Ubiquitous Commerce: Theories, Technologies, and Applications

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***Abstract*—With the rapid development of ubiquitous computing and mobile communication technologies, the traditional business model will change drastically. As a logical extension of e-commerce and m-commerce, ubiquitous commerce (u-commerce) research and application are currently under transition with a history of numerous tried and failed solutions, and a future of promising but yet uncertain possibilities with potential new technology innovations. At this point of the development, we propose a suitable framework and organize the u-commerce research under the proposed classification scheme. The current situation outlined by the scheme has been addressed by exploratory and early phase studies. We hope the findings of this research will provide useful insights for anyone who is interested in u-commerce. The paper also provides some future directions for research.**

***Index Terms*—ubiquitous commerce, u-commerce, ubiquitous application, pervasive computing, wireless sensor network, RFID, location**

I. INTRODUCTION

With the rapid development of ubiquitous computing and mobile communication technologies, the traditional business model will change drastically. As a logical extension of e-commerce and m-commerce, Watson [1] proposed the concept of ubiquitous commerce (u-commerce) in 2000. As the next generation business model, it immediately triggered a lot of attention among academic circle, enterprises and governmental agency. Not only many foreign universities and institutions joined this research project, but also many companies such as Accenture begun the application research of U-Commerce. To facilitate the development of better u-commerce research and application, it is important to propose a suitable classification scheme and organize the u-commerce research under the proposed classification scheme.

The contribution of this paper is the proposed theoretical framework, around which the paper is organized. Our framework provides a guiding structure that allows us to effectively accumulate knowledge, and to interpret previous findings. The framework not only helps to explain the existing body of knowledge on each factor of the framework, but, more importantly, it also provides an overview of the U-Commerce's current research situation, illustrating how the various perspectives and research findings fit together as part of the big picture.

The study is organized as follows: first, a classification scheme used in the study is described; second, the current situation outlined by the scheme is addressed by exploratory and early phase studies; finally, conclusion are presented and the future research trend are discussed.

II. A CLASSIFICATION SCHEME FOR U-COMMERCE RESEARCH AND APPLICATION

To facilitate our research that would be made valid and reliable, we designed a suitable classification framework for u-commerce research, as depicted in Fig.1.

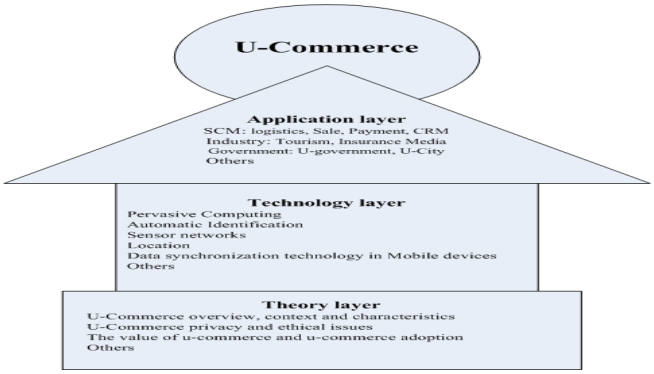

Figure 1. Classification framework for u-commerce research and application

Figure 1 shows that u-commerce research consists of three layers and each of them is discussed as follows:

- The theory layer includes the definition, character, the components, and security of u-commerce. It is the basis of the other layers, which provides guidance for other layers.

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- The technology layer includes Pervasive Computing, Automatic Identification, sensor networks, location and data synchronization technology in Mobile devices.
- The application layer includes SCM, Industry Application, Government and etc.

III. THE CURRENT SITUATION OF U-COMMERCE RESEARCH AND APPLICATION

A. Theory layer

1) The defition of u-commerce

U-commerce emerges as a continuous, seamless stream of communication, content and services exchanged among businesses, suppliers, employees, customers, and products [2]. It will enable interactions and transactions to happen anywhere and at any time without being constrained to stay connected through power and telephone lines. Through the convergence of the physical and digital means, u-commerce can create higher levels of convenience and added value. Hence, u-commerce can be defined as: The use of ubiquitous networks to support personalized and uninterrupted communications and transactions between a firm and its various stakeholders to provide a level of value, above and beyond traditional commerce [3] [4]. Sheng Hong [5] identified these stakeholders that include customers, suppliers, governments, financial institutions, managers, employees, and the public at large. U-commerce can be viewed as an application of ubiquitous computing that supports communications and transactions between organizations and their stakeholders.

2) From E-Commerce, M-Commerce, to U-Commerce

U-commerce can be viewed as a logical extension of e-commerce and m-commerce. It represents the next phase of commence, which is initiated by e-commerce and propagated by m-commerce [3].

E-commerce refers to the use of Internet technology for communications and transactions between an organization and its various stakeholders; m-commerce extends e-commerce into mobile and wireless channels and possesses unique features such as portability, reachability [8], accessibility [9] [10], localization [8] [9] [10], and identification [3].

Junglas and Watson [3] identified four factors that can shape m-commerce into u-commerce: mobile applications, mobile networks, mobile devices, and data synchronization. Currently, most of these factors/dimensions appear to be limitations, but with time, these limitations are expected to be overcome, i.e., mobile applications, networks, and devices are expected to merge and data are fully synchronized in the future.

3) Characteristics of u-commerce

Watson mentions in his paper 《U-Commerce: The Ultimate》 in 2000 that: U-commerce should be the ubiquitous, universal, unique and unison.

In 2006, Watson made further description about these four characteristics in the literature [3]. He pointed out that:

Ubiquity = Reachability + Accessibility + Portability
Uniqueness=Localization+ Identification + Portability
Universality = Mobile Networks + Mobile Devices
Unison = Mobile Applications + Data Synchronization

Ubiquity means that computers are everywhere, and people are able to access networks and be reachable at anytime and any place. Universality will eliminate the problem of incompatibility caused by the lack of standardization, so people can have universal devices that stay connected all the time regardless of their locations. Uniqueness suggests that users can be uniquely identified not only by identity and preferences, but also in terms of geographical positions. Therefore, uniqueness incorporates the idea of identification, personalization, and localization. Unison allows data to be integrated across different applications so that people have a consistent view of information [3][4][12] .

These four 'U' constructs differentiate u-commerce from m-commerce and can serve as foundations for understanding u-commerce [3]. The four 'U' constructs proposed by Watson [4] are similar to the key drivers of nomadic computing identified by Lyytinen and Yoo [13]. According to Lyytinen and Yoo [13], the essential characteristics of a nomadic information environment are high levels of mobility, large scale services and infrastructures, and digital convergence (which refer to the diverse ways in which data is processed and transmitted). These three characteristics – mobility, mass scale, and digital convergence – are the key drivers of a nomadic computing environment (see Figure2).

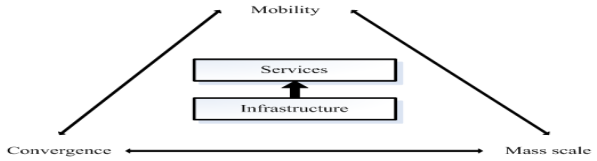

Figure 2. A Framework for Nomadic Information Environment

Ubiquity is conceptually similar to mobility; both of them express the idea of "anytime, anyplace". Mass scale is an implicit prerequisite for the 'U' constructs to exist [14]. Digital convergence, according to Lyytinen and Yoo [13], encompasses two of the "U" constructs identified by Watson [1] [4]: universality and unison.

The four "U" constructs define the key drivers of u-commerce and describe the fundamental characteristics of u-commerce; therefore, the four 'U' constructs will serve as conceptual foundations in this dissertation to provide the basis of defining and understanding u-commerce.

4) Components of ubiquitous commerce

The following subsections provide a description of each type of commerce that makes up u-commerce. Galanxhi-Janaqi, H and F. Nah identified that U-commerce is a new environment that combines wireless, television, voice and silent commerce with traditional e-commerce [7].

a) E-Commerce(Electronic commerce)

With the development of global information technology and Internet-based Web services, a new business model- electronic commerce is coming up. It not only sparked a revolution in the field of circulation, but

also has brought profound changes in social development. With the rapid development of e-commerce, many new body of the knowledge, legal, value and social organization theory emerged. Liang TP and Chen DN in the literature [15] propose ten basis theoretical knowledge of the e-commerce: TCT(Transaction Cost Theory), DT(Diffusion Theory), NET(Network Externality Theory), MRT(Media Richness Theory), TAM(Technology Acceptance Model), RRT(Resource Reliance Theory), SET(Social Exchange Theory), ST(Structuring Theory), TTF(Task Technology Fit) and SCT(Social Cognitive Theory).

b) M-commerce (Mobile commerce)

Mobile commerce is a key part of u-commerce, because it creates the possibility for communications between people, business and objects to happen anywhere and any time. People can use mobile phones or mobile devices to contact at any time and any place such as mobile phone, and PDA.

With the success of the 2008 Beijing Olympic Games, m-commerce is becoming increasingly popular, valuable and important for consumers and businesses. However, there are some obstacles to the full realization of the current mobile commerce, as follows:

- The use of mobile devices have certain limitations such as: different communications standards in different countries that do not allow the global use of devices, limited computational power, slow data transmission rate, and difficult navigation[7].
- In the field of technology, the mobile business wireless network infrastructure has been relatively mature, but the research of mobile middleware and end-user is still accordingly weak.
- Because the display interface of mobile device is relatively small, how to combine other equipment has become a worth studying issue.
- Trust is another major obstacle in its adoption and development [7].

c) V-commerce (Voice commerce)

V-commerce is a commerce based on listening and speaking. V-commerce, including automated speech-recognition, text-to-speech and voice-identification, enables business to reduce call-center operating costs and at the same time, to improve customer service. V-commerce can also be used to generate new sources of revenue, but this will probably take more time to materialize. Companies are mostly pursuing voice commerce as a part of a multi-channel strategy.

Accenture in the literature [2] mentioned the challenges to v-commerce, which include:

- it is still best suited for transactions that are simple, standard and frequent, such as simple account enquires, requests for information, placing orders and account payments;
- customer resistance may be high in cases when services cannot recognize speech accurately enough (basic voice-recognition systems can achieve accuracy rates of up to 97 percent);
- Language differences are another obstacle that needs to be overcome. Voice commerce is challenging for countries where multiple languages are used.

d) T-commerce (Television commerce)

Television Commerce is a commerce model, which provides a new audio-visual away and the diversity of choice by broadcasting the products information in the 24-hour non-stop television shopping channels.

Compared to mobile commerce and voice business, successful television commerce requires companies to build up partnerships with broadcasters, which also requires a relatively higher cost [7]. In the future, with the rapid development of 3G networks and communication technology, television commerce and mobile commerce will be integrated, such as mobile TV during the launch of the Beijing Olympic Games, which is a very successful example. This will inevitably break the monopoly advantages of traditional television media, so the integration of the business model between t-commerce and m-commerce is bound to be a valuable research.

e) S-commerce (Silent Commerce)

Silent commerce uses advanced tagging and sensor technologies, as well as wireless mobile communications, to make everyday objects intelligent and interactive, creating new information and value streams [7]. It is "silent" in that objects can communicate and commerce can take place without human interaction. It includes the following major technology: RFID technology, MEMS, NEMS and Telematics.

Most of today's silent commerce applications are simple solutions that deal with an isolated problem within a business. Closed solutions provide considerably more advantages since they can capture information at a number of points in a supply chain of a single business, but there is also a need to link the new data and devices with legacy applications. Open solutions offer the option of operating across multiple businesses. Silent commerce applications can improve productivity and service such as material management, inventory tracking, supply-chain management, theft prevention, asset management, production management, vehicle management, employee safety, access control, micro payment, customer convenience, and customer service.

5) Privacy and ethical issues

Despite the promising future of u-commerce and the tremendous benefits it can bring to customers, customers' privacy concerns appear to be the biggest obstacle and social issue. Consumers' concerns in the u-commerce application mainly from two aspects: (1) fear that they will continue to be tracked; (2) worried that their private information will be spreaded and illegal used. For example, if the physical entity embedded RFID tags, any of the people who carry RFID tags can get the relevant information of the entity without the owner's permission.

Privacy closely related to two issues: trust and security. In order to solve the trust issues in u-commerce, we need to build a good certification program. The literature [18] can offer a certification program (UC-TBAS) for the u-commerce services, which is based on the consumer's

transaction time and transaction-specific context. It is composed of two mechanisms: the mobile certification (MCA) and the static certification (SCA). However, the certification program has certain limitations for considering too little factor.

In a word, an organization needs to be aware of pertinent legislation prior to initiating the u-commerce venture [20].

B. Technology layer

1) Pervasive Computing

Embedded computing and wireless communication technology are developing rapidly, which promoted the combination of computing, communications and sensor fusion technology. This makes human's three-dimensional physical space unprecedented with full of data and information, and people also hope to get an access to information and computing services in our life and the environment any time and anywhere. Thus, Mark Weiser proposed the idea of ubiquitous computing based on preliminary studies such as human-computer interaction, network technology, computing technology and the evolution of the graphical user interface and so on in 1988. In 1991, Weiser [21] has done a more systematic and comprehensive exposition on ubiquitous computing in his paper" The Computer for the 21st Century". He described a computing environment where computing devices are seamlessly embedded in the everyday objects of our lives and interwoven with the physical world through a continuous network, so that the computer itself disappeared from the people's attention, and people's attention can back to the task itself [22].

Now, a number of relatively self-contained research fields based on ubiquitous Computing have been formed such as smart space, wearable computing, Context-aware computing and nomadic computing [24]. But the papers about the relationship between ubiquitous Computing and u-commerce are also rare. Scholars should strengthen the research in this respect.

2) Automatic Identification

Automatic identification techniques refer to methods of collecting object data and entering it directly into computer systems without human involvement [25]. In recent decades, automatic identification technology has had rapid development on a global scale, which has initially formed a high-tech discipline including a bar code identification technology, radio frequency identification technology, biometric identification technology, sound identification technology, image identification technology, and magnetic identification technology. Among them, radio frequency identification (RFID) technology got the highest concern.

RFID is an automatic data capture (ADC) technology that comprises small data-carrying tokens ("tags"), and fixed or mobile scanners ("readers"). The technology revolves around the fundamental concept of a reader reading the tag information when the latter is near it regardless of the tag's orientation. This technology does not require contact or line-of-sight to operate, and can function under a variety of environmental conditions. Because it is difficult to counterfeit, it provides a high level of data integrity and security. RFID is similar in many ways to bar coding as an identification technology but essentially differs in the methods they each operate in.

The earliest article on RFID research is Harry Stockman's "Communication by Means of Reflected Power", which was published in 1948 [26]. Then, a large number of research institutes, commercial corporations and government agencies started putting a lot of manpower and material resources in the research, and made a lot of results such as A. Koelle, S. Depp and R. Freyman's paper "Short-range radio-telemetry for electronic identification, using modulated RF backscatter", which was published in the 1975 [27].

Trends in RFID technology are providing increasing functionality and processing capability located on the tag. In addition, research is underway toward improving the power capability of passive tags to minimize the use of onboard battery sources. In addition, RFID systems are being incorporated into real-time systems for improved responsiveness of logistics and transport systems.

3) Sensor networks

Research on sensor networks was originally motivated by military applications. Examples of military sensor networks range from large-scale acoustic surveillance systems for ocean surveillance to small networks of unattended ground sensors for ground target detection. However, the availability of low-cost sensors and communication networks has resulted in the development of many other potential applications, from infrastructure security to industrial sensing.

Sensors networks in general pose considerable technical problems in data processing, communication, and sensor management (some of these were identified and researched in the first DSN program). Because of potentially harsh, uncertain, and dynamic environments, along with energy and bandwidth constraints, wireless ad hoc networks pose additional technical challenges in network discovery, network control and routing, collaborative information processing, querying, and tasking.

Current and potential applications of sensor networks include: military sensing, physical security, air traffic control, traffic surveillance, video surveillance, industrial and manufacturing automation, distributed robotics, environment monitoring, and building and structures monitoring. The sensors in these applications may be small or large, and the networks may be wired or wireless. However, ubiquitous wireless networks of microsensors probably offer the most potential in changing the world of sensing.

4) Location

Location is a core component of ubiquitous commerce. Because there are numerous technical solutions available, it is not possible to review here all the different options. Instead, we will only briefly examine three approaches which are characteristic of the general approach so as to provide useful insight in the operation of such systems, namely the wireless location, location and tracking using RFID and sensor network node.

Wireless location technology uses the parameters of the wireless signals to determine the location of the wireless terminal within a radius. The parameters include transmission time, the reached angle, and etc. Initially, location determination for mobile phones was solely cell-based, and location accuracy was determined by the cell size. Whereas cell-based approaches do not require modifications to the handset or network, other localization techniques, such as COO, TA, TOA, E-OTD, DOA, TDOA, TOA-DOA, AOA, TOA-AOA, handset-based (GPS), and hybrid approaches (A-GPS), require modification to give increased location accuracy.

The use of RFID for position tracking is an active area of research. There are several companies incorporating real-time location in RFID applications. For example, active tags that communicate with satellites to obtain precise location and movement. These tags also have global positioning system (GPS) capabilities and can read/write at 500 meter distances. Active tags have also been developed that can be located in real-time at ranges of 1000 meters. There has been less published work in real-time monitoring using passive tags due to the limited read range compared to active types. In some related applications, Kalman filtering is a very useful tool in navigation, and has been used in GPS applications. Thus, it is proposed that applications utilizing passive tags could use a Kalman filter approach to locate and track object positions.

Wireless sensor network node positioning technology is the process that determines the specific physical location or the logic location of network nodes in the network. Generally, it obtains information of general network node through beacon node. According to the current research of wireless sensor network node technology, wireless sensor network node positioning technology can be divided into two categories: Range-based Localization Scheme and the Range-free Localization Scheme [28].

5) Data synchronization technology in Mobile devices

With the emergence of u-commerce, a wide range of mobile terminal equipment will be endless, so users can carry out receiving and sending information using a handle device to run the application any time and anywhere. This resulted in a need to maintain a data consistency of a variety of types of terminals, which requires help of synchronization technology.

At present, the data synchronization technology widely used in mobile devices business can be divided into two main types: Synchronization middleware and data synchronization method used in distributed database.

C. Application layer

1) SCM

U-commerce is a new commerce model. With the emergency of it, the traditional supply chain management theory and technology has brought profound changes. There is clear rationale for businesses to keep the supply chain process simple, standard, speedy, and certain. In the context of the emerging ubiquitous and pervasive commerce technologies in particular, it is necessary that all participants in the supply chain exchange information frequently and accurately, supply chain costs be minimized, and all goods and services moving through the supply chain be unequivocally identifiable at all times. In the literature [25], the authors discuss solutions of Sap's enterprise software. The purpose of supply chain support solutions is to provide businesses with all software necessary to analyze, control, operate, and plan its supply chain activities.

In the area of inventory management and logistics, RFID technology will play a huge role. In the literature [25] (Chapter 3), Gregor Hackenbroich studies a case of a large retailer in Europe. In the example, the main process covered by RFID technology was the tracking of deliveries from the distribution center to one dedicated store, as well as the movement of goods from the store's back room to the shop floor. Tagging was done on case and pallet level. The main benefit provided by RFID technology in this example was increased visibility of the goods, which could be used to make better decisions on when to reorder goods, leading to cost reductions because of lower inventory levels and increased sales because of increased on-shelf availability.

In the area of sales, the literatures [38] [39] propose an RFID (Radio Frequency Identification) technology-based pervasive comparison shopping business model. RFID will allow consumers to be seamlessly connected to the network, and the advent of a new shopping network will enable a smoothly functioning incentive mechanism between displayers and retailers. Ultimately, a new shopping network will enable consumers to be engaged in seamless commerce. In the literature[25] (Chapter 8), Panos Kourouthanassis and George Roussos figured that the shopping cart can be installed in a micro-computer embedded in RFID reader so that customer can perform all the activities usually associated with web browsing and shopping, that is, finding products, information and general browsing, transacting and communicating. The solution also has some shortcomings. First of all, the solution will requires high costs. Secondly, the speed and stability of wireless internet is very difficult to guarantee. So, we think it is more suitable for elite groups.

In the area of payments, Accenture began key technologies' application research of u-commerce as early as 2001[2]. In the literature [40], they identified the early indicators, market drivers, building blocks, and future trend of u-commerce in payments industry. The security and privacy are two important blocks in the u-payments [41] [42]. In the literature [43], Kyoung Jun Lee proposed a solution to these two questions, which is U-PR (Ubiquitous Payment and Receipt).

Proactive service and high personalization will enable a great number of improvements in the current CRM processes and open a new area of customer satisfaction. U-CRM must pay due regard to 'context-aware' characteristics of U-commerce. In the literature [44], Sang-Chan Park defines the term 'context' and 'context-aware computing', and suggest a practical framework of U-CRM as equipped with context data warehouse correspondingly.

2) Industry Application

U-Commerce technologies also can be used in some industries. The literature [45] talked about the application of u-commerce location technology in the tourism industry. Jong Hwan Suh in the literature [46] considered the u-commerce as a new channel of the insurance industry, and built a complete case - Well-Being Store. Kyoung Jun Lee has put forward the concept of u-media and its mode of operation [47].

3) Government

Mobile communication technologies include wireless broadband 3G cellular networks, Near Field Communications whilst mobile devices such as 3G phones and Personal Digital Assistants (PDAs) now have the computing power equivalent to small laptops. Governments are considered candidates as mobile enterprises as they seek ways to interact with their constituents in, a fast, efficient and effective manner, anywhere and in real time. The literature [48] proposed a framework of the enablers, barriers, and outcomes of u-government, and present propositions for future research.

Recently, developing a U-City as an integrated set of ubiquitous space services has been regarded as a promising field in realizing ubiquitous computing technology. U-City, a "ubiquitous city" is defined as a next generation urban space that includes an integrated set of ubiquitous services: a convergent form of both physical and online spaces. These services ultimately aim to enhance quality of life factors, such as convenience, safety and welfare. This paper [49] proposed a set of unique U-City construction philosophies, and to analyze which services would be offered in the U-Cities ubiquitous space services.

IV. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

U-commerce creates an economy that is more flexible, fluid, interconnected, efficient and resilient. U-commerce will widely affect many aspects of businesses. It will provide improved operating efficiency, enhanced customer services, increased service personalization, continuous supply chain connectivity, and continuous interactivity [7]. However, now, a great deal of research issues and challengers are required to solve and understand as follows:

- The Scholars from many different areas have conducted extensive research on u-commerce technologies such as pervasive computing, sensors, location and data synchronization technology. But, few scholars would be to link them with the u-commerce. Of course, they also didn't study the commerce models of these technologies, which is very important in u-commerce research and application.
- Current applications are already demonstrating the value of a constant stream of information and interactivity, even though they are simple and closed solutions. However, it is surprising not to see many articles on other u-commerce applications. We think that u-commerce entertainment services and games have a great deal of potential in the future. Additional research is required in other related areas such as ubiquitous education, ubiquitous supply chain management, and do forth.
- The deployment of u-commerce in the real world has implications beyond the technically obvious ones: social, economic, legal, etc. Companies need to know how they are going to manage the change. U-commerce applications offer many benefits, but they also face many challenges and raise many new questions such as privacy, trust, and security.

TABLE I.
EMERGINF TREND RELATED TO U-COMMERCE

subject	Future research trend
Theory layer	➢ The combination of different components of u-commerce, especially in T-Commerce and M-Commerce, T-Commerce and Silent Commerce, as well as M-Commerce Silent Commerce; ➢ Communication protocols and standards research of u-commerce; ➢ Research issues on privacy, trust and security in u-commerce environment; ➢ Research issues regarding strategy in adopting u-commerce; ➢ Research issues relating to the pace of u-commerce adoption and technology;
Technology layer	➢ The systematic study of u-commerce key technology, especially in the crossing aspects of technology; ➢ The business models research related to the combination of RFID and mobile phone; ➢ The research and application of MIP(Moving Information Platform) based on RFID, Location, data synchronization, and mobile terminal ➢ The research of Mobile Intelligent Terminal identification and authentication technology; ➢ The research of Distributed nodes of business intelligence data acquisition technology.
Application layer	➢ The further study of u-commerce in SCM application, especially the integrated platform of SCM in u-commerce environment; ➢ The application research of u-commerce key technologies in wireless city; ➢ The application research of u-commerce key technologies in digital library; ➢ The application research of u-commerce key technologies in ubiquitous government and ubiquitous society ➢ The further research of u-commerce in other industries

This Paper proposed a suitable classification scheme, organized the u-commerce research under the proposed classification scheme, and outlined the roadmaps for future research, as depicted in Table 1.

In conclusion, our findings provide some strong indication and evidence that u-commerce has attracted the attention of both practitioners and academics. We are confident that with u-commerce applications becoming increasingly pervasive, research in u-commerce will gain more international importance.

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