, and transport so that they are able to avail the product based on the availability and affordability. Promotion creates awareness of the product among the customers and is one of the important tools used for increasing sales revenue. Marketing managers decide the expenditure of promotions depending on advertising, sales force, public relations, etc. [13]. The COVID-19 pandemic has further highlighted the importance of a strategy for a unified omnichannel experience [14] and thereby one spanning all four Ps.

As part of this work, we provide our vision for how IoT technology can impact the digital marketing spectrum, focusing on people, products, and places in the context of the smart city environment. As with other domains, IoT enables fine-grained data capture pertaining to consumers, products, and consumer experiences relating to these products. In particular, we foresee that IoT will merge the physical and digital worlds to enable finely tailored consumer experiences. This will be achieved through the exchange of granular data in a privacy-preserving manner, allowing for accurate and targeted recommendations through immersive advertising. In Section 3, we present the motivation and scenarios behind our vision. Section 4 presents a literature survey of the current existing state of the art in IoT that focuses on people, products, and places. A blueprint architecture of how IoT and data analytics fit into a marketing application is provided in Section 5. Section 6 details the future research directions, with a focus on privacy, real-time delivery of advertisements, customised fine-grained recommendations, and generation of revenue from IoT-based digital marketing. Finally, we conclude the paper in Section 7 by summarising our vision and the current state of art for achieving this vision.

2. Methods

The methods adopted in this paper involve a two-pronged approach that helps inform our vision for Marketing 4.0, which leverages the benefits of IoT and data analytics. Firstly, we identify key trends in marketing that are driving the adoption of IoT and data analytics, and we define key motivating scenarios based off of these trends. Subsequently, we conduct a review of the existing literature concerning the application of IoT and data analytics in marketing.

Based on the identified motivation and state of the art in IoT and data analytics, we propose a blueprint architecture for marketing applications. Using the blueprint architecture as a basis, we propose future research directions towards the seamless integration of IoT and analytics into marketing.

The methodology adopted is outlined in Figure 1.

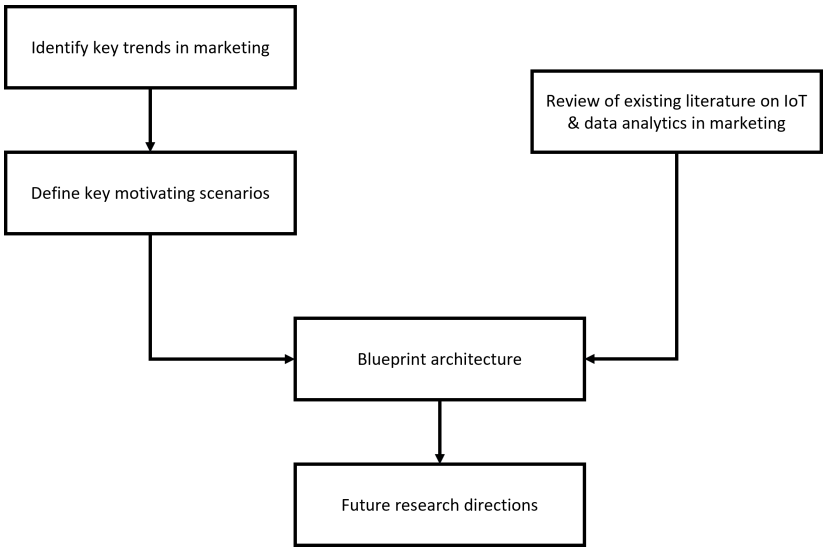

Figure 1. Methodology adopted.

3. Motivating Scenario

Omnichannel capabilities such as buying online and picking up in-store, online visibility of store inventory, and the ability to return products anywhere are now more important than ever [15]. As most retailers fail to blend the physical and digital channels, a growing digital divide is stripping them of potential revenue and creating a risk of customer alienation. Even though the retailers are already tinkering with IoT through smart lighting, smart thermostats, tablets, and equipment sensors, experts say that it is barely scratching the surface of the potential that IoT can offer. Nearly three-quarters of retailers have some

sort of IoT project underway, and a 2015 report found that retailers would be spending an estimated USD 2.5 billion on hardware and installations by 2020 [16]. There are five main areas in the brick-and-mortar environment where retailers will be able to leverage IoT to create a frictionless store of the future. These include the areas of store entry, customer interaction, smarter merchandising, rapid mobile pay, and data measurement.

Digital advertisements in smart cities are also becoming more common. The smart city revolution is about the networked connections that are linking up people, processes, data, and things; walking down a kilometre would make people see a couple of examples of digital signage. This is called out-of-home (OOH) advertising [17], and it is a form of advertising that is found outside of the consumer's home. Traditionally, this would include everything from billboards to bus shelters, as well as benches and everything in between. This indeed helps to generate revenue for the government, which they can contribute towards maintaining the smart city infrastructure. Tech startups such as FireFly have raised around USD 21.5 million in seed funding to equip mountable digital smart screens in order for their ride-hailing vehicles to display ads. Furthermore, smart city kiosks are platforms that are almost incomplete without the display of digital advertisements. The UK government is said to be planning to launch sponsored highways by enabling business branding. Another start-up, UZE Mobility in Germany, is offering the rental of its electric vehicles for free to users, and the company is planning on making money by mounting digital screens on the vehicles and selling the ad space [18]. For this OOH [19], the media industry handling digital advertising must begin thinking about smart cities integration with the four elements of people, process, data, and things.

- People: Connecting people in more relevant, valuable ways. Today, most people connect to the Internet through devices such as PCs, tablets, TVs, and smartphones. In the future, other devices such as pills or sensors embedded under the skin may provide relevant information regarding people's health and vital signs. For OOH marketing, this could mean changing the current attitudes about new technologies, shifting the emphases of OOH assets by making them more adept at integrating data from multiple sources.
- Process: Delivering the right information to the right place, person, or machine at the right time. The good news for the OOH industry is that there are potent new methods powered by digital tools that allow for the presentation of more meaningful information to consumers, especially geo-located information that becomes more relevant to interactions with an OOH asset.
- Data: Leveraging data into more useful information for decision making. The transformation from data to information is important because it will allow people to make faster, more intelligent decisions, as well as control environments more effectively.
- Things: Physical devices and objects connected to the Internet and to each other in ways that encourage more intelligent day-to-day decision making.

Smart cities have adopted IoT technology with an interest in developing intelligent systems, such as smart offices, smart retail, smart agriculture, smart water, smart transportation, smart healthcare, and smart energy [20–22]. IoT offers a platform for sensors and devices to communicate seamlessly within a smart environment and allows for information sharing across platforms in a convenient manner. IoT has emerged as a new trend in the last few years, where mobile devices, transportation facilities, public facilities, and home appliances can all be used as data acquisition equipment for IoT. All surrounding electronic equipment that facilitate daily life operations, such as wristwatches, vending machines, emergency alarms, and garage doors, as well as home appliances such as refrigerators, microwave ovens, air conditioners, and water heaters are connected to an IoT network and can be remotely controlled [22]. The recent adaptation of different wireless technologies places IoT as the next revolutionary technology due to the technology benefiting from the full opportunities offered by the Internet. A large number of communication devices in the IoT paradigm are embedded into sensor devices in the real world. Data-collecting devices sense data and transmit these data using embedded communication devices. The

continuum of devices and objects are interconnected through a variety of communication solutions, such as Bluetooth, WiFi, ZigBee, and GSM. These communication devices transmit data and receive commands from remotely controlled devices, which allow for direct integration with the physical world through computer-based systems to improve living standards [22]. IoT offers a real-time infrastructure that provides access to data about the entities within it.

In digital marketing environments, the availability of these large data sets from IoT infrastructure has facilitated the use of data science for decision making and the extraction of actionable insights and knowledge from the data. These data, coupled with advances in artificial intelligence (AI), can provide a great platform for digital advertising in both community and individual settings. The acquired knowledge can be put to use in many different ways. For instance, personalised, emotionally appealing advertisements can be created with this information and can be digitally shared using pragmatic advertising strategies [23]. Specifically, AI systems can identify themes, emotions, or sentiments from textual data, enabling marketers to understand how customers engage with brands. Moreover, it helps marketers with one-to-one segmentation and targeting, ultimately resulting in engaging and appealing to every customer with individually customised messages [24], thus significantly altering traditional human-centric sales processes and affecting the B2B sales funnel. AI has also enabled brands to engage with their individual customers through many different touch points, thereby generating data that may be used to develop marketing strategies.

In order to achieve the marketing with a focused goal, we first define the scenarios that would help us to expand and explore the details of the digital marketing.

- Scenario 1: In this scenario, we focus on advertisements tailored towards an individual using devices such as smart phones, smart watches, etc. It focuses on using information such as the profile of the user, mood, activity, fine-grained location information, and the individual's interest in the place, linking these aspects to the product data.
- Scenario 2: In the second scenario, we target community advertisement using devices such as billboards. The scenario would focus on using information such as general mood, current interest of the crowd, the current place where it is happening, and how it becomes linked with the interest of the group towards the product.

4. Current State of the Art in IoT and Analytics (Underpinning the Pillars)

In this section, we explore the current state of the art in IoT and analytics, emphasising the three pillars of marketing: namely, people, products, and places. Figure 2 explains how a privacy-preserving advertisement recommendation engine is deployed in an IoT cloud facility retail establishment. Its aim is to recommend various products to different people irrespective of whether the product or the people are located in the same place or different places. The advertisements may be pushed to different devices such as billboards, personal handheld devices, etc., depending on whether they are targeted to a group of people or an individual, respectively.

4.1. State of the Art in IoT

The primary role of IoT in marketing is to enable the collection of fine-grained data about how people interact with products and services in retail environments.

IoT has evolved to the phase of an ecosystem, where it behaves as a system of other systems. As part of an ecosystem, smart devices can communicate with each other spontaneously without being locked into the silo of a company producing the device or software [25]. Here, extracting context from IoT data plays an important role as an input to any of the decision-making systems. Context is defined as any information that is used to characterise the situation of an entity [26]. The entity is a person, place, or object that is considered relevant to the interaction between a user and an application. A situation can be treated as a context with a higher level that was derived from the raw context by applying specific algorithms [25]. In the domain of digital advertising, which may use an

indoor positioning system (IPS), the entity can be the user of an overall system of digital advertising, i.e., the device that the user uses to interact with the system, the products displayed on the shelves, the WiFi sensor, and many others. IPS systems that are specifically designed for retail environments can help obtain accurate information of shopper movements. In [27], the authors proposed a WiFi-based technique for indoor positioning that can scale to large retail spaces; in [28], the authors proposed using ensemble filters on a BLE-based indoor positioning system. Both of these techniques are targeted towards enabling location-based services, such as personalised offers to shoppers. If we consider the user of the application as the entity, their attributes such as their bank balance, credit limit, current indoor location, etc., are being termed as the context attributes [29]. The combination of the context attributes of the user along with the context attributes from other entities can be used to define the situation *goodForBuying* that is related to a product [30]. This situation can be used as an input for recommending an advertisement to the user.

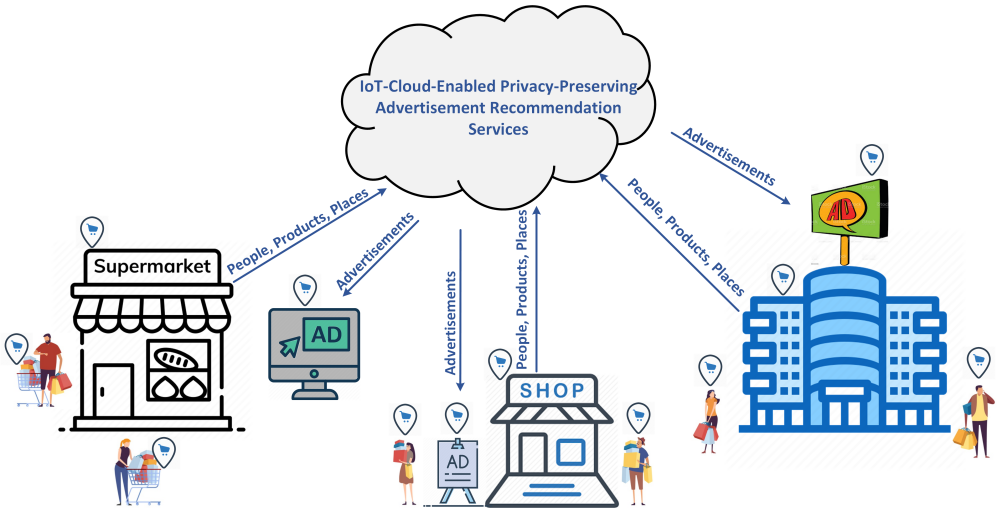

Figure 2. An overview of IoT cloud-enabled privacy-preserving advertisement recommendation services.

One of the most promising paradigms that allows for marketing is mobile crowdsensing (MCS). MCS leverages the sensors and location-awareness of mobile personal devices (smartphones) by assigning a set of tasks to a crowd of participants of MCS campaigns in order to gather information about phenomena of common interest [31]. MCS campaigns can be voluntarily joined by citizens, in most cases in exchange for a small reward; alternatively, the citizens themselves are sometimes interested in the goal of the campaign itself. In many other cases, the MCS campaign is piggybacked into an application that provides convenient free services to citizens who, in turn, do not mind sharing their location data in exchange for such services. Examples can be found in traffic monitoring systems based on GPS probes, such as the Google Maps navigation system [32]. There are several other active fields of research that are capable of supporting MCS in providing individual or collective context awareness. Transportation mode detection [33] is extremely important for providing context to individuals shifting from one location to another.

Additionally, sensor data from devices have also been used to capture data pertaining to shopper activities. In [34], the authors presented a system that uses a network of cameras in a store to recognise shopper interactions with products on shelves. This includes detecting activities such as picking up or replacing products from shelves and the products touched, indicating varying levels of shopper interest in the products. The information obtained can then be used to devise marketing strategies. More recently, in [35], Wen et al. proposed making use of customer behaviour primitives in conjunction with object tracking to achieve accurate customer behaviour recognition. In [36], Radhakrishnan et al. also looked at detecting such activities, but instead by using sensor data from wearable devices in combination with smartphones. Given that wireless network deployment is ubiquitous,

especially in retail environments, the existing literature has looked into leveraging WiFi signals for shopper activity recognition so as to avoid additional infrastructure. Zeng et al. [37] proposed a method of using WiFi channel state information (CSI) to detect movement patterns that indicate shopper interest, such as walking fast or slow inside a store or at its entrance. In [38], the authors used WiFi signal data combined with process mining to determine shopper pathways inside a fashion store and how these are impacted by changes to the store's layout.

Finally, data from IoT devices can be used to complement the above information with that of the products themselves. Smart labels have seen a lot of attention as organisations look to provide greater amounts of information about a product compared with traditional methods such as printed labels or barcodes [39]. Smart labels can incorporate multiple technologies such as QR codes, BLE, etc., and can be used to enable the availability of a wide range of information about products, such as dynamic pricing [40] and storage conditions [41]. Moving forward with the functionality of smart labels, Google's Jacquard project envisions such a functionality being woven into everyday objects [42].

4.2. State of the Art in Analytics

IoT data can be used to obtain enriched information about customers to build just-in-time marketing strategies. These can be further combined with user profile data and can be used to generate effective recommendations. As a matter of fact, recommender systems are a major trend in IoT-based marketing. Recommender/Recommendation systems are information-filtering mechanisms that seek to feed users with suggestions based on their preferences in order to avoid users getting lost in information overload. These systems are rather present in fields such as healthcare, transportation, and agriculture; however it is in e-commerce and retail that they show their highest potential [43]. They can be divided into several classes depending on the source of the knowledge used for filtering. For instance, they can exploit demographic correlations between buyers, user similarity based on the purchase history and ratings, domain correlation between products and users' needs, and so on. While they are being extensively used for tracing online browsing behaviours, they have been seldom adopted in brick-and-mortar stores, as appropriate responses to in-store behaviours are rare. For instance, the work in [44] presented a real-world experience of a recommender system in the fashion domain that uses data from both online and offline (i.e., in-person) shopping; however, it does not detail any feedback to the offline shopper. This gap can be filled by using IoT-enabled recommender systems, which are indeed in their rising phase [45]. One of these systems was designed and prototyped in [46], where geofencing was used as a primary context in a tourism-driven use case. Another notable work is [47], where the authors leveraged the concept of digital signage and used smart city IoT nodes that provide city dwellers with timely and localised information such as news and weather. Among such information, the authors suggested to treat it as a powerful marketing tool, which would allow for bi-directional communication with viewers for advertisement purposes through a recommender engine. In [48], IoT technology was efficiently used in a study on physical stores, where the data about customers and purchases were collected through IoT devices and the profiling of trends took place through fuzzy neural network models.

IoT analysis processes are vastly applied in tailoring advertisements through the use of the localised context of mobile users. As a matter of fact, some of the literature about MCS specifically targets marketing purposes. The work in [49], for instance, used the crowd-sourced trajectories of a set of mobile users and clustered them by the longest common subsequences (LCSS) and commonalities in the visited hotspots. This allowed for a more focused marketing based on the habits of the groups of people. In [50], the authors leveraged crowdsensing vehicle trajectory data to empower audience-targeted billboard advertising by studying the hypothetical advertisement spread based on the semantic topic. There are several other active fields of research that are capable of supporting MCS in providing individual or collective context awareness. In fact, regarding transportation mode

detection, different conditions of need occur based on whether the user is driving, walking, or using public transportation; therefore, the tailoring market offers that are present in light of such conditions is highly desirable. A study on how market fragmentation occurs in urban commuting recently revealed how dedicated service offerings can be distributed to individual travellers [51]. Another powerful tool that can help determine trends in communities based on places are social networks; indeed, several studies have used local social networking for viral marketing, such as in [52], which builds upon selected influencers to promote initiatives in smart cities. Unlike Internet advertising models in which marketing revenue is generated based on user intentions estimated from clicks on websites, no such models exist for IoT-enabled digital marketing. In [53], the authors sought to fill this gap by proposing a set of metrics that could be computed based on the detected shopper activity, such as the activities summarised above.

The influence of IoT and analytics technologies, such as those described in this section, on marketing strategies was explored in [54]. However, although the use of IoT and analytics in retail has been extensively explored in the literature and has also been shown to be accepted by shoppers [55], the real-world implementation of these technologies continues to be at a nascent stage [56]; there is still a lack of maturity in these technologies in retail environments. With this in mind, we propose a blueprint architecture for integrating IoT and data analytics into marketing applications in the next section.

5. Blueprint Architecture

In this section, we envision a hyper-connected blueprint architecture to cater to the needs of citizens by connecting people, products, data, and things. The main objective is to enable highly personalised, secure, and privacy-preserving product recommendations to shoppers. However, the application designers need to consider the core requirements below before configuring and deploying the digital advertisement applications.

- **Information Freshness**: It is a core requirement to consider the frequent changes in the IoT data and the collection and processing of fresh data that determine the current situation to make informed decisions. Currently, most of the big data processing systems for IoT applications focus on the speed and size of the data to extract the valuable information; however, determining this value in real-time is a daunting task. Furthermore, fresh and accurate data are needed to be captured to establish the correct context of advertisement delivery to each user.
- **Fine-grained Targeted Advertising**: Customer preferences, price dynamics, and customer interest in specific products help to establish the right contexts and generate product recommendations. However, when considering the real-time requirements to provide on-the-go advertisement deliveries, the mobility patterns, customer interactions, and proper contextual information are required to target the potential customers at the right time and exact place.
- **Fairness**: Targeted advertisements in IoT and smart city scenarios could lead to complex situations where the customers could be easily identified and their information could be linked to predefined advertisement policies. However, the predicate rules in the advertisement applications must be defined to deliver fair and unbiased advertisement without compromising on the data attributes of age, colour, gender, ethnicity, buying power, interaction/non-interaction with smart products, search history, and people protected by the law (e.g., homeless people).
- **Privacy Preservation**: IoT-enabled digital advertisement platforms pose serious privacy threats where the customers could be directly or indirectly identified and the targeted advertisements could be delivered to their proximal devices and systems. However, considering the multi-customer interaction with IoT devices, there is a dire need to preserve privacy while equally delivering targeted advertisements. Moreover, the privacy policies must comply with local and regional privacy regulations such as HIPPA (USA), GDPR (EU), and PIPEDA (Canada), to name a few.

- **End-to-End Security**: Considering the openness and ubiquity of IoT devices and the collection of personal profiling data, the IoT-enabled digital platforms must ensure the end-to-end security of users, data, devices, and systems.
- **Personalisation**: Traditional solutions try to collect the maximum amount of datapoints about the customers and execute different profiling mechanisms to maximise the targeted ad delivery. However, considering the multi-device and multi-user phenomenon in IoT-enabled digital advertising platforms, the collection of personal data, maintaining its fresh state, and developing privacy-preserving secure customer profiles require prime attention. System designers are required to create a balance between privacy preservation, personalisation, and data security.

Considering the above-mentioned requirements, we envision a components-based layered architecture, as depicted in Figure 3 for: (1) data collection; (2) communication; (3) storage, management, and processing; (4) recommendation generation; (5) advertisement delivery; and (6) security and privacy preservation.

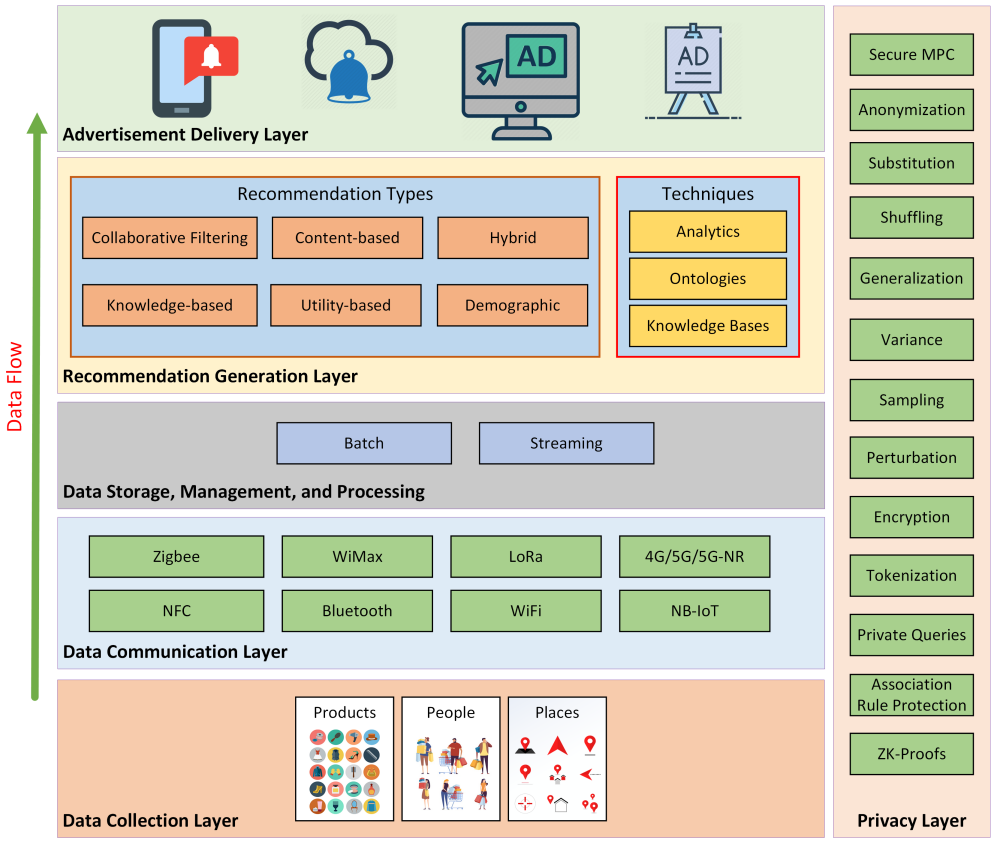

Figure 3. A blueprint layered architecture for IoT advertising applications.

- **Data collection layer**: The data input layer needs to allow for interfaces with different types of data sources to collect data about people, products, and places. These data sources could produce data from first-person devices such as wearable devices and smartphones or third-person devices such as video cameras, interactive display screens, and voice shopping assistants (such as Amazon's Alexa). The produced data could be acquired via sensors (such as GPS, proximity, accelerometer, camera, microphones, etc.), user input (such as mobile application, interactive displays, smart cards, QR/barcode readers, intelligent carts, etc.), or third party data collectors (such as marketing databases, online reviews, product ratings, collaborated recommendations, etc.). The data sources can produce a wide variety of numerical, categorical, or multimedia data that contain a large number of datapoints about customers' personal, behavioural, interaction, and mobility data. However, customers must be explicitly and formally

educated about the data collection and data handling policies to abstain from legal and ethical complications and enable a trustworthy interactive user experience [57].

- **Data communication layer**: Considering the heterogeneity of IoT devices and communication protocols, various communication technologies with varying frequency ranges could be enabled at the data communication layer. For low-frequency and short communications, the near field communication (NFC), Bluetooth low energy (BLE), low-power WiFi, and ZigBee technologies could be used. However, for long-range and high-frequency communication requiring high data throughput, the narrow band IoT technology coupled with cellular network technologies such as 4G/5G/5G NR could be used. However, the application designer needs to select from among various types of device-to-Device (D2D) and ad hoc communication protocols, such as the constrained application protocol (CoAP), message queue telemetry transport (MQTT), advanced message queue protocol (AMQP), and extensible messaging and presence protocol (XMPP), to name a few.
- **Data storage, management, and processing layer**: The advertising applications need to maintain various states of the data for efficient data handling. Like other business applications, the advertising applications need to manage the data at rest, where the data are stored in centralised cloud servers for lateral data processing. This type of data normally uses traditional batch data stores such as relational database management systems (RDBMS) or key-value stores (KV-stores), and the data are iteratively processed using batch data processing techniques such as SQL queries or map-reduce algorithms. However, considering the information freshness and privacy compliance (i.e., the need to forget the customer data) requirements, the advertising applications can adopt the data at transit schemes, where the datapoints remain valid for a limited time and iterative batch data processing schemes are applied to uncover the maximum amount of useful patterns from customer data. Finally, a few application components can use data at processing strategies, where the customer data are completely managed and processed using in-memory databases and in-memory data stream processing architectures. These strategies help to efficiently manage the streaming data by enabling early data duplication and the maintenance of on-the-fly privacy-sensitive information, e.g., information capturing the time and locations of customers to uncover in-store movement patterns or tracking the customers' product browsing activities to find the correlated products and offer better on-the-fly promotions.
- **Recommendation generation layer**: IoT-enabled business applications can explicitly collect contextual information by enabling customer interactions with in-store IoT devices. This explicit data collection helps to determine the right situations to recommend highly relevant products on-the-go. Similarly, implicit or indirect contextual information could also be extracted using person identification, activity monitoring, and in-store trajectory monitoring applications. Despite having the contextual information of the customer, the choice of product recommendation methods varies among collaboratively filtering the customers' data, generating content-based recommendations, or segmenting the customers' data based on their prior buying patterns, utility to customers, or demographic features. However, these recommendations are generated by using various analytics-driven, ontologies-based, or knowledge-driven algorithms [58].
- **Advertisement delivery layer**: Delivering the right product advertisement at the right time with the right tool can lead to successful product checkouts from the store. Therefore, IoT-based advertisement applications should enable context-driven situation-awareness mechanisms before advertising [59]. The advertisements could be pushed to customers' devices such as smartphones or wearable devices. Alternatively, the advertisements could be delivered via the screens that a customer is interacting with; otherwise, the proximal display screens could be used to persuade potential customers.
- **Privacy and security layer**: Because IoT-enabled advertisement applications are mainly deployed in MCS environments and there is a need for the collection of

massive datapoints to deliver high-quality, fine-grained, and personalised advertisements [60], it is hard to achieve the right balance between privacy, end-to-end security, and fair advertisements [61]. Customers are always conscious of identity theft due to personal identification, localisation, tracking, and profiling. Furthermore, there is always a probability of linking customer information to other, undesired business objectives (which customers do not want to link with). Alternately, customers are always prone to various security and privacy attacks, such as membership inference attacks, data inference attacks, attribute disclosure attacks, fingerprinting and impersonating attacks, identity theft, re-identification attacks, database reconstruction attacks, model stealing, and model inversion attacks, to name a few. Therefore, we foresee a parallel layer of privacy and security methods that ensure the maximum protection of customers' data and that equally provides the maximum user experience. There is a large plethora of security and privacy techniques, such as secure multiparty computation, anonymisation, substitution, shuffling, perturbation, encryption, mix networks, private queries, association rule protection, attribute-based credentials, zero-knowledge proofs, and blind signatures; however, the detailed discussion on the promises and perils of these techniques is not within the scope of this paper.

6. Future Research Directions

In this section, we identify the key research directions that require further investigation towards the realization of the vision of Marketing 4.0.

- **Privacy:** IoT-based marketing and advertising is fundamentally based on the massive gathering of data about users. At such a scale, much like in MCS scenarios, this will pose the threat of sensitive information disclosure. Privacy is in fact considered a major challenge nowadays due to the structural limitation imposed by personal data collection scenarios [62]. The introduction of privacy policies is imperative for IoT-based marketing, which often means taking a path involving *k-anonymity* or *differential privacy* policies [63], or even location perturbation and cloaking [64]. However, the trade-off between precise and timely information and the quality of the recommendation is very delicate and challenging. On the other hand, we could look into introducing strategies aimed at collecting just as much data as needed as dictated by the context. This would unburden the computation on the edge and, possibly, provide enough warranty in favour of information disclosure [65].
- **Real-time delivery:** The real-time delivery of advertisements in an IoT-enabled digital marketing ecosystem is dependent on the real-time extraction of related context information from IoT data. These applications, which are dependent on real-time context about external entities, are often referred to as context-aware applications. The introduction of IoT-triggered context-aware computing as services to the real world is in its infancy because of universal acceptance, standardisation, and accessible technologies [25,66]. The usability of the context information is dependent on various parameters such as the freshness, latency, availability, etc., of the IoT data because of its constant temporal movement [25]. This leads to the research requirement of an efficient and adaptive context caching for fast concurrent access in IoT applications [67].
- **Generation of fine-grained recommendations:** Existing recommender systems can accurately enable group-level recommendations; however, designing a personalized recommender system is a challenging task. To address this issue, IoT devices and their users need to be actively monitored, the customers inside and outside the shopping areas need to be correctly identified, and the detection of their activities is essential. Moreover, potential buyers and customers are targeted to be attracted to the products right after the delivery of advertisements. Therefore, the recommendation engine must be able to personalize the advertisements at the fine-grained level and the IoT advertisement applications should capture the data at the finest-grained level to establish the right context and determine the exact situations and modes for advertisement delivery.

- **Monetization of IoT-based digital marketing:** Unlike online advertising models in which marketing revenue is generated through pay-per-click business models, no such models exist for IoT-enabled digital marketing. While user interest in advertisements are estimated based on web browsing activities [68] for online advertising, it is challenging to do so for physical environments. The existing literature has looked to leverage IoT to measure usage behaviour [69] and shopper intention in retail environments [70]. A set of metrics for digital marketing in offline retail was proposed in [53], which relied on shopper intent based on movement patterns. For the widespread adoption of IoT-based advertising, it is necessary to develop a generic set of metrics to measure various kinds of shopper behaviour.

7. Conclusions

In this work, we presented a vision of Marketing 4.0 in which IoT and data science play key roles in enhancing the marketing paradigm. We assessed the current state of the art in IoT and data analytics with a focus on the three marketing pillars of people, products, and places. We were motivated to illustrate how the brick-and-mortar retail industry can exploit the offerings of IoT and analytics towards digital marketing. We found that although various approaches have been explored in the existing literature, there is a lack of focus on how these technologies can be integrated and deployed as part of a marketing application.

Given this background, we presented a blueprint architecture that integrates data from IoT devices, pertaining to these three pillars, with data analytics. The insights generated through this data fusion are converted into tailored recommendations that are delivered through immersive privacy-preserved advertising. Furthermore, using this blueprint architecture as a basis, we identified key research directions that require further investigation towards the realization of the vision of Marketing 4.0 in practice.

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