Extended User Interface: NFC-Enabled Product Packaging for Enhanced User Experience

Justina Lydekaityte(✉)

Aarhus University, Birk Centerpark 15, 7400 Herning, Denmark
justina@btech.au.dk

Abstract. User-centered physical-digital systems let designers create interactive interfaces filled with special moments and experiences, giving brand owners the chance to have profound communication with their consumers. In fact, product's packaging has recently begun to investigate as one of such interfaces to form a strong link between manufacturers and their end-users. Microprocessors, sensors, actuators and wireless data-exchange supporting chips can be embedded, into packaging design creating an extended user interface – a touchpoint for a visual, tactile and digital encounter with consumers. Near Field Communication (NFC) is one of the rapidly increasing technologies that researchers begin to investigate as a potential tool for enhanced consumer-brand communication. However, although NFC is available in the market since late 2010, the technology is still not widely applied to the packaging industry. As a result, the main purpose of this research is to investigate the current state-of-the-art and potentials of NFC system. The results of this study provide a systematic review of NFC characteristics, including technological capabilities, consumer- and brand-oriented benefits, and technology- and user-centered potential barriers for NFC to become widely accepted. The findings of this study are expected to contribute to a better understanding of the effectiveness of NFC-enabled packaging, allowing brands to dynamically adapt to emerging consumer needs by improving their products and services.

Keywords: Near field communication · Smart packaging · Technological capabilities

1 Introduction

In the recent years, the accelerating adoption of enabling technologies, such as Internet of Things (IoT), cloud computing, augmented reality, smart sensors, touch-sensitive surfaces and gestural interfaces, has induced the emergence of interconnected systems, where smart, sensory and interactive objects communicate among themselves, as well as with their users [1, 2]. At the same time, the cost of the tools needed to connect products to the internet has dropped down to enable the continued growth of the Internet of Everything [1]. As a result, the increasing use of the internet and the development of interconnected digital-physical systems have merged engineering and design due to a common objective to enhance user experience [3]. Consequently, according to [4], the

N. Streitz and S. Konomi (Eds.): HCII 2020, LNCS 12203, pp. 285–304, 2020.
https://doi.org/10.1007/978-3-030-50344-4_21

concept of Human-Computer Interaction (HCI) has gone beyond the traditional mechanical computer systems and begun to penetrate into everyday objects and environments people are in touch with in their daily life.

User-centered physical-digital systems let designers create interactive interfaces filled with special moments and experiences, giving brand owners the chance to have profound communication with their consumers [5]. In fact, product's packaging has recently begun to investigate as one of such interfaces to form a strong link between manufacturers and their end-users [6–8]. Microprocessors, sensors, actuators and wireless data-exchange supporting chips can be embedded, laminated or directly printed onto packaging design creating an extended user interface – a touchpoint for a visual, tactile and digital encounter with consumers.

Although the traditional passive packaging already served as an effective communication medium [8], advances in conductive ink and nanomaterials, printed electronics techniques and ICT allowed packaging to enter digital innovation and become connected. In this work, such packaging is referred to as Smart Interactive Packaging. The latter provides an interactive dimension between the consumer and the brand with the help of informing and measuring sensors, light-emitting displays, standardized communication protocols and other electronic elements that increase the design freedom for new packaging applications.

Near Field Communication is one of the rapidly increasing technologies that researchers begin to investigate as a potential tool for enhanced consumer-brand communication. In general, NFC is a standard for a wireless data transmission that provides secure, short-range, and paired communication capability between devices triggered by a simple touch [9]. However, despite the fact that NFC is available in the market since late 2010, the technology has not yet reached its way to enhanced consumer engagement through the product's packaging. Even though the technology has been already commercialized, it is still not widely applied to the packaging industry. As a result, the main purpose of this research is to investigate the current state-of-the-art and potentials of NFC system, including the overview of the main characteristics, technological capabilities, benefits, and potential barriers for NFC to become widely accepted.

2 Methodology

This research methodology employs multi-method research approach to combine the current theoretical knowledge about NFC technology from the scientific literature with real-world empirical cases to expand the understanding of both theory and observed phenomena [10]. As a result, the study is based on a systematic literature review focused on scientific publications related to the topic of Near Field Communication and its application, particularly for smart packaging. Moreover, this research employed a set of empirical examples from the industrial cases of diverse NFC technology providers collected by desk research (including product datasheets, technical reports, press releases, whitepapers), direct observations and semi-structured interviews with companies' representatives during the attended industrial events. Practical industrial data was needed to verify current NFC specifications, to broaden the scope of collected knowledge, and increase data triangulation.

Literature review used the keyword-based search approach in the largest databases of peer-reviewed literature, namely Scopus and Web of Science. A wide range of keyword variations was used to come up with the best combination yielding publication results concerning and related to the selected research scope.

During the keyword search, a few insights were gained that allowed to limit the search process. For instance, the abbreviation of NFC also refers to fluorescent nanofibrillated cellulose/carbon dot (NFC/CD) that is also present in the packaging research, and therefore in order to prevent confusion and irrelevant research outcomes, the abbreviation was changed to the specific phrase of "near field communication".

Another observed insight was that packaging could also be referred to electronic packaging, where research is carried out in regards to sophisticated electronics systems. Therefore it was decided to limit the search specifically to product packaging.

Also, some publications related to materials science and fabrication of the NFC, as [11–14], were included only to support the theoretical background of the research in terms of NFC components.

Moreover, a handful list of research [7, 13, 15–17] investigates NFC as a way to communicate sensor information in regards to food spoilage, track and trace, monitoring of the package surrounding environment.

However, this study aims to take a more novel approach and investigate NFC potentials substantially related to enhanced consumer, retailer and brand experiences, such as engagement and entertainment, confirmation of authenticity, prevention of counterfeiting and grey market division. It has been an increasing interest from the industry for anti-counterfeiting and entertaining capabilities provided by NFC technology [18–24], therefore the search was narrowed down to these specific experiences. Also, several studies [25–27] have been selected to include that identified factors facilitating or impeding the adoption of NFC technology and consumer acceptance of NFC system.

The final determined limitation was not to take into consideration the mobile payment possibilities with NFC since a significant number of researches towards NFC and user experience is done in terms of contactless payment.

The outcomes from systematic literature review based on keyword search and empirical data collection yielded results presented in this paper as (1) an overview of the main components of NFC system, (2) a list of technologies capabilities provided by NFC attached to product packaging, (3) a list of contributed/created consumer and brand experiences, (4) an overview of potential barriers for NFC to become widely accepted.

3 Theory

3.1 From Passive to Connected: Smart Interactive Packaging

Nowadays, the consumer market brings into play many different digital interfaces to create the link between consumers, products and brands in order to deliver unexpected and unique user experiences [5]. Recently, product packaging also became one of such digital interfaces. The emerging infrastructure of digital-physical systems consisting of everyday items and advanced wireless communication devices, such as wireless networks, light-emitting devices, smart sensors and tags, opens a new digital dimension for human-packaging interaction (Fig. 1).

In general, the packaging is defined as a combination of product, package, and distribution, which is intended to provide protection, convenience, containment, and communication throughout the entire supply chain until goods reach the end-user [8, 28]. However, recent advances in enabling technologies improved the communication function profoundly and allowed the packaging to become connected. As a result, such packaging improves the traditional one-way information flow and triggers continuous interaction between the consumer and the brand [29]. Therefore we define smart interactive packaging as packaging that provides an interactive dimension between the consumer and the brand with the help of various enhanced communication devices, where the user initiates the interaction willingly to get some response.

In fact, there are several different environments/touchpoints, where users-packaging interaction takes place: manufacture, distribution system, retail or in-store, and at-home. This study investigates human-packaging interaction enabled by NFC technology in retail and at-home settings – the environments that are likely to benefit the most from of NFC systems. The following section will provide more detailed information about the main characteristics of NFC technology.

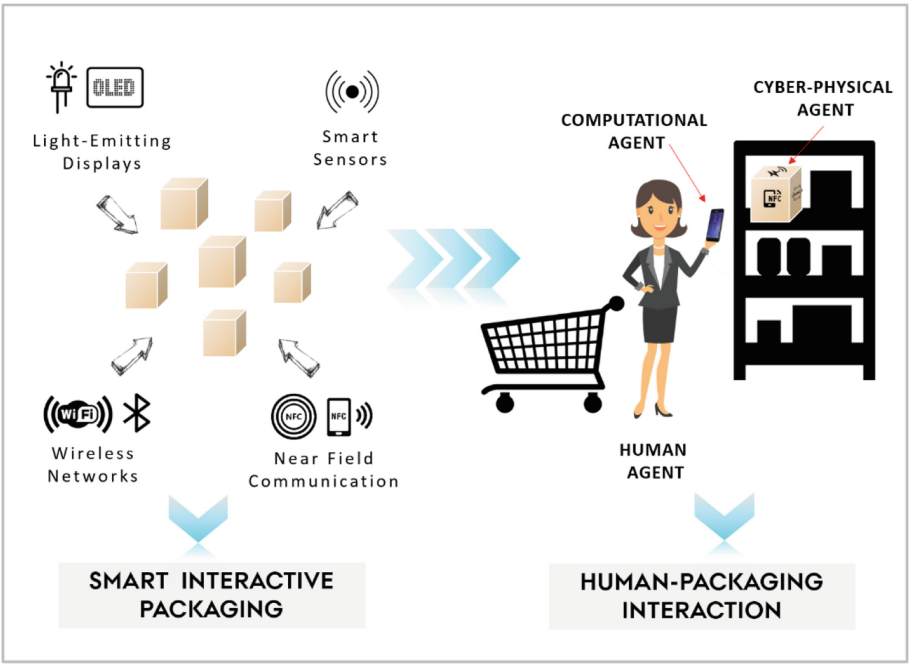

Fig. 1. Smart Interactive Packaging as interactive system that includes actions from the human agent, computational agent (mobile device), and cyber-physical agent (packaging).

3.2 Near Field Communication

In recent years, different types of short-range communication technologies have been integrated into smartphones, including Bluetooth, infrared transceivers, RFID, and NFC [25]. The former is currently perceived as one of the most promising technologies for mobile devices in the coming years [25]. Although NFC has existed for more than a decade, it has just recently come into the surface with the remarkable growth of the Internet of Things [16].

In general, NFC is a standard for a wireless data transmission that provides secure, short-range, and paired communication capability between devices triggered by a simple touch [9]. NFC technology is based on the ISO/IEC14443 protocol. It operates at 13.56 MHz frequency with a maximum transmission speed of 424 kbit/s within an operation radius of 4 cm (up to a maximum of 10 cm) to create a peer-to-peer network for sending and receiving information between the initiator and target [11, 30]. In the NFC system, the initiator or the reader is always an element that actively functions, e.g. mobile device, whereas the target or receiver is usually a passive element, such as NFC tag [31]. In order to initiate the data exchange, the target (NFC tag) is placed in the magnetic field created by the reader (mobile phone), the tag antenna harvest energy received from the mobile device to wake the tag up, and data is then sent to the reader using a standardized format created by NFC Forum called NFC Data Exchange Forman (NDEF) [16]. NDEF permits to storage and transport various types of information, like Uniform Resource Locators (URLs), Record Type Definition (RTD), or Multipurpose Internet Mail Extensions (MIME) messages [31].

Currently, NFC applications are widespread in transport cards, door access, contactless payment, and other mediums where simple data as an identification number or text is exchanged securely and promptly between devices without pairing [16]. NFC technology is becoming more commonly used for various purposes for product packaging as well. First of all, food and beverage packaging industries utilize NFC tags to read, store and transmit data from oxygen, relative humidity, temperature and other sensors to monitor the conditions of the packaged products to ensure their quality [7]. Also, packaging can be equipped with an NFC chip to provide brands with an additional level of protection by enabling traceability and authenticity of the product, especially to fight against counterfeiting [6]. Finally, digitalizing products via NFC technology allows personalized and customized mobile promotions and reward-based interactions to increase product perception and brand loyalty [6].

Below, in Table 1, there is a list of NFC technology providers that manufacturer, create and build various elements or services related to NFC technology. Some of the given providers present fully-integral NFC systems, where all physical and digital components are developed in-house. On the other hand, other providers specialize in specific NFC system elements. For instance, NXP's expertise lies in NFC chips, whereas Avery Dennison specializes in printed NFC antennas and inlays. Providers are also establishing collaborations to create joint technological solutions.

Table 1. The summary of NFC providers (retrieved from products' datasheets [32–39])

Provider	Key NFC technologies	Main capabilities
Thinfilm	OpenSense™ and SpeedTap™ NFC tags, opening sensors	Refill fraud, anti-counterfeiting, identification, track and trace, authentication, tampering, real-time monitoring
NXP	NTAG 213, NTAG® 424 DNA & DNA TagTamper, sensors (touch, magnetic, capacitive, motion, pressure)	Cryptography, secret keys, authentication, tampering, real-time monitoring, refill fraud, anti-counterfeiting, cloud-based services
Toppan	CorkTag™, Cachet-Tag™ with antenna circuit, InTact, OD Tag	Detection of removal and piercing of the cork, prevention of fraudulent re-labelling, cork protection, authentication and opening detection
Avery Dennison	AD-740/750 NFC Wet/Dry Inlays, T Sensor Plus™ NFC tag	Temperature data logging, originality signature, automatic serialization NDEF messages, password protection, fraud prevention, unique 7-byte serial number
PragmatIC	ConnectIC®, FlexIC®	Flexible integrated circuits, item-level monitoring, grey market, authentication, gamification, promotional offers
Identiv	NXP ICODE® SLIX, NXP ICODE® SLIX HC, ST SRI	Consumer interaction, brand protection, product integrity, status awareness, anti-counterfeiting, authentication, physical security
Stora Enso	Bobbin NTAG213	Authentication, password protection, targeted marketing, consumer engagement and experience
WISeKey	WISeCryt™ based digital authentification, NanoSeal®	Anti-counterfeiting, authentication, brand loyalty, consumer insights, access control, tamper/opening detection, traceability, maskable identifier

4 Results

Technological capabilities of NFC system have been divided into three main groups: data and information services, security services, and other services (Table 2).

4.1 Data and Information Services

Data Storage. As discussed in the theory section, the NFC tag mainly consists of a chip and antenna. The majority of technological capabilities provided by NFC technology rely on its chip. NFC tags specifically designed for smart packaging application usually comprise Read/Write memory size of between 144 and 888 bytes and they are wirelessly powered by a smartphone [11, 33]. NFC tags can store NDEF (NFC data exchange format) data in the form of URL, telephone number, geolocation, SMS, plain text, network connection and similar that makes them fully compatible with every NFC-enabled smartphone and the entire ISO/IEC 14443 infrastructure [33]. As a result, the very primary NFC functionality is to store encoded/written data in heterogeneous formats. Usually, the product-specific or customer-specific data is already encoded in the chip before the tags are shipped to the manufacturer [32].

The most common type of stored data is the URL that redirects the user to particular content, in most cases, hosted by the brand owner's CMS [32]. Consequently, NFC provides novel opportunities for brands and retailers to communicate engaging and dynamic content, such as more explicit product information, proof of legitimate distribution, region and year of production, recipes and etc [34, 40], in different means of media. For instance, NFC tag attached to a wine bottle can contain information about the product's origin, traceability, or even all processes followed up for its fermentation [18].

Data Collection. Some of the data not only can be encoded/written in advance but also it can be collected during the entire life-cycle of packaging. The combination of sensing devices and NFC connectivity allows the autonomous data collection. The collected data is uploaded securely into the cloud via NFC by a simple tap with a smartphone [33]. There are various smart sensors that can be incorporated in the overall NFC integrated circuit to monitor conditions such as relative humidity, shocks, vibrations, oxygen levels, temperature and similar, and, in turn, to collect the quantitative data of the current status of the packaged product and its surrounding environment [7, 33]. For instance, reference [15] fabricated a flexible system of NFC and sensing devices that collected data regarding ammonia (NH3) and oxygen levels in the meat packaging. Similarly, reference [17] demonstrated an NFC-enabled sensing system that was able to detect and collect the data about the level of water-soluble gases in the packaging atmosphere.

Data Logging. Another method of data collection is manual or autonomous data entry by human agents. Even though this activity might happen in every process of the supply chain, NFC technology due to its short-range reading capability is mostly related to data entry or logging that happen in the retail and at-home environments. Therefore, marketing campaigns in-store are increasingly interested in NFC capabilities for instantaneous feedback, streamlined data collection and entry that allow capturing real-time consumer interaction with products [40].

Data Transmission. Once data is stored, automatically collected or manually entered, it can be transmitted, read or exchanged between devices upon the initial request from the human agent, commonly, to receive access to the respective additional information

[7, 30]. Data from sensors not only can be collected but also be read by NFC reader to retrieve the information in a visual form on the smartphone's screen [13, 41]. According to [7] more recently, NFC has been adopted as main technologies attached to the packaging for the reading of the sensors and the transmission of data by a remote NFC reader.

Furthermore, data transmission is becoming more favorable in the retail setting, where shoppers can check and obtain diverse data about the products, for instance, the availability or stock information directly at the point of sale with their NFC-enabled smartphones [19]. When the NFC tag is positioned in the RF field, the transmission of the data is around 106 kbit/s [33]. In terms of peer-to-peer communication, NFC Simple NDEF Exchange Protocol (SNEP) permits an application on an NFC-enabled device to exchange (NDEF) messages with another NFC Forum device while operating in NFC Forum peer-to-peer mode [42]. This protocol utilizes particular connection-oriented transport modes to ensure a reliable data exchange that, for instance, is essential for voucher transmission [42].

In practice, all the sub-functions of data services capability are connected and operate in succession. For instance, Bon-Ton, a regional, departmental store company, launched an initiative to inform shoppers about the current stock status of particular sizes of [40]. First, the data about the inventory was stored and continuously updated in the NFC chip and the database. Once the consumers tap on the NFC-enabled packaging, the data transmission is initiated and the specific information, if a specific size shoe is in stock or not, is provided. NFC-enabled packaging provides shoppers with access to information through their mobile devices [43].

4.2 Security Services

Identification. Currently, the majority of NFC applications contain simple data such as an identification number or text that are exchanged immediately and safely between two devices [16]. Similarly to barcodes that contain the International Article Number (EAN), RFID tags are designed to store the Electronic Product Code (EPC) – a standard for automated item-level product identification [19]. In the last decade, there were many attempts to develop a solution of NFC that uses HF frequencies to be compatible with EPC [19, 44]. At the moment, NFC chips store a unique identifier that provides the capability to be uniquely identified in through the Internet or managed in a supply chain [18, 20, 45]. As a result, NDEF on the NFC tag can store unique (serialized) identifiers in Unique Resource Identifier (URI) format [19], or Unique Identifier (UID) format [33]. For example, in the manufacturing line, Industrial Line Manager (ILM) consisting of a computer and NFC reader can detect any thresholds and deviations from accepted standards by reading product/packaging information written in its tag's UID [34].

Validation and Redirection. In regards to validation and redirection, UID is closely related to database and cloud services, where identities of items are protected and controlled, giving each product a persistent, addressable web-based presence [32]. For example, NXP provided NFC solutions use could services that are accessible using standard RESTful APIs to permit straightforward and prompt integration into brand owners

database/business intelligent system and software [32]. In other words, validation and redirection processes link products to manufacturers' digital platforms. As a result, NFC tags obtain a specific code that allows brands to identify and launch a unique experience for each individual package in-store [37].

Authentification. NFC-enabled intelligent packaging applications encompass a wide variety of other technological capabilities related to product's security and authenticity [31, 46]. Contrary to a prime understanding of authenticity as an action for authenticating who is accessing the information, smart packaging applications are more about the user aiming to know that the system, in this case, a product, is a product it claims to be. Consequently, some research has already been carried out to analyze the potential of NFC technology as means of the authenticity of the product [22, 45, 47, 48, 55]. According to [48], NFC tags grant a simple, small-sized and secure way to verify the genuineness of the product. NFC technology permits any object to securely authenticate itself and communicate this information online through NFC readers [39]. Currently, smart packaging contains NFC tags that are not only capable of detecting counterfeits, grey-market products, and tampering, but also implement secure marketing campaigns by assuring that only requests originated from authentic tags are forwarded to brand's web systems [32, 45]:

- Anti-counterfeiting. Counterfeit products are one of the main threats to commerce accounting up to 5–7% of all world trade goods and global economic value of over $ 865 bn [45, 48]. The development of consumer-centered NFC tags allows shoppers to determine the legitimacy of a product at the point of purchase, and, in turn, enhances direct-to-consumer digital strategies [45]. EPC standard can be used as an anti-counterfeiting measure by tracking the physical location of a tag and uploading the results in the database [45]. Consequently, product diversion can be detected by a simple scan and reported directly to the manufacturer contributing to grey market prevention [34].
- Tampering. Product tampering is another threatening factor to modern commerce. Diverse tamper-related incidents might happen in the entire supply chain that can be handled and controlled by adherence of NFC tags, including prevention of fraudulent re-labelling, opening detection/unopened product proof, refill fraud, detection of removal and piercing of the bottle cork, and other fraudulent events [33, 34]. For instance, once the wine bottle protective cork foil is removed, a brittle antenna circuit is damaged, and the tag is unreadable that might indicate a refill fraud.

Encryption. Another, more sophisticated, anti-counterfeiting approach is based on cryptography [42, 45]. In this method, each tag contains a secret encrypted value that is unreadable by anyone who does not possess a decryption key [45]. In general, this approach utilizes an encrypted challenge-response protocol and may be based on symmetric key or asymmetric key cryptography (or Public Key Cryptography (PKC)) [45]. In-store environment, where shoppers use their smartphones to read NFC tags, PKC is preferable for authentication purposes [22].

There are to main categories of counterfeiting prevention based on cryptography: off-line and on-line [45]. The former encompasses no shared secret between the NFC

reader and the tag attached to a product, i.e. if the tag's contents are verified, and the tag is authenticated, the packaged product is presumed to be genuine [45]. The latter contains secret information shared between the reader and a tag, i.e. in order to determine the authenticity of a product, the reader requires access to a server containing a database of secrets [45].

NXP developed cryptography solutions in NTAG™ 424 DNA and NTAG 424 DNA TagTamper support relevant cryptographic operations and offer trust provisioning services, including creation, provisioning and managing of (1) customer dedicated keys in hardware secure modules that have access to master secrets, (2) secure key exchange and management, (3) SUN (Secure Unique NFC) message and encrypted SUN message verification, (4) tamper message verification (5) mutual authentication [32]. Such advanced security solutions: encrypt all critical data in transit and storage, protect access to target URL or tag memory, protect the master secret against malicious attacks or breaches, permit logging of data requests and changes, detect valid/invalid authentication request, provide patent ending dynamic cryptographic digital signature [32]. To summarize, based on NXP developed products, NFC uses symmetric cryptography with secret keys for encryption and decryption to protect the information, therefore whenever a key exchange is needed, it is done with encryption applying a secure communication channel [32].

4.3 Other Capabilities

Coupons and Vouchers. NFC technology proposes several diverse opportunities for brands and retailers to interact and engage with consumers with promotional efforts, especially couponing [24, 30, 40]. Reference [42] states that "the system is responsible for diffusion, distribution, sourcing, validation, redemption and managing of vouchers, loyalty cards and all kind of mobile coupons using NFC". The potential scheme of the NFC-coupon system might be as presented by [42]: at the point of sale, the shopper uses his/her smartphone to touch the NFC-equipped product to redeem a voucher, then the information is read from the smartphone and sent to the server for the voucher validation, once the validity is confirmed, the voucher is sent to the shopper.

NFC technology also employs location-based promotional offers, when users receive coupons on their mobile phones depending on their physical location and can redeem them at the offered retail outlet [40]. Furthermore, the NFC-based promotions can also be personalized. Depending on the shopper's previous visits to the stores, time-stamped promotion coupon can be forwarded and displayed on shopper's mobile phone to facilitate purchase decisions, when a shopper enters the store [20].

Loyalty, Bonus and Memberships. With the use of NFC technology, brands and marketers can carry out better customer loyalty programs in several techniques [40]. First of all, if loyalty, bonus and membership cards are stored on the mobile phone, NFC provides a possibility to automatically accumulate points, receive discounts, coupons, priority reservations, special offers, event invitations, product samples or other incentives [30, 34, 35]. Also, NFC allows instantaneous consumer feedback and streamlined data collection and entry [40] that benefits brands with in-depth real-time insight about

their products and enables instant response to a consumer to contribute and enhance consumer loyalty.

Location-Based Services. NFC technology can be used for a wide range of context-aware services, including:

- Previously described location-based couponing, advertising, in-store marketing, and mobile marketing [21, 30, 49]. Once a registered shopper carrying an NFC-enabled smartphone with an app for personalized promotion system comes to a close range of a passive NFC tag attached to any items in the store, the is activated, and its unique ID and its location information is collected to grant a shopper with special promotions [20].
- Transparent tracking in the supply chain [32, 34, 35]. NFC enables traceability solutions relation to serialization, aggregation and data handling to provide real-time supply chain visibility in order to protect brands against grey market distribution, i.e. NFC scan allows to detect item's location at the specific time.

Social Networks. Reference [43] argues that the purchase of a product is motivated by the attempted acquisition of a certain status that is granted by a social reference group. In other words, the buying decision is highly dependent on suggestions and opinions from other consumers, such as friends, relatives, partners, etc., i.e. people tend to seek information before choosing [43]. Consequently, the opinions of others might reduce or increase the perceived credibility of the product [43]. If there is no physical presence of other consumers, the opinions and recommendations can also be derived from social networks. The NFC-enabled system is able to make links with social media to provide first-hand experience and recommendations from others [30, 34, 50].

Energy Harvesting. In general, a passive NFC tag is able to obtain energy from the radio frequency generated from the active NFC reader (smartphone) due to the electromagnetic field induced by the active device [7, 20]. Recently, NFC-based energy harvesting has been attracting more research attention in regards to its promising potential [16]. It might not only be used for data transmission, but also for powering up embedded sensor modules that measure diverse environmental parameters such as pH, soil moisture, temperature, gas concentration, humidity, and similar [16]. Reference [16] has fabricated battery-free smart sensor capable of less than 1 mW of power consumption, thus the energy from active NFC reader is enough to power up the sensor and read its data. NFC-based energy harvesting reduces the system cost by removing the need for a specialized NFC reader [16].

Network Access. The capability to provide network access is twofold. First, NFC technology redirects the user to the web through the encoded links (URLs). Second, users tapping on an NFC tag can also be logged onto a Wi-Fi or connected to a Bluetooth [30].

Device Pairing. By a simple tap, for instance, on a Bluetooth speaker, NFC technology makes the pairing process effortless, and the two devices are securely paired automatically with no need to search for a connection or type a code [30, 33].

Table 2. The summary of investigated NFC technological capabilities

Technological capabilities	Short descriptions
Data storage	To store encoded/written data in heterogeneous formats
Links to URL	To redirect the user to a particular content hosted by the brand owner's CMS
Data collection	To collect data autonomously using sensing devices that monitor different conditions
Data logging	To allow manual or autonomous data collection by human agents (e.g. feedback)
Data transmission	To transmit, read or exchange data between devices upon the initiative request from the human agent
Identification	To store a unique identifier that provides the capability to be uniquely identified in through the Internet
Validation and redirection	To protect and control product identities giving each item a persistent, addressable web-based presence
Authentication	To provide a simple and secure way to verify the genuineness of the product
Encryption	To secure data with secret keys and provide trust provisioning services/cryptography
Coupons and vouchers	To diffuse, distribute, source, validate, redeem and manage coupons and vouchers based on location or personalization
Loyalty, bonus, membership	To implement better customer loyalty programs by automatically accumulating points, providing discounts, offers and other incentives
Location-based services	To grant a user with diverse incentives based on location, and to enable traceability solutions to provide real-time supply chain visibility
Social networks	To provide a link with social media to provide first-hand experience and recommendations from others
Energy harvesting	To enable data transmission and power up embedded sensors and read their data
Network access	To log onto Wi-Fi or get connected to a Bluetooth by a tap
Device pairing	To securely and automatically pair two devices without searching for a connection or typing a code

5 Discussion

In this section, two different matters are addressed: consumer- and brand/retailer-oriented benefits from NFC, and potential user- and technology-centered barriers for NFC to become widely accepted.

5.1 Consumer-Oriented Benefits

Consumer Engagement. By attaching NFC tags to traditional customer engagement mediums, such as signage, posters and packaging, brands can create unique interactions and experiences for their customers [37, 40]. NFC-enabled packaging is able to transform products into a direct engagement channel to connect with shoppers directly at any time [34]. Reference [43] concurs and states that context-awareness technologies and ubiquitous networks provide users with access anywhere and anytime to information through their smartphone with no need of special assistance in the retail environment. As a result, the retail settings are shifting to new forms of store/space filled with increasing use of advanced technologies, such as NFC [43]. These technological innovations impart unique, interactive and entertaining tools to search, compare, and purchase products [43]. Consequently, the progressively increasing use of technologies during shopping may have an impact on consumers' shopping practices and behavior [42, 43].

Fast-moving technology-based shopping experience induced by NFC capabilities allows facilitating such elements as convenience, trust, loyalty or even intent to purchase the product. Previously presented cased of the NFC-enabled packaging for shoes not only converts the package to engaging media but also provides a straightforward and convenient way for customers to get the information about the right size availability [40]. Furthermore, NFC capability to verify authenticity, integrity, safety and quality of the packaged items builds consumer trust in both products and manufacturer/service provider [34, 49]. Finally, context-based NFC technology is also used as a mean to motivate customers to come to stores. Depending on interpreted customer interests in the displayed items, the personal promotion strategies are formulated in order to increase the intent to purchase [20].

Customization. Naturally, the employment of NFC technology allows gathering a vast amount of customer-related information about their preferences, behaviors, and responses [30, 50]. For instance, based on the purchase history from customer's previous visits to the stores, personalized promotion strategies are built and sent to customer's smartphone in forms of coupons or vouchers [20]. As a result, customization and geo-localization have beneficial effects in regards to increased market visibility for brands and products [30], as well as a deeper and more personal relationship with consumers [33].

5.2 Brand/Retailer-Oriented Benefits

There is a handful list of benefits NFC-enabled packaging brings to brand owners, including sales process optimization and increase, brand protection, enhanced brand-consumer relationship, consumer satisfaction and loyalty, and new marketing positions. Reference [19] presented the Mobile Sales Assistant (MSA) system allowing users to instantly check the availability and stock information of products might increase customer satisfaction with a fast and simple experience that, in turn, might can a positive outcome for product sales. Consequently, increased NFC-enabled engagement with consumers can

be directly related to driving sales. Likewise, the combination of digital product authentication and enhanced consumer engagement help brands improve their reputation and maintain valuable relationships with consumers.

On the other hand, NFC-based packaging also creates new forms of in-store marketing campaigns. An example of such campaign given by [20] describes a promotion scheme to increase the number of shoppers visiting the stores, where each checking with an NFC tag provide a bonus mark to the consumer. The accumulated points can be transformed into discount and purchase benefits [20].

Real-Time Analytics. Web-based or cloud-based data management and analytic platform is an integral part of the NFC system. In general, such a platform is responsible for collecting data from consumers using NFC tags and performing advanced analytic techniques to gain meaningful and actionable insights for business development [23, 34]. This platform is capable of providing:

- Real-time analysis of scan/tap activity to measure the effectiveness of the integrated NFC technology [32, 34].
- Real-time analysis of regionally-focused data (geolocation), product status awareness, notification of use-by-date and other [34].
- Real-time analysis of products' performance [32].
- Real-time detection of irregularities related to authenticity, tampering or counterfeiting that can be dealt with momentarily [32].
- Recognized changes in consumers' shopping behavior due to the impact of NFC technology [23, 43].
- Captured real-time consumers interaction with the NFC-enabled product and their experiences based on feedback [34, 35].
- Captured individual consumer engagement to provide personalized and customized promotions [35].

Overall, described capabilities contribute to product and brand data management system, customer content management system, distribution management system, marketing analysis and other with the main purpose of increasing revenue from consumers' repeated purchases due to successful analytics [23, 34]. All the findings from collected data analysis are seamlessly linked to the brand's business intelligent system in order to help gather knowledge to make better decisions and take corrective actions [32].

5.3 Technology-Centered Barriers

Despite all the advanced and beneficial capabilities and benefits of NFC, the technology is still not widely accepted by the end-users or brand owners [26]. It might be related to any technological obstacles, consumer acceptance of the technology, or the economic benefit to implementing the technology into the business model, therefore this section shortly describes the possible and potential barriers for NFC to become widely accepted.

In relation to HCI theory, the design of NFC-enabled packaging, as a digital interactive system, has to follow the main principles of the interaction design in order to create a functional and effective connection between the consumer and the brand. However,

the success of creating this bond highly depends on whether the created digital-physical object can impart a pleasing interface with the user addressing both technology- and human-related factors. Reference [27] concurs and states that the intention to adopt NFC technology is affected mostly by product-related factors, personal-related factors and attractiveness of alternatives. Likewise, reference [26] also distinguishes factors regarding NFC adoption into user-oriented and system-oriented.

Two studies [26, 27] employed the Technology Acceptance Model (TAM) to provide a profound understanding and identify factors facilitating or impeding the adoption of NFC technology. Study [26] identified four system-centric variables beneficial for such adoption, including user mobility, reachability, compatibility, and user convenience. Any issue related to these factors might have a negative impact on the user's decision to use an NFC system [26]. Likewise, study [27] identified six product-related factors: perceived usefulness, perceived ease of use, compatibility, perceived risk, perceived cost, and trialability. However, named factors by [27] are highly related user's belief and perception rather than engineering- and technology-related concerns. Overall, based on both studies, product- or system-related elements seem to have a stronger effect on the intention to adopt NFC systems [26, 27].

In addition, based on the literature review, other more practical/technological obstacles have also been identified, including:

- The stability of the regulated voltage by the NFC chip. According to the authors, there are two external parameters that have an impact on stability: the powering time and the position of the mobile device when it is brought close to the NFC antenna. The chip requires a particular level of the induced electromagnetic field to provide the regulated power supply, therefore not every position of the smartphone can activate the tag. Only a small displacement is permitted to avoid the deactivation [7].
- Transmission speed. Due to low transmission speed (up to 424 Kbps), NFC technology is not capable of large files transfer, therefore it intercommunicates with other wireless networks as Wi-Fi and Bluetooth that permits greater in size transfers [31].
- Battery saving mode. Consumers are used to switching off various settings of mobile apps connecting the mobile device with a service provider to save battery power [40]. It might cause inconvenience during data transmission, as several intermediate steps will be necessary to enable the process, i.e. set up the right settings permitting internet connection.
- Privacy settings. Very commonly due to privacy concerns customers also switch of the permission to always track their geographical location on mobile devices [40]. In this case, personalized promotion strategies might not function as accurate as expected.
- A limited number of devices that support NFC technology [51].
- Awareness of NFC technology. Finally, NFC is still not widely known by consumers, therefore public prominence has to take place before the exponential growth in usage of this communication protocol [30].

5.4 User-Centered Barriers

Since interaction design is about creating the overall essence and structure of products and systems to ensure that they support user's needs, desires, goals, perspectives and

address their problems to provide enhanced user experience in their everyday lives, it is essential that interaction would be intuitive, enjoyable and effortless [52–54]. However, NFC technology has not yet reached its way to enhanced consumer engagement through the product's packaging. Even though the technology has been already commercialized (Seritag, Toppan, Identiv), it is still not widely applied to the packaging industry. The investigated literature addresses several user-related factors regarding the efficient adoption of NFC technology.

Three different studies related to Technology Acceptance Model and NFC that include consumer-related factors very investigated [25–27]. A study by [26] indicated the main two user-oriented factors, i.e. personal innovativeness and NFC knowledge, and two additional belief factors, i.e. perceived ease of use and perceived usefulness. Similarly, reference [25] included a few more concerns: personal innovativeness, convenience, perceived ease of use, perceived usefulness, perceived security, and perceived compatibility. Research by [27] tested two individual constructs, namely innovativeness in new technologies and absorptive capacity, and two additional constructs, namely trust and attractiveness of alternatives. User-oriented factors that are common amongst three studies:

Personal innovativeness. It refers to user's willingness to try out or embrace new information technology [25–27]. Therefore the difference in consumers' personal innovativeness should be taken into account in order to facilitate the usage of NFC technology. Also, one should consider that there are two different groups of people: early adopters and late adopters, i.e. users with a higher degree of personal innovation find NFC system more approachable [26].

- Perceived ease of use. It relates to the degree to which a user believes that the NFC system would require no substantial effort, i.e. NFC system has to be easy to use and easy to learn [25, 26].
- Perceived usefulness. The acceptance of NFC system highly relies on its provided unique advantage in comparison to existing solutions, like barcodes, QR codes, or Electronic Article Surveillance (EAS) tags [25, 26]. If users perceive alternatives as more attractive, it will have a negative effect on the intention to adopt NFC [25].
- Security and trust. According to the survey results by [25], users are more willing to use the NFC technology, if the perceived security is high. Users seem to be more interested in the security and trust of the NFC operations than on its ease of use [25, 27]. Moreover, it might also raise some privacy concerns, thus NFC system, for instance, has to offer valuable incentives in exchange for data [30].
- Knowledge and absorptive capacity. Users already having some knowledge about NFC would find the technology easier and more encouraging to adopt [26]. Moreover, understanding, acquisition and application of knowledge play a major role in user's absorptive capacity [27].

6 Conclusion

Equipped with NFC and other supporting computational devices capabilities physical items become uniquely identifiable, traceable, and, most importantly, interactive so they

are able to increase the value from the point of manufacture to the end-user hands. NFC ability to connect products to the network by a single tap brings the technology to light to be spotted by innovation-seeing brand owners and retailers. The engaging and interactive medium provided by the Internet can be handed over to consumers' palms through NFC and mobile devices. Technology-enriched stories about products, instant verification of product's genuineness, just-on-time received offers can significantly improve consumers' experiences and positively influence their perception of products. Likewise, since brand identity and reputation are built through consumers' interaction with their products, NFC enables brands to dynamically adapt to emerging consumer needs by improving their products and services, and deliver personalized value-added solutions.

This study brought a comprehensive understanding of prominent technological capabilities provided by NFC technology applied to the product packaging. The incorporation of NFC into overall packaging design allows the package to become an interactive digital interface with infinite possibilities depending on brands and retailers creativity. Based on the results, NFC technology can contribute and create better experiences for consumers, brands, and retailers. Furthermore, in order to build an intuitive, enjoyable and effortless system, packaging designers have to take into consideration technology- and user-centered factors that might form barriers for successful adoption of NFC technology.

To conclude, the study aimed to build a bridge and establish a close relationship between the industry and academia and merge both sources of knowledge to contribute to a better and more practical understanding of the current state-of-the-art of the NFC and overall human-packaging interaction.

References

1. Horan, B.: Branded interactions: trends and strategies for digital-physical products. Appl. Des. **64**(1), 16–19 (2016)
2. Tolino, U., Mariani, I.: Do you think what I think? Strategic ways to design product-human conversation. Strateg. Des. Res. J. **11**(3), 254–262 (2018)
3. Lowgren, J.: The Encyclopedia of Human-Computer Interaction. https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/interaction-design-brief-intro. Accessed 11 Oct 2019
4. Carli Lorenzini, G., Olsson, A.: Towards patient-centered packaging design: an industry perspective on processes, functions, and constraints. Packag. Technol. Sci. **32**(2), 59–73 (2019)
5. Bezerra, P.F., Arruda, A., Araujo, K.: Experience Design as a tool to promote interaction among users in the beverage market: proposal for a new emotional approach in usability. Procedia Manuf. **3**, 6028–6035 (2015)
6. Forcinio, H.: Smarter Packaging Comes to the Pharma Market: active and intelligent packaging technologies benefit brand owners, caregivers, and patients. Pharm. Technol. Eur. **31**(1), 12+ (2019)
7. Escobedo, P., et al.: Flexible passive near field communication tag for multigas sensing. Anal. Chem. **89**(3), 1697–1703 (2017)
8. Schaefer, D., Cheung, W.M.: Smart packaging: opportunities and challenges. Procedia CIRP **72**, 1022–1027 (2018)
9. Coskun, V., Ozdenizci, B., Ok, K.: The survey on near field communication. Sensors **15**(6), 13348–13405 (2015)

10. Dubois, A., Gadde, L.E.: Systematic combining: an abductive approach to case research. J. Bus. Res. **55**(7), 553–560 (2002)
11. Zhu, L., et al.: Silver nanowire mesh-based fuse type write-once-read-many memory. IEEE Electron Device Lett. **39**(3), 347–350 (2018)
12. Jung, M., Kim, J., Koo, H., Lee, W., Subramanian, V., Cho, G.: Roll-to-roll gravure with nanomaterials for printing smart packaging. J. Nanosci. Nanotechnol. **14**(2), 1303–1317 (2014)
13. Zhang, X., Shan, X., Wei, J.: Hybrid flexible smart temperature tag with NFC technology for smart packaging. In: 2017 IEEE 19th Electronics Packaging Technology Conference (EPTC), pp. 1–5. IEEE, December 2017
14. Yang, Y., Zhang, H., Li, J.: Effects of sintering temperature on microstructure and magnetic properties of NiCuZn ferrites for NFC application. In: 2018 19th International Conference on Electronic Packaging Technology (ICEPT), pp. 928–932. IEEE, August 2018
15. Li, S., et al.: Achieving humidity-insensitive ammonia sensor based on Poly (3, 4-ethylene dioxythiophene): poly (styrenesulfonate). Org. Electron. **62**, 234–240 (2018)
16. Nguyen, T.B., Tran, V.T., Chung, W.Y.: Pressure measurement-based method for battery-free food monitoring powered by NFC energy harvesting. Sci. Rep. **9**(1), 1–10 (2019)
17. Barandun, G., et al.: Cellulose fibers enable near-zero-cost electrical sensing of water-soluble gases. ACS Sens. **4**(6), 1662–1669 (2019)
18. Jara, A.J., Skarmeta, A.F., Parra, M.C.: Enabling participative marketing through the Internet of Things. In: 2013 27th International Conference on Advanced Information Networking and Applications Workshops, pp. 1301–1306. IEEE, March 2013
19. Karpischek, S., Michahelles, F., Resatsch, F., Fleisch, E.: Mobile sales assistant-an NFC-based product information system for retailers. In: 2009 First International Workshop on Near Field Communication, pp. 20–23. IEEE, February 2009
20. Lam, K.Y., Ng, J.K.Y., Wang, J., Ho Chuen Kam, C., Wai-Hung Tsang, N.: A pervasive promotion model for personalized promotion systems on using WLAN localization and NFC techniques. Mob. Inf. Syst. **2015**, 1–13 (2015)
21. Rohm, A.J., Gao, T.T., Sultan, F., Pagani, M.: Brand in the hand: a cross-market investigation of consumer acceptance of mobile marketing. Bus. Horiz. **55**(5), 485–493 (2012)
22. Urien, P., Piramuthu, S.: Framework and authentication protocols for smartphone, NFC, and RFID in retail transactions. In: 2013 IEEE Eighth International Conference on Intelligent Sensors, Sensor Networks and Information Processing, pp. 77–82. IEEE, April 2013
23. Wang, Q., Mohammed, S., Fiaidhi, J.: Near field communication tag-based system in retail marketing. Int. J. Future Gener. Commun. Network. **10**(7), 67–76 (2017)
24. Yildirim, K., Dalkiliç, G., Duru, N.: Formally analyzed m-coupon protocol with confirmation code (MCWCC). Turk. J. Electr. Eng. Comput. Sci. **27**(1), 484–498 (2019)
25. Bandinelli, R., Fani, V., Rinaldi, R.: Customer acceptance of NFC technology: an exploratory study in the wine industry. Int. J. RF Technol. **8**(1–2), 1–16 (2017)
26. Pal, D., Vanijja, V., Papasratorn, B.: An empirical analysis towards the adoption of NFC mobile payment system by the end user. Procedia Comput. Sci. **69**, 13–25 (2015)
27. Pham, T.T.T., Ho, J.C.: The effects of product-related, personal-related factors and attractiveness of alternatives on consumer adoption of NFC-based mobile payments. Technol. Soc. **43**, 159–172 (2015)
28. Mumani, A., Stone, R.: State of the art of user packaging interaction (UPI). Packag. Technol. Sci. **31**(6), 401–419 (2018)
29. Lydekaityte, J.: Smart interactive packaging as a cyber-physical agent in the interaction design theory: a novel user interface. In: Lamas, D., Loizides, F., Nacke, L., Petrie, H., Winckler, M., Zaphiris, P. (eds.) INTERACT 2019. LNCS, vol. 11746, pp. 687–695. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-29381-9_41

30. Basili, A., Liguori, W., Palumbo, F.: NFC smart tourist card: combining mobile and contactless technologies towards a smart tourist experience. In: 2014 IEEE 23rd International WETICE Conference, pp. 249–254. IEEE, June 2014
31. Cerruela García, G., Luque Ruiz, I., Gómez-Nieto, M.Á.: State of the art, trends and future of bluetooth low energy, near field communication and visible light communication in the development of smart cities. Sensors **16**(11), 1968 (2016)
32. NXP Whitepaper. https://www.nxp.com/docs/en/brochure/NXP-NFC-E2ESOLUTION.pdf. Accessed 01 Mar 2020
33. NXP Ntag213 Datasheet. https://www.nxp.com/docs/en/data-sheet/NTAG213_215_216.pdf. Accessed 01 Mar 2020
34. Toppan Whitepaer. https://www.toppan.com/event/aipia2019.html. Accessed 1 Mar 2020
35. Avery Dennison Whitepaper. https://label.averydennison.com/content/dam/averydennison/lpm-responsive/na/doc/case-studies/product/intelligent-labels/industry-solutions/cs-eu-mineral-fusion-directLink-12172015-en.pdf. Accessed 01 Mar 2020
36. PragmatIC Website. https://www.pragmatic.tech. Accessed 01 Mar 2020
37. Identiv Report. https://www.identiv.com/community/2019/11/06/identiv-collaborates-with-nxp-to-power-new-kraft-heinz-intelligent-instant-redeemable-coupon-for-more-meaningful-frictionless-customer-connections/. Accessed 01 Mar 2020
38. Stora Enso Bobbin NFC Datasheet. https://www.storaenso.com/-/media/documents/download-center/documents/product-brochures/intelligent-packaging/bobbin-nfc-label.pdf. Accessed 01 Mar 2020
39. WISeKey Website. https://www.wisekey.com/nfctrusted/. Accessed 01 Mar 2020
40. Abhishek, Hemchand, S.: Adoption of sensor based communication for mobile marketing in India. J. Indian Bus. Res. **8**(1), 65–76 (2016)
41. Zhu, R., Desroches, M., Yoon, B., Swager, T.M.: Wireless oxygen sensors enabled by Fe (II)-polymer wrapped carbon nanotubes. ACS Sens. **2**(7), 1044–1050 (2017)
42. Borrego-Jaraba, F., Garrido, P.C., García, G.C., Ruiz, I.L., Gómez-Nieto, M.Á.: A ubiquitous NFC solution for the development of tailored marketing strategies based on discount vouchers and loyalty cards. Sensors **13**(5), 6334–6354 (2013)
43. Pantano, E., Gandini, A.: Exploring the forms of sociality mediated by innovative technologies in retail settings. Comput. Hum. Behav. **77**, 367–373 (2017)
44. EM Microeletronic. https://www.eejournal.com/industry_news/20150414-01/. Accessed 01 Mar 2020
45. Saeed, M.Q., Bilal, Z., Walter, C.D.: An NFC based consumer-level counterfeit detection framework. In: 2013 Eleventh Annual Conference on Privacy, Security and Trust, pp. 135–142. IEEE, July 2013
46. Simske, S.J.: Smart packaging for security and logistics. In: NIP & Digital Fabrication Conference, vol. 2011, no. 2, pp. 801–804. Society for Imaging Science and Technology, January 2011
47. Przyswa, E.: Protecting Your Wine. Stop counterfeiters from selling cheap imitations of your premium brand. Wines and Vines, pp. 38–47 (2014)
48. Schilling, J., et al.: Secured miniaturized system-in-package contactless and passive authentication devices featuring NFC. In: 2016 Euromicro Conference on Digital System Design (DSD), pp. 439–445. IEEE, August 2016
49. Violino, S., et al.: Are the innovative electronic labels for extra virgin olive oil sustainable, traceable, and accepted by consumers? Foods **8**(11), 529 (2019)
50. Kneißl, F., Rottger, R., Sandner, U., Leimeister, J.M., Krcmar, H.: All-i-touch as combination of NFC and lifestyle. In: 2009 First International Workshop on Near Field Communication, pp. 51–55. IEEE, February 2009
51. Đurđević, S., Novaković, D., Kašiković, N., Zeljković, Ž., Milić, N., Vasić, J.: NFC technology and augmented reality in smart packaging. Int. Circular Graph. Educ. Res. **11**, 52–65 (2018)

52. Stolterman, E., Wiberg, M.: Concept-driven interaction design research. Hum. Comput. Interact. **25**(2), 95–118 (2010)
53. Coiera, E.: Interaction design theory. Int. J. Med. Informatics **69**(2–3), 205–222 (2003)
54. Wray, T.B., Kahler, C.W., Simpanen, E.M., Operario, D.: User-centered, interaction design research approaches to inform the development of health risk behavior intervention technologies. Internet Interv. **15**, 1–9 (2019)
55. Yiu, N.C.: An NFC-enabled anti-counterfeiting system for wine industry. arXiv preprint arXiv:1601.06372 (2016)