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Context Management for m-Commerce Applications: Determinants, Methodology and the Role of Marketing

Benou Poulcheria[1], Vassilakis Costas[1], Vrechopoulos Adam[2],

[1]University of Peloponnese, Department of Computer Science and Technology, Terma Karaiskaki, 22100 Tripoli, Greece

pbenou@ethnodata.gr, costas@uop.gr

[2]Athens University of Economics and Business, Department of Management Science and Technology, ELTRUN-IMES (Interactive Marketing and Electronic Services) Research Group, ELTRUN-The E-Business Research Center, 76 Patision Str. 104-34 Athens, Greece

avrehop@aueb.gr

Abstract: Studying consumer behaviour and usage of environmental determinants in the mobile services domain contributes to the identification of context information which is critical for the effective operation of mobile commerce applications. Exploiting this information towards providing enhanced and innovative mobile services offers a competitive advantage within the highly demanding domain of m-commerce applications. However, in order to effectively exploit such context information, there is a need to design the necessary methods, software tools and information systems that will be employed for collecting, processing and disseminating this information. In this paper we develop a theoretical framework which defines the context information necessary for m-commerce applications, taking into account relevant marketing dimensions as well as privacy protection perspectives. Then, this framework is operationalized through the design of an appropriate software architecture which enables the standardization and management of context information.

Keywords: mobile commerce; consumer behaviour; innovative services; context-awareness; adaptivity; privacy; mobile business

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1 Introduction

The increased popularity of new mobile and embedded computing devices and the advent of wireless communication technologies have led to the extension and evolution of *e-commerce* to *m-commerce*. According to [4], "*Mobile commerce* or *m-commerce* is defined as any activity related to a commercial transaction (or a potential one) – an exchange of services or goods for money - and is conducted via wireless and mobile communication networks and uses wireless and mobile devices as user interface".

Mobile commerce is a complex process and involves a number of participating entities, such as mobile network operators, device manufactures, service providers, content providers, application developers, trading companies, consumers, etc., which constitute the *m-commerce value chain* [22]. These participating entities have different interests and pursue different goals while engaging in the m-commerce process; therefore, effective mobile commerce applications have to, directly or indirectly, satisfy all of them [22]. An important stakeholder of the m-commerce value chain is the end-user (i.e. consumer), who actually conducts the commercial transactions. Investigating and satisfying his/her needs and wants is, therefore, of vital importance for the viability and potentiality of any type of commerce, naturally including m-commerce [57].

A special characteristic of m-commerce application users is mobility [33], which dictates an anytime – anywhere capability of conducting mobile tasks. This extension of usage in place and time creates several challenging research directions and business opportunities (e.g. personalized advertising based on user location, following marketing rules). Thus, there is a need to explore and define the dimensions of the mobile context of use and how they potentially affect consumer behavior in order to guide information management actions. To that end, Koutsiouris and Vrechopoulos [44] developed a framework summarizing the Location Based Mobile Services Environmental Determinants that have influencing power on User-Consumer Decision Making Process. Specifically, these determinants are the digital (i.e. mobile interface), physical (i.e. location) and social (i.e. social density and displayed emotions of others) environment along with the mobile device and connection. These determinants are also known under the general term *context*.

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The identification, management and exploitation of *context* constitute recurrent and interdependent processes [58] and exist in all m-commerce applications. However, no theoretical framework for the management and standardization of these processes has been developed yet. Such a framework should offer the capability of i) studying and analyzing consumer behaviour, ii) performing the identification of the m-commerce application context in a methodological and standardized way; context identification should lead to the recognition and cataloguing of the consumer's behavioural and environmental characteristics that are of importance to the success of m-commerce iii) defining the context in a way suitable for computerized information systems, iv) designing the software subsystems which will manage context and v) designing the adaptation process of the m-commerce application to the changing context dimensions, (e.g. location), in order to offer value added and/or more effective and user friendly consumer-user services.

In this paper we investigate four of the aforementioned issues. Specifically, the paper aims to i) explore consumer behavioural and environmental characteristics in the context of m-commerce, which could be exploited for increasing effectiveness in this emerging shopping channel, ii) define context information in a way that is suitable for representation and processing within computerized information systems, iii) provide a methodology for context identification that extends previous approaches by incorporating the contribution of the marketing discipline and iv) propose a high architecture for context information management through m-commerce applications.

Taking into account i) the complex technological environment within which context aware m-commerce applications should operate, ii) the continuously changing environmental parameters caused by mobility (e.g. location, lighting or even weather) and iii) the challenge of exploiting opportunities regarding customer acquisition and retention, it is clear that there is a need to establish collaborative research among experts from different disciplines and domains (e.g. system analysts, business analysts, marketing). Specifically, the role of marketing is of high importance during the process of context identification and exploitation. To that end, this paper highlights the contribution of marketing in the tasks of (a) context identification and (b) formulation of the proposed architecture. Specifically, the marketing discipline has a key role in

these two tasks, since it i) investigates consumer behaviour and identifies its important determinants, ii) identifies environmental determinants that potentially affect user-consumer behavior in the context of m-commerce and iii) contributes to the mobile users'/consumers' requirements capturing phase, thus facilitating the design of innovative services that add value to the core functionality of m-commerce applications and hence attract new customers.

The remainder of this paper is organized as follows: In section 2 we analyze the mobile consumer behaviour and his/her environment as well as point out the role of Marketing in m-commerce applications' context identification and exploitation. In section 3 we review the related work regarding the generation and definition of context, emphasizing m-commerce application context. In section 4 we define a framework which includes i) a formal definition of context ii) a standardized method for context identification for m-commerce applications, iii) a catalogue of metadata for context information elements, which complement the context information element values with important knowledge that can be exploited within the application adaptation process. Section 5 presents a methodology for managing the life cycle of m-commerce applications that takes into account the contribution of marketing and briefly describes two important tools for this process, namely (a) the context-aware UML use case diagrams for documenting context-aware usage scenarios and (b) an extension of UML class diagrams for the representation of context elements, including the related metadata. In section 6, we present a high-level view of an architecture for context management. In section 7, we compare our work with other proposed models in the field of m-commerce and in section 8 we propose a modification of our context model suitable for m-business applications. Finally, section 9 summarizes the paper and outlines future work.

2 Consumer Behaviour and Environmental Determinants in m-Commerce Applications

2.1 Analyzing mobile consumer behaviour and usage environment

There are several variables which affect the user-consumer decision-making process while he/she interacts with a mobile commerce application. According to the typology described in [44] the *digital environment* (i.e. mobile

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interface), the *physical environment* (i.e. location), the *social environment,* the *mobile device* and the *mobile connection,* are the most important determinants which affect user-consumer behaviour against a mobile commerce service. Additionally, the individual *user-consumer characteristics* play a crucial role in the evaluation and adoption process of mobile commerce services [41]. Love [47] emphasizes the importance of investigating individual characteristics that could have an impact on how we use, and our attitude towards mobile applications, devices and services. Consequently, during the development process of m-commerce applications, there is a pressing need for the investigation and exploitation of these parameters in order to adjust the corresponding offering (i.e. the mobile service, the integrated marketing communication activities) accordingly.

The above factors/determinants, which should be taken into account during the m-commerce applications analysis and design process, can be organized into the following categories: i) user-related determinants, ii) computing-related determinants, iii) environment-related determinants and iv) application-related determinants.

2.1.1 User Related Determinants

2.1.1.1 Characteristics to be taken into consideration

M-commerce applications are addressed to an audience with greatly varying qualities regarding their personal characteristics, preferences, computer literacy and skills, needs and desires [41]. These characteristics of the mobile consumer should be taken into account during m-commerce application requirement analysis, design and development process. In the framework suggested by Malhotra and Kubowitz [49], it is indicated that the utilization of user preferences and habits as well as the user's history of service consumption for the provision of Relevancy-Based wireless web services are important parameters for the adoption of wireless web services in the U.S.
Similarly, Venkatesh and Ramesh [74] clearly indicate that interface issues such as information quality, usability and attractiveness have significant influence on a consumer's intention to purchase from or use a website, and affects how much they are willing to pay.

Additionally, Tombs and Kennedy [69] bring out the emotional aspect of the consumer, which may influence the consumer's behaviour towards a mobile service. In their proposed Social-Servicescape Conceptual Framework, they present the social density (the presence of other people during the service consumption process) and the susceptibility to emotional contagion and awareness of the emotions of others as important determinants of user behaviour. Many of the aforementioned consumer characteristics have been investigated in the area of *personalization of e-commerce applications* and especially in adaptive user interfaces design process [23], which pursues the tailoring of the behaviour of a system's interaction to match the skills, tasks and preferences of its users.

Another factor that should be taken into account is the mobility of the consumer. By reason of mobility, the user/consumer interacts with the mobile commerce application while concurrently engaging in other activities (e.g. driving). Hence, the full attention of the user cannot be assumed and alternative communication modes may need to be explored (e.g. auditory instead of visual) [16], [32].

2.1.1.2 Privacy Concerns

The collection of user-related information by sensors (e.g. location sensors) or the provision of this information by the user him/herself and the recording of the user's habits and preferences give rise to a significant challenge regarding protection of the user's privacy. The same concerns apply also to user-related information that has been interpreted to a higher level of abstraction (e.g. mapping of the GPS coordinates to indications such as "on train" "at home" [54]). In this case a privacy breach could be more severe, as compared to a breach in uninterpreted data, since interpreted data convey more information regarding the user. Westin [79] defines privacy as "*the claim of individuals, groups or institutions to determine for themselves, when, how and to what extent information about them is communicated to others*". The privacy concern is a multidimensional concept including collection, improper access, error and secondary usage of personal data [6], [83]. Similarly, marketing rules and guidelines must be followed.

As a result, the user must have the capability of being aware of the way in which his/her personal data is being used and controlling how it is transmitted and to whom [10]. Additional steps towards ensuring the user's privacy are i) the

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transmission of personal data without revealing the user's identity to the service provider utilizing that data for the provision of adaptive services [66], ii) the encryption of personal data stored on the mobile device [57], so as to protect it in case of theft of the mobile device, as well as iii) the assurance by service providers that there is protection against unauthorized resale of personal information, intrusion and theft of customer databases [57].

2.1.2 Computing Related Determinants

M-commerce applications operate in diverse technological environments. Within these environments, there are greatly varying characteristics regarding (a) the properties of the individual devices (memory capacity, battery lifetime, processing power, input/output and communication capabilities, supporting software, usability, performance) [4], and (b) the properties of the networking infrastructure (latency, bandwidth, disconnections, availability, speed, trust, cost) [61]. Malhotra and Segars [50] reveal that specific form factors, (voice recognition capabilities, voice read-back capability, and larger screen size), are some of the most important device attributes that will promote the wireless web services adoption. Rao and Minakis [57] mention that a key driver of location-based services (LBS) will be the degree of compatibility between the system's technical feasibility and the overall marketing strategy guiding its usage. All the aforementioned aspects should be taken into account while designing the m-commerce applications, since – for instance - image download and display may be omitted to save battery power and/or communication costs; smaller size images can be used if the available communication bandwidth is limited or the screen size is small (to avoid scrolling); limited input capabilities also dictate the need for less typing through the keyboard. Similarly, Schmidt [60] reports that when a user interacts with the mobile device s/he does not face the device as something that does not belong to the environment but as an element of the whole environment in which s/he operates.

2.1.3 Environment Related Determinants

User-consumer mobility leads to the need for extending the use of m-commerce applications both temporally and spatially. Therefore, the properties of the natural surroundings (location, time, noise level, brightness, temperature, etc.)

have to be taken into account in order to support and influence mobile users during the consumption process of a mobile service. Possibly, the most important factor of the environment for m-commerce applications is the user's location [45] and the contemporary positioning techniques [82], which allow for the detection of the location for subsequent exploitation in Location-Based Services (LBS), always following privacy protection guidelines (discussed above). Additionally, due to user-consumer mobility, certain parameters of the user environment are prone to change more rapidly as in the case of stationary users (e.g. lighting, noise level, etc), and this is an aspect that should be modeled and taken into account in the m-commerce application design process.

2.1.4 Application-Related Determinants

Application-related information could be potentially exploited for improving the communication between users and mobile applications towards meeting the objective of increasing effectiveness. Thus, this information could be perceived as context. For example, in a mobile brokering application, the information regarding a forthcoming increase in the prices of a stock may trigger alerts that will lead users-consumers to conduct transactions that will provide them important benefits. Thus, stock price, when exploited in such way, may be perceived as application-related context.

During an m-commerce application usage, the importance consumers attach to each of the aforementioned parameters varies, since each parameter has a varying effect on the usability degree of the applications that exploit these parameters for providing adaptive services. In a recent study [43], [44] conducted for that purpose, a Location-Based Mobile Service (LBMS) application was designed and employed within an experimental design. This LBMS retail shopping application offered information of the available points of interest that are close to the user's location and refer to the entertainment business (e.g. clubs, restaurants, bars, concert halls, etc.). Also, users were able to conduct some commercial transactions through their application in a simulated environment (e.g. book a table, buy a ticket, order songs, etc.). The results of this study, regarding the importance users attach to mobile context environment determinants (presented above), indicate that the most important ones belong to the *computing determinants* category. Specifically, these determinants are the mobile device and

connection followed by location and social density (e.g. noise). Also, authors note that adapting mobile user interface to the evolving environmental determinants (e.g. city center vs. park) is very important for the effectiveness of the mobile application as perceived by its users.

2.2 The role of Marketing in m-commerce applications context identification and exploitation

Mobile user and environmental characteristics reported in the previous section set the concept of context for m-commerce applications. However, m-commerce applications possess some specific characteristics which differentiate them from traditional mobile applications (e.g. voice services). Specifically:

1. m-commerce commercial applications aim – by their very nature - to the realization of sales. Therefore, factors of the context specific to the domain of sales [45], [82], should be taken into account in the process of context identification and exploitation. Such a factor is the introduction of innovative services to increase market share [22], using context information to seize sales opportunities [8], [9] (e.g. in the event of sudden, heavy rain, suggest nearby stores for purchasing an umbrella). Another factor is, for instance, the time limitations that may be present for completing a transaction (e.g. a ticket purchase should be completed before the customer arrives at the train station or information on local offers should be timely delivered to a driver before s/he moves away from the offering stores). Maintaining loyalty to the application and/or the merchandise are also factors that are mostly addressed in the context of m-commerce.
2. m-commerce applications target a very wide range of end-users and access devices, with no opportunity whatsoever to train the users (as can be the case with, for instance, a context-aware computer-assisted learning environment that is used in a school [46]) or exclude access devices. Failing to provide a suitable interface levelled to each user's needs [41] or excluding a device will result to reducing the number of sales that will be realized; therefore, the application's sole goal will not be achieved.
3. The m-commerce application domain is a highly competitive one, while other application domains that involve context may be far less competitive. For instance, a context-aware computer-assisted learning environment that

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is used in a school is considered as "given" and cannot be changed, while in the m-commerce environment a lot of alternatives exist and switching to a competitive application is very easy (typing a different URL or using a different bookmark).

4. Finally, cost effectiveness is a major concern while designing an m-commerce application. Information regarding the target group of the services, the cost of collecting and exploiting the context, and the added value that will be provided by the introduction of certain context factors has to be reviewed, by both technology experts – to determine feasibility - and business analysts – to assess cost effectiveness - alike.

All these characteristics of m-commerce applications highlight their core objective which, at the end of the day, is the increase of commercial transactions and sales through establishing and maintaining win-win long term relationships with mutual benefits, based on trust and loyalty and through guarding consumer privacy. These particular characteristics should guide research towards tracing and exploiting the suitable m-commerce application context elements in order to realize the basic objective of increasing sales figures. Thus, the involvement of the Marketing discipline and its contribution in this process is critical. Specifically:

In order for the (a) sales opportunities to be seized, (b) transactions to be executed within a specific time window in order to avoid losing sales and (c) consumer commitment to application and its products/services to be retained (1st characteristic of m-commerce applications), Marketing expertise should be employed towards creating value added services that could be potentially offered through appropriately managing innovation and covering the specific needs for each target group of users-consumers separately (i.e. the essence of customization). Also, Marketing involvement in this process contributes to the selection of appropriate promotional strategies for new products and services that will be executed through the m-commerce applications.

In order to ensure an effective manipulation of diversity among consumers and to avoid excluding mobile devices, (2nd characteristic of m-commerce applications), Marketing research should be employed towards continuously monitoring and exploiting information regarding consumer [43] and environmental characteristics in order to design and develop suitable mobile services. Also, Marketing research should contribute towards identifying ways

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through which each product could be effectively promoted to specific groups of the target population. Through that, the benefits could be the following: (a) the specific characteristics of the users that are needed for the purposes of the m-commerce application will be identified and incorporated into the users' profile (b) methods for collecting the values of these characteristics will be determined (e.g. direct provision by the user, inference from other characteristics and/or behaviour etc) and (c) the adaptivity parameters will be provided. Also, Marketing research mechanisms should be employed for measuring the effectiveness of the selected services [42], through formulating and executing the appropriate research designs and contributing through that to the continuous improvement of the process of identifying and exploiting mobile context.

In order to retain customers in this highly competitive environment (3rd characteristic of mobile applications), Marketing research techniques can be employed to analyze consumer behaviour, as well as the environment through which customers interact with the m-commerce application, in order to suggest ways of improving the m-commerce application's effectiveness.

In order to assess the cost effectiveness of the introduction of context factors (4th characteristic of m-commerce applications), Marketing research should help towards (a) identifying and studying each target group of users-consumers that will use and take advantage of these context factors, (b) identifying the expected benefits derived through this exploitation and (c) assess the cost/performance factor of collecting and exploiting information for each of these context factors.

In sum, it is clear from the aforementioned discussion that the role of the Marketing discipline contributes towards i) identifying mobile context, through studying consumer behaviour within the environment in which he/she operates, ii) identifying the enhanced and adaptive services which could potentially be offered through an m-commerce application and iii) assessing the effects of each selection as far as context exploitation is concerned and, possibly, reconsider the promotional strategies and modify the application adaptation strategies.

Then, having ensured robust requirements through the involvement of Marketing, information system analysts can proceed to redesigning-transforming context from the business to the technological perspective. After this

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transformation, context could be easily exploited by the computerized information systems.

Thus, the employment of an interdisciplinary research approach (i.e. Information Systems and Marketing) is suggested for designing and evaluating information systems in the case where these systems operate also as retail channels (in the sense that users-consumers can buy products and services through them). Besides, one of the objectives of the present study is to explore and highlight the Marketing's role in the design of effective m-commerce applications.

3 Related Work

Many of the parameters that comprise the operational environment of mobile commerce applications, including context, have been studied in recent research, mostly in the areas of *pervasive and ubiquitous computing,* as well as in the areas of *mobile computing* and *personalization*.

Regarding the area of *pervasive and ubiquitous computing*, the vision of Mark Weiser for transparent interweaving of technology and user environment [78] has led to studying the parameters that comprise the operational environment (i.e. *the context*) of an application, aiming to enhance it with intelligence to the benefit of the user. Schilit [59] was the first to introduce the concept of context as location, identities of the people around the user, time of day, season, temperature, etc. Later, more researchers followed Schilit's approach and defined context through a series of enumerations [7], [55]. Dey [15] adopted a more global view and presented a generic definition according to which, '*context is any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves'*. He also defined [15] an application to be *context aware*, *'if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task'*.

The approach of defining context through a series of enumerations suffers from the drawback that the context is modelled too rigidly and specifically and, thus, parameters not listed in enumerations may be disregarded. Moreover, in the cases that enumerations suggest implementation details, these may be

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inappropriate for the specific situation and/or necessitate extensive implementation changes in case the parameters considered in the context are modified. The alternative approach of defining context through a generic definition that can potentially accommodate any information as a context element, definitely provides the freedom to choose the context elements suitable for the specific situation. This definition needs, however, to be complemented with means allowing the identification and modelling of all relevant context parameters, otherwise context specification may be incomplete and the application's potential for adaptation will be diminished [5]. Indeed, most current context-aware systems employ a small portion of the available context, comprising typically of elements related to the user's identity and location [63].

In the area of *mobile computing,* efforts mainly target the development of adaptive systems having *multichannel delivery* and *network adaptation* as their main adaptation focus; the context was explored in alignment to this focus [5]. Multichannel delivery attempts to provide services, through web applications, that can be readily used on various diverse mobile devices with different hardware characteristics. *Network adaptation*, on the other hand, mainly addresses two issues: the first is *communication autonomy*, i.e. the adaptation of the application to sudden disconnections, either initiated by the user (in an attempt to avoid disturbance, reduce cost or power consumption, etc) or imposed by the infrastructure (inadequate battery, signal loss, etc). The second issue targeted by network adaptation is the adjustment of the services to changes in the network bandwidth (e.g. switch from WiFi to GPRS). Bandwidth changes and limitations often dictate the need to change the transmitted data content (lossy vs. lossless compression mechanisms, change of multimedia resolution or quality) or alter the underlying protocol [3].

Finally, the aspect of *personalization* has been investigated in various areas of application development, including that of adaptive user interfaces [23], which pursue the tailoring of the behaviour of a system's interaction to match the skills, tasks and preferences of its users. Personalization also examines issues of content adaptation, through research on *information filtering and recommender systems* [2]. Systems employing these technologies aim to present to the user the information considered most appropriate for his/her current information needs. In

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the area of personalization, the meaning of context revolves around the user and his/her preferences.

Regarding the area of methodological approaches to the standardization of the management of m-commerce application lifecycle, little research is available. Notably, Benou and Vassilakis [5] present such a methodology, which however targets the design and development phases of the m-commerce application, and does not cover important phases of the application lifecycle, such as the feasibility study (including consideration of strategies to be implemented through the applications, definition of goals and measurable objectives) and the evaluation and maintenance.

4 The Conceptual Model of Context for m-Commerce Applications

4.1 The Definition of Context

After analyzing the concepts of context in the domain of m-commerce applications [41], [64], [74], [75], we define context as the set of all possible conditions and states that surround an electronic commerce operation, whereas we define context information as the set of data elements comprising the operation context. Context is, therefore, an abstract model, which - through a series of design and implementation activities - will be mapped into concrete context information elements; the latter will be finally utilized to support the adaptive services.

In the stages of m-commerce application analysis, design and development, we will mainly address *context information*; for the requirements of these stages, context information may be extended as follows:
'Context information of an m-commerce application is every piece of information which may be used to characterize a state of an entity that can be considered to be relevant to the interaction of the user with the particular application. The entity state may be either static or dynamically changing, while the relevance of the entity to the user-application interaction can be derived from the potential to exploit the information describing the entity state to optimize this interaction, so as to maximize the commercial value of the application.'

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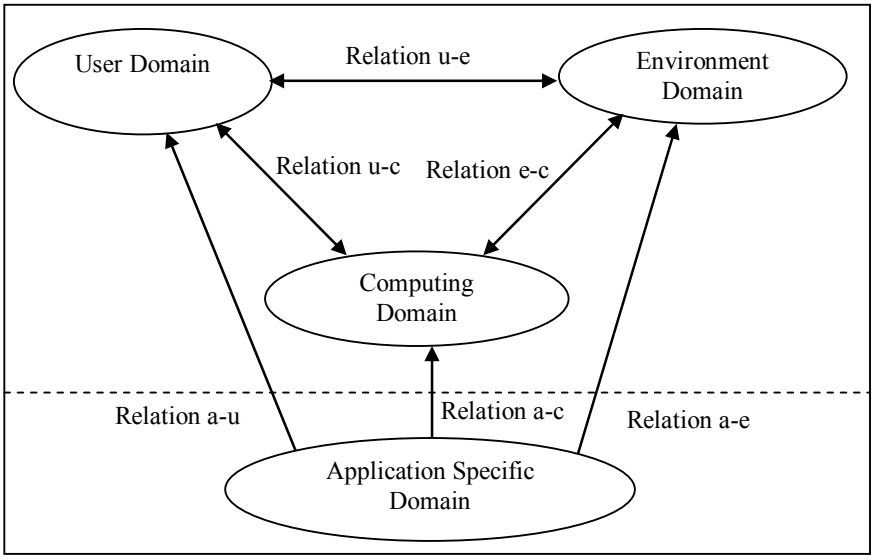

Fig 1. Types of Context Information

With the term "entity", we refer both to the term "entity" and the term "relationship" of the Entity Relationship Model (ER-Model) [29]. We also organize context information in four domains: i) *the user domain*, ii) *the environment domain*, iii) *the computing domain* and, iv) *the application-specific domain* (Fig 1). Context domains are thoroughly discussed in the next section.

4.2 The Formal Definition of Context Information

Although the definition which we have proposed in the previous section sets the boundaries of context information for m-commerce applications, the exploitation of such information from computerized information systems demands a more formalized and computer-oriented approach. Hence, we will present a series of definitions which standardize the notion of context information and further elaborate on the definition that we have introduced in section 4.1.

Definition 1: An entity O_i is defined as a tangible or intangible real-world entity, such as a device, a place, a CD, an electronic product such as an mp3 file or a customer order.

Definition 2: The *context domain* is a high-level abstraction which partitions entities into the following categories: *{user, computing, environment, application-specific}*.

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Definition 3: An entity O_i, may be modelled using a number of properties that describe aspects of the object O_i and a number of relationships, which describe how the entity relates to other entities. The set that includes all attributes (i.e. both properties and relationships) for entity O_i will be denoted as $A_i = \{a_{i,1}, a_{i,2}, \ldots, a_{i,m}\}$. Note that relationships may model the "part-of" semantics.

Definition 4: The *state* of an object O_i during a particular transaction *t* will be denoted as *Si(t)* and is derived by assigning a concrete value to each attribute of *Ai*. Each value may be atomic, record-typed, array-typed or any combination of the above. Orthogonally to their types, attribute values may be *sensed* (i.e. be gathered from physical or logical sensors), *explicitly provided* (i.e. the user enters the value) or *derived* (i.e. other values are processed to compute the value of the particular attribute). This is effectively the *context information* of object O_i during transaction t.

Definition 5: The context of a transaction *t* will be denoted as *C(t)* and is defined as the collection of all states of objects O_i which can be perceived as relevant to the user, the executed application or their interaction during the transaction *t*. Formally, $C(t) = \cup_k S_k(t)$ for all objects O_k that are considered relevant.

According to the definitions above, context information for a particular transaction can be denoted as a set of quadruples *(object context domain, object, attribute*, *value*). The element *object* denotes the object to which the particular piece of context information corresponds, e.g. a particular stock share (which includes information regarding "share description", "share daily prices", "shareholders registry," etc.), location (which includes information regarding the longitude and latitude, but may include more "high-level" information such as "office," "home"), etc. The element *object context domain* specifies the context domain to which the *object* belongs; the element *attribute* identifies the particular attribute that is measured; and the *value* element gives the exact value for the attribute within the specific transaction.

Note that the level of abstraction considered in the selection of an entity is dependent on the requirements of the application domain and the choices of the systems' analysts. For instance, a PDA may be modelled as a single entity O_{pda},

having attributes representing its keyboard, screen, etc., or these parts may be modelled as separate entities and be connected to the O_{pda} entity through relationships of type "part-of" (cf. "FIPA Device Ontology Specification" [21]). These modelling choices do not affect the generality of the modelling method, since the goal of capturing all the required context state information can be accomplished independently of whether this information has been represented as a value of a property within a linked entity or as a component of a structure-valued attribute of a single entity.

4.3 The Metadata of Context Information

Context information is greatly heterogeneous regarding the characteristics of its elements – e.g. quality and persistence [30], a fact that stems both from the variety of sources the information element values are gathered from and from the nature of the elements (e.g. some are time-varying while others are permanent). *Sensed context information* (i.e. context information, the values of which are gathered through sensors) is typically dynamic, in the sense that it changes often and it is not uncommon to be imprecise owing to sensing errors, sensor failures or network disconnections, or to delays introduced by distribution [24]. On the other hand, *explicitly provided context information* may be dynamic or static – in the sense that it changes less often - and is prone to human errors [27]. Finally, *derived context information* may be imprecise due to imperfect inputs or deficient derivation mechanisms [27]. Therefore, to reflect these aspects of the context information elements [27], [30] which may be exploited by their consumers we use a set of attributes for the elements, which are effectively the *context information metadata*. These attributes are the following:

- *Source attribute:* this refers to the provider/sensing service of the value, e.g. user, physical sensor, application service.
- *Timestamp*: this reflects the instance that the value was produced; a granularity of second is expected to be adequate for most applications. This piece of meta-information is of more value when dynamic context information is considered.
- *Confidence*: this attribute reflects the degree of belief that the value is correct. When dynamic context information is considered, *confidence* may be considered to be a "probability of correctness," and can be determined

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after a series of trials (e.g. testing the accuracy of the sensing device or evaluating the relevance of an advertised product with the actual purchases of user, in order to assess the accuracy of user preferences). For static context information, the *confidence* attribute may reflect the certainty of its provider that the provided value is correct (credibility)[1].

- *Frequency*: this attribute expresses the periodicity of recording for the specific value. It can be used both for static or dynamic context information.
- *Validity Period*: this attribute states the time duration for which the information is valid, i.e. it may be used without obtaining an up-to-date value.
- *Metric*: this expresses the unit/scale used to measure the context information element value. This is necessary when different units/scales are used by different providers to measure the value, in order to allow value interpretation and meaningful comparisons. We have opted to include the metric as part of the metadata, rather than as part of the value (as for instance is suggested in [39]), in order to facilitate arithmetic operations and comparisons on the values; for instance, if the value of temperature is "9" and the accompanying metadata indicates that temperature is expressed in Celsius degrees, then it is straightforward to compare the value to a threshold of "15", which may be included in a service's adaptivity condition. If the metric were included in the value, to obtain a meaningful comparison between "9^{o}C" and "15^{o}C" would necessitate a parsing step and, therefore, encumber the process.
- *Confidentiality:* This characteristic shows the degree to which a piece of information is sensitive to unrestricted use and must be defined as to whom and circumstances under which it may be revealed, within the context of the definition of privacy policies [6]. This attribute should encompass all privacy/confidentiality requirements stemming from legislation (e.g. UK Data Protection Act [72], EU Data Protection Directive [18]), corporate

[1] Some researchers distinguish between *accuracy*, which is an objective measure of the "probability of correctness," and *confidence*, which is a subjective measure of the same quantity. Since objectivity cannot be easily defined and quantified, we will adopt a single measure for this aspect.

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policy and user selections, while it should also reflect the privacy class of each piece of data (e.g. sensitive vs. personal data).

Note that it is not mandatory to assign all the aforementioned meta-information attributes to each context information element. The attributes assigned to each context information element will be determined by examining the means for acquiring its value, whether the value is dynamic or not, and the aspects of the value's dynamic nature. Metadata may be exploited by applications that make use of the context information towards the end of assessing the quality of the context information and to select the data that satisfies certain requirements.

5 A Methodology for Context Identification: Incorporating the Contribution of Marketing

Although we have set the limits of context for m-commerce applications in paragraph 2.1, the process of defining the exact context of a specific m-commerce application is relatively complex [20]. Despite the strong interest by the global scientific community in context-related issues, little effort has been placed in the standardization of a methodology for the definition of the context of m-commerce applications. Notably, Benou and Vassilakis [5] present such a methodology, which however covers only the design and development phases of the m-commerce application, therefore important phases of the application lifecycle, such as the feasibility study (including consideration of strategies to be implemented through the applications, definition of goals and measurable objectives) and the evaluation and maintenance, are not considered. In the following, we present an extended version of the methodology presented in [5], which covers the whole lifecycle of m-commerce applications, and explicitly stating the expected contribution from the domain of marketing. The proposed methodology is presented below as a series of distinct steps.

- **Step 1:** Marketing experts (consulting studies from their target groups and product/service domains) formulate the promotional strategies for each product/service and specify the innovative services for attracting new customers and maintaining the loyalty of existing ones [50]. For each one of the strategies and the innovative services, the aspects of context that may be exploited are identified at a high level.

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- **Step 2**: Marketing experts formulate the appropriate research designs through which the effectiveness of the promotional strategies, loyalty retention policies and overall customer satisfaction will be assessed. This step is performed at an early stage so as to allow setting of clear goals and be as objective as possible (i.e. avoid cases where the goals or methods are *a posteriori* defined in an ad-hoc fashion to allow for characterizing any obtained result as "success"), and to allow for incorporation of appropriate monitoring mechanisms, collecting data needed for the assessment, into the m-commerce application. The research designs should include provisions for assessing the effectiveness of the incorporation of context factors identified in step 1, both collectively and – wherever appropriate - individually.
- **Step 3:** Promotional strategies, innovative services and "typical" m-commerce application operation is mapped to tasks that should be incorporated into the m-commerce application.
- **Step 4:** Each individual operation/task T is described textually and documented through the "usual" use cases diagrams, illustrating the system's main goals, which are related to the product's commercial value. Note that in this step, the core system functionality is captured without taking into account the context, e.g. "the user is searching for parking space" (task T), so the (initial) service which will support the task will give "a list of parking places". The metrics related to the assessment procedure that need to be collected for each individual task, if any, are also defined in this step.
- **Step 5:** In this step, marketing experts define the different scenarios/situations under which task T is performed, taking into account the high-level aspects of context that have been identified in Step 1. A scenario/situation has the form "on a rainy day, user X, equipped with a mobile phone having wireless communication capabilities is driving in the centre of city Z searching for parking space." Technology experts will assist in this step, elaborating on the context parameters and sensing capabilities, e.g. distinguishing "wireless communication capabilities" to "Bluetooth" and "Wi-Fi," pointing out the capabilities and/or limitations of

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each particular technology. Research designs defined for high-level context factors in step 2, should also be elaborated accordingly.
The metrics defined in the previous step may be here enriched with context capabilities that seem appropriate for the situation (e.g. the "weather conditions" context aspect should probably be recorded when assessing the effectiveness of an application promoting products sold in an outdoor market, since results may significantly vary according to such conditions).

- **Step 6.** Critical factors for each scenario/situation are identified during this step. These include (a) the objects involved in *how* the information/service will be delivered to the user, and (b) the actors that are (implicitly or explicitly) present in the scenario and will possibly affect the user's decision regarding the purchase of product. For instance, the scenario/situation listed in step 5, includes the specification "rainy day" which is related to the actor "weather conditions" and can lead the user to choose an indoor parking space (as opposed to outdoor parking). The objects listed in the scenario/situation text are a starting point for this process. However, some of these objects may be considered irrelevant (or infeasible to exploit) and be disregarded later on (step 11), whereas other objects that are not apparent in the text may be added to the critical factor list (step 10).
- **Step 7:** Scenarios/situations and their corresponding probable adapted/enhanced services (identified in step 1) are elaborated on in order to determine the details on *how* the application will be affected by the context elements in each of them. Within this step, the final adaptive services, which are related to the application's commercial value and eventually will be offered by the system, will be concluded after answering the following questions:
  - How will the core information required by each task be shaped under the specific conditions of each scenario? *(information adaptation)*
  - Which additional information and/or functionality should be offered to the user under the specific conditions of each scenario? *(functionality adaptation)*
  - How will the information/functionality be delivered to the user? (*presentation adaptation)*

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The suggested adaptive services must satisfy the end user, promote the adoption of m-commerce and, as a result, their design must be thoroughly examined in order to offer the best possible behavioural compatibility, increased needs compatibility, less complexity and capability for trialability [50].

- **Step 8:** In this step, the attributes of the critical factors of scenarios/situations should be determined. Additionally, the relations of these attributes with the scenarios/situations should be captured and documented. To facilitate and formalize this process, critical factors -together with their identified attributes of interest- and scenarios/situations –together with their corresponding adapted services- are listed in a table. The columns of this table correspond to the scenarios/situations (with their adapted services) and rows correspond to critical factors (context objects) and their attributes. The (i, j) cell of the table is checked (marked with an X) if the attribute listed in the i row plays a role in the scenario/situation listed in the j column (see Table 1). Therefore, each scenario/situation can be determined using a logical expression e.g. $((attr_1=val_1)$ and $(attr_2=true)$ and … and $(attr_n=val_n))$. Note that Table 1 does not intend to capture the full complexity of mobile commerce applications context on its own right; its purpose is to correlate the critical factors (context factors) identified in step 6 with the scenarios/situations identified in step 5 and their corresponding probable adaptive/enhanced services identified in step 1 and step 7. Therefore, Table 1 serves the purpose of documenting *which context factors are relevant to each scenario/situation*. The context factors affecting each scenario can also be illustrated using a graphical notation through the context-aware use case diagrams, described in section 5.1.
  At this stage, the critical factors represent real-world objects that comprise the context, but for which further elaboration and modelling is required so as to provide the entities of definition 3. A software modelling process, such as UML [51] or Booch methodology [80], will be subsequently employed to determine the entities' respective properties and relationships and shape the software artefacts for the entities' representation and manipulation.

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Scenarios/Situations-Adapted/Enhanced Services / **Critical Factors (Context variables)**	Scenario1/ Situation 1 – Adapted/ Enhanced Service 1	Scenario2/ Situation 2 - Adapted/ Enhanced Service 2	Scenario3/ Situation 3- Adapted/ Enhanced Service 3	…….
Environment				
Temperature		x		
Wind	x			
Sunshine		x	x	
Location	x			
Device				
Channel	x			
Screen size		x		
Memory			x	
Parking Place				
Kind of parking	x			
Distance from city center		x		
Capacity	x		x	

Table 1. Context-Situation-Adapted Services matrix

- **Step 9:** Within this step, we revisit the list of critical factor attributes to recognize attribute combinations that can be effectively modelled as new scenarios/situations which can increase the application's commercial value. For example, we can consider combining the weather conditions with the user location and intention, such as "the user wants to go to a specific shopping mall (intention/location) on a day with heavy rain (weather conditions), thus the parking space s/he seeks should be *very close* to the user's target location." The new scenarios/situations will be documented and an iteration of the methodology will start from step 6. This is necessary, since each new scenario/situation identified in this step needs to be analyzed and documented. Additionally, new critical factors,

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which may be recognized in each new scenario/situation, should be considered in combination with (a) each other and (b) critical factors already documented for other scenarios/situations.

- **Step 10:** Steps 1-9 are iteratively performed to identify more scenarios/situations and/or critical factors, which potentially could affect the application's commercial value and which were not initially considered. In the example of the parking space, for instance, *time* may emerge as a critical factor after taking into account that the price charged by parking garage proprietors varies according to the time of the day and, thus, the user should be informed regarding these variations. In this manner, factors can be incrementally taken into account and details can emerge progressively as suggested in the stepwise refinement approach [81].
- **Step 11:** Technology experts, developers and marketing experts review the critical factor attributes to determine the degree to which the automated collection of their values is feasible. This examination includes *both* the technological potential to determine the values of the attributes of interest *and* the cost implied for performing the automated collection. Additionally, among the issues that should be examined is the cost of incorporating the necessary sensors, developing or leasing software services, how much the user will be charged *per service use* [49],[50]; all these factors may affect the population of the target group. As a result of this review, certain adapted/enhanced services may be dropped or the degree of automation may be reduced (e.g. some context's attribute values are provided by the user instead of being sensed or derived).
- **Step 12:** Technology experts, developers, marketing experts and legislation experts review the critical factors to determine whether private or sensitive data are required for service realization, and examine whether it is beneficial in overall to use these critical factors. On the one hand, using private or sensitive data may enhance adaptivity of offered services and the added value they offer to their users. However, maintenance of private/sensitive data is associated with a number of risks such as:
  - users may be reluctant to provide their private/sensitive data and, thus, may refrain from using the services altogether.

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- the decision to store and process private/sensitive data will probably necessitate additional administrative load (e.g. notifying the state commissioner regarding the intention to maintain private/sensitive data; obtaining the necessary permission; etc) and additional technical load, such as installing and maintaining enhanced security systems (firewalls, intrusion detection systems and so forth). Hiring additional staff and/or training the existing staff for implementing and maintaining the elevated security measures may also be required.
- in the event of a security breach which will lead to the leakage of private/sensitive data maintained, the organization/enterprise may be held legally responsible, while the impact on the organization's reputation will be severe.

The issues listed above should be considered both globally and in a *per context element* basis. The designers will thus need to address privacy issues [54] against:

1. What information is private and to whom are they associated?
2. From whom is private information withheld?
3. What benefits are realized by withholding or not withholding private information and in whose interests are they?

In essence, there should be a definition of the context information that is private and the privacy policy model [17], [49] defining to whom and under which circumstances the private data may be distributed. The characterization of context information as "private" may be implemented with the use of metadata (confidentiality property) in its corresponding UML class diagram.

The definition of the privacy policy model lies in the definition of data practices which describe the ways users' data would be dealt with. Examples of such practices are *purpose*; (i.e. describing for which purpose(s) the information will be used including whether the user must explicitly consent or deny the use of his/her data for each individual purpose), *recipient* (i.e. who collects the data and with whom the collected information will be shared, such as affiliated companies) and *retention* (i.e. for how long the collected information will be kept) [68]. Data practices could be expressed using P3P vocabularies [14], although the

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P3P vocabulary should be extended to include the different context parameters that are of interest [53], [67]. All service providers that will use the context management subsystem to get context information will have the obligation to adhere to the privacy policy (expressed through data practices).

The approach used in order to recover the users' privacy demands would be that of the users being asked for their privacy preferences. The P3P preference exchange language (APPEL) [13] may be used as the language for expressing user preferences. APPEL is a machine-readable specification of a user's preferences that can be programmatically compared against a privacy policy. Additionally, techniques of weighting mechanisms [17] may be used, which offer more flexibility in controlling users' privacy as well as different virtual identifications (IDs), i.e. pseudonyms, when the user allows the transmission of personal data [31].

After examining the above issues, the organization/enterprise may decide to alter the critical factors included in each scenario to remove certain private/sensitive data for which the overall cost incurred from their use surpasses the expected benefit. The organization/enterprise may also opt to introduce "cut-down" versions of the scenarios which do not require the use of private/sensitive data, in order to service users that would be reluctant to provide their private/sensitive data. This step may be further formalized by adopting specialized methods for addressing privacy requirements in the requirements engineering and system design phases, such as the PriS method [35], [36].

- **Step 13:** In this step a final iteration over all previous steps is performed. Table 1 is carefully reviewed, to identify innovative services that were not included in the original specifications, which will provide a further competitive advantage to the application and reinforce the user's loyalty to the particular application.
- **Step 14:** The system design phase commences. Since the software artefacts in the m-commerce application must take into account the context factors, standard UML class diagrams should be extended to accommodate context information. The critical factors will subsequently undergo further processing –described in more detail in paragraph 5.2– in order to produce

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the entities of the context as they have been defined in definition 3. The documented situations along with their respective critical factors and adaptive/enhanced services will be used for the design of the initial service's adaptivity process, which, however, is beyond the scope of this paper. An extension of UML class diagrams that incorporates notation for context is presented in section 5.2. In order to handle the privacy requirements for the private and sensitive data, appropriate design techniques may be adopted such as privacy design patterns [52], [56]. The system is afterwards implemented and deployed.

- **Step 15:** In a post-deployment phase and after adequate research information has been collected, marketing experts will assess the effectiveness of the promotional strategies, customer loyalty retention policies, new customer attraction approaches, context factor inclusion, and overall m-commerce application operation. Based on the results of this assessment, marketing experts will revisit the relevant aspects of the m-commerce application, triggering the re-execution of the appropriate steps of the methodology.

5.1 Context-aware Use case Diagrams

The context factors that should be considered in each scenario should be clearly identifiable and documented, and a standard means of representation, easily perceivable by all actors involved in the formulation of the feasibility study, requirement analysis and design phases should be adopted. To this end, the context-aware UML use case diagrams shall be composed. The context-aware use case diagrams document which application usage scenarios are affected by the context and for each such scenario which context factors are taken into account and which adapted services will be offered.

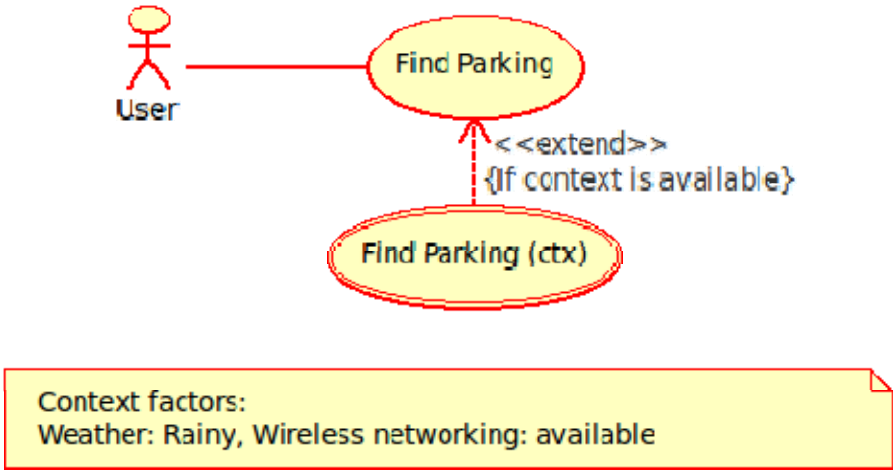

Fig 2. Context-aware use case diagrams

An example of a context-aware use case diagram is illustrated in Fig 2. For each use case of the m-commerce application that should incorporate context, an additional use case is introduced whose name is the same as the original use case followed by the notation "*(ctx)*"; since the new use case extends the non context-aware one by taking into account context. The additional use case is denoted using a double ellipsis outline, to visually distinguish it from its non context-aware counterpart. The two use cases are connected using the standard UML "extend" notation, and the label of the arrow states the condition under which the extension applies (*if context is available*). The specific factors of context that should be available are listed and detailed in the documentation area of the additional use case, in order to avoid cluttering the diagram area. The documentation area of the new use case will also host any additional details, e.g. what type of adaptivity is foreseen for this use case (content, functionality or presentation adaptation) and the scenarios under which this adaptivity will take place.

5.2 Context-aware Class Diagrams

The context factors comprising the context, together with their attributes (as these have been determined during the process of context identification), will undergo a typical software engineering modelling process (e.g. UML [51] or Booch methodology [80]) to finally determine the entities' (cf. definition 1) respective properties and relationships (cf. definition 3). These entities and their interrelationships will be illustrated as enhanced UML class diagrams, in which

the enhancement refers to the inclusion of the special characteristics of context information and more specifically:

- the *dynamicity of the value of each attribute*, given that context information is distinguished in *static* and *dynamic*, depending on how often it changes.
- the *acquisition method* of each attribute value (sensed, explicitly provided, derived).
- the *metadata information* accompanying each attribute.
- the *need to record past values* for the information.
- the possibility that *the type of a related entity may change*. This is important in adaptive services, since such a change may make new context items or sensing methods available or may terminate the availability of context items/sensing methods, which in turn may trigger changes to the user interface, processing or available data. For instance, a change in the user's location from an instance of "office" to an instance of "shopping mall" may lead to the withdrawal of the user interface item "Read corporate memos" and establish the item "Get offers."
- the privacy requirements for each information element.

An example of an enhanced class diagram is illustrated in Fig 3. The notations used in this diagram are described in the following paragraphs.

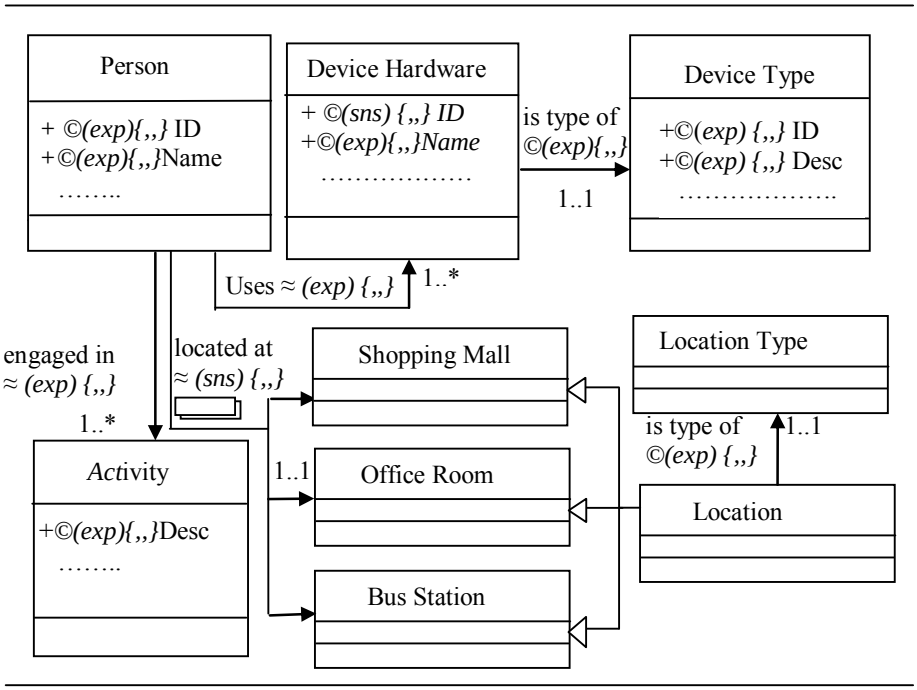

Fig 3. Context-aware class diagrams

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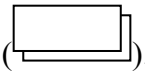
In accordance with the UML class diagrams, entities are represented using rectangles with three areas. The top area contains the class name, the middle area lists its properties and the bottom area lists the basic operation it provides. Its relationships, (associations), with other entities are denoted using arrows (→), which are labeled with the relationship cardinality (e.g. 0..1, 1..1, 1..*) [51]. The special-type *generalization links* (▷) denote the parent/child class relationships. Each attribute or relationship may be labeled with additional marks that denote the special nature of context information as follows:

- *Information dynamicity* is denoted using:
  - the symbol © for static information
  - the symbol ≈ for dynamic information
- The *acquisition method* is denoted using:
  - (sns) : for sensed information
  - (exp): for explicitly provided information
  - (drv): for derived information
- The *metadata* associated to the context information are denoted as a series of values with each value corresponding to a piece of metadata, e.g. {source, timestamp, confidence, frequency, validity period, metric, confidentiality}.
- the *need to record past values* for the information is illustrated through a double rectangle ().
- the *possibility that the type of a related entity may change* is denoted using an arrow splitting to multiple ends (), one end for each possible type.

6 The Context Information Manager

The process of designing the system that will manage context information is common to all context-aware mobile applications (CAMCA) and can thus be standardized. Therefore, a well-defined software architecture, which will describe the components of the context management subsystem, the characteristics and

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functionality of each component and the interaction between the components will constitute a useful tool for speeding up the development of context-aware applications and minimizing the probability for errors or omissions.

Both the international practice and the state-of-the-art [20], [26], [28], [40] in the areas of pervasive and ubiquitous computing indicate that a context information management subsystem should be able to:

- *capture* context information from its sources, which are physical and logical sensors, as well as the users. This includes the discovery of the context information sources within its vicinity.
- *store* context information or parts of it, so that it can be exploited in subsequent situations.
- *interpret* the context to a higher level of abstraction, which will be more meaningful (and useful) to the application that will use it. As an example, we can consider the interpretation of a *(longitude, latitude)* pair to a representation of the form *"home"*, *"office"* or *"shopping mall."*
- *transit* the context information to the application that will use it.

In accordance with the above requirements we will present the design of the *Context Manager* module, i.e. the module that will be responsible for: i) gathering the context information from the various sources of the application environment; ii) interpreting the context information to a higher level of abstraction; iii) storing the context information for subsequent use; iv) distributing the context information to the applications that need it and v) discovering the context information that can be made available to the interested parties. The interested parties are essentially the *adaptation managers* of the various information systems, who will use the information provided by the Context Manager to perform the adaptation of the application they provide.

In line with the aforementioned functionalities, the Context Manager module (Fig 4) can be decomposed into the following components:

- the Context Gatherer
- the Context Interpreter
- the Context Storage
- the Context Distributor
- the Discovery Agency

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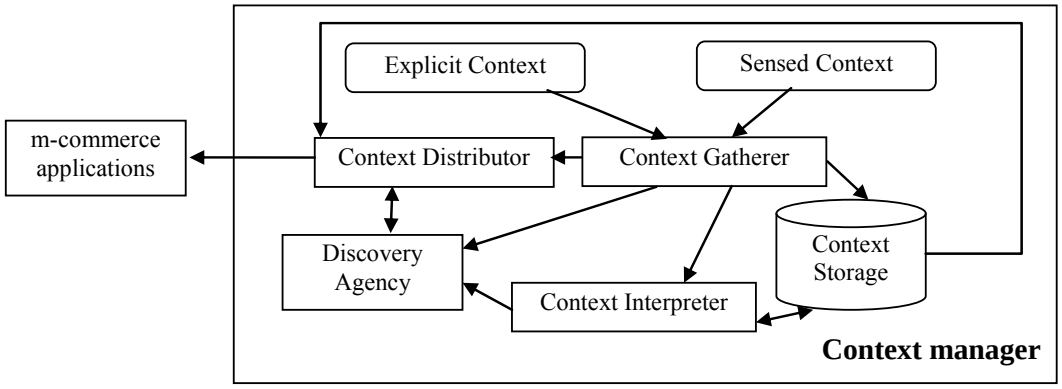

Fig 4. The Context Manager

The *Context Gatherer* is the subsystem which is responsible for collecting the context information. Context information can be gathered from *physical sensors* (e.g. location sensors, identification sensors, motion sensors, etc.) or from *logical sensors* (e.g. APIs provided by the operating systems which allow the retrieval of information regarding the processing power, the available software and hardware components, the current time and so forth). Logical sensors include the software modules that retrieve information from the main application database (e.g. which user is currently logged in, which has been his/her observed behaviour up to this time, etc). An additional source of context information is the *user*, who is the source of explicitly provided context information (i.e. information directly entered by the user, such as gender, date of birth and so on). Depending on the source of the context information (physical sensors, logical sensors or users), the mechanisms that will capture it will be designed.

The *Context Interpreter* gathers information from *Context Gatherer* and *Context Storage* and conducts aggregation and inference activities. The resulting context is either passed to the *Context Distributor* or stored to the *Context Storage* for later retrieval.

The *Context Distributor* makes contextual information uniformly available to other systems (i.e. an m-commerce application, an adaptation manager). It provides information in two different modes: *request-response* and *event triggered*, supporting the "push" and "pull" character of the context. In *request-response* mode it grants context only on explicit request while in *event triggered* mode the provision of context is fired from specific events. The distribution of context information will take place after taking into consideration the privacy

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policy [6], [17] defining to whom and under which circumstances private context information may be distributed. When a user requests a service, a Rule Engine inside the Context Distributor will request the privacy policy of the service provider (m-commerce application) on behalf of the user. The service provider will respond to the Rule Engine of Context Distributor and supply its privacy policy to Rule Engine. After the Rule Engine obtains the service provider's privacy policy, it will automatically compare the privacy policy of the service provider with the user's privacy preferences (e.g. expressed as a set of APPEL rules) and accordingly provide or hide the context information.

The context information *Discovery Agency* implements facilities for locating the sources of context information and for informing interested parties on how they may be contacted.

The *Context information Storage* allows for long-term storage of context information; this can be produced by any context information provider and once stored in the context information store can be later retrieved by context consumers. The implementation details of the context information store, including storage format, policies for purging past information and query language (e.g. SQL or SPARQL) are beyond the scope of this paper.

7 Evaluation

The necessity for a different approach towards developing m-commerce applications in relation to e-commerce applications ($m \neq e$) [64], [74], [75] and the challenge of investigating the context of mobile commerce applications as well as the advantages of its utilization have been discussed by many researchers [74] [75]. Many researchers have studied the factors affecting the adoption of mobile commerce services (e.g. usefulness, ease of use, enjoyment, relative advantage) [37], [50], [74] and have pointed out important context parameters (location, time, user context), which are of great importance to m-commerce applications [49], [74]. Also, they have provided certain guidelines for the development of wireless web services making use of context [49], [74], [75] which will satisfy the end user and promote m-commerce.

However, in the field of m-commerce, and despite the description of related context categories and definitions of many of the important context parameters [41], [64], a complete approach providing a definition of context for

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m-commerce applications suitable for computerized systems has not been presented. Also, there has been no diagrammatical tool for the depiction of context for m-commerce application, nor a methodology for development and a software architecture facilitating the process of design and development of context-aware m-commerce applications. This is the gap that our conceptual model comes to fill. The proposed model also emphasizes the important role of Marketing in the design and promotion of context-aware m-commerce applications. Table 2 summarily reports the similarities and differences of our work compared with other suggested models for the development of context-aware m-commerce services.

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Methodology for identifying and specifying Context Information for m-commerce Applications (MCA)	**Proposed Approach by the Present Study**	**The Frame-work for Relevancy – Based Wireless Web Services [49]**	**The research for the "Value-based adoption of Mobile Internet" [37]**	**The study for the "Evolution of Mobile Location – Based Services" [57]**	**The model for "Designing Mobile Commerce Applications" [64]**	**The study for "Understa-nding Usability in m-Commerce" [75]**	**The study for the "Web and wireless site usability" [74]**
Determines the role of Context for MCA	To a limited extent, since it has already been analyzed by other researchers	Yes, extensively	To a limited extent, emphasizing the factors affecting the perceived value of services on mobile internet	Yes, but within the scope of location	Yes, extensively	Yes, but not extensively	Yes, but within the scope of "ease to use"
Determines the context that MCAs are interested in	Yes, emphasizing application-specific context	To a limited extent, defining location, time and user preferences and habits as basic parameters	To a limited extent, by enumeration	To a limited extent	Yes, but not through a general definition but by listing context parameters	To a limited extent, only some parameters of context	To a limited extent, only some parameters of context
Offers a computer-oriented definition of context	Yes	No	No	No	No	No	No
Reveals context's aspects relative to m-commerce (application-specific context)	Yes	To a limited extent. It offers some guidelines	No	No	No	No	No
Includes diagrammatic representa-tion of context	Yes, context is represented using UML-compliant methods	No	No	No	No	No	No
Provides guidelines and/or architecture for software construct	Yes, at high level	To a limited extent; it offers some guidelines	No	No	To a limited extent	To a limited extent	To a limited extent
Discusses Privacy Issues	Yes	Yes	No	Yes	Yes	No	No

Table 2. Differences and overlaps between existing approaches and the proposed conceptual model in the m-commerce field

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8 Context and m-Business Applications

8.1 The Difference Between m-Commerce and m-Business

Even though Mobile Commerce (m-Commerce) and Mobile Business (m-Business) have certain similarities and are commonly used interchangeably in the literature, they cover different application areas. M-Commerce is involved only with monetary transactions that are executed by wireless information transfer using mobile devices [4]. MacDonald [48] summarizes m-Commerce as "*making money through the phone*". On the other hand, Gerpott [70] defines m-Business as "*a generic term of m-Commerce, but which covers additional support of non-financial exchange processes in and between companies via mobile information services*". Therefore, m-Business can be defined as business transactions over mobile telecommunication networks that are executed via mobile devices; adapting the definition from [34] *"m-business includes both the front- and back-office applications that form the core engine driving contemporary business transactions. In the broadest sense, m-business is the overall strategy of redefining old business models, with the aid of technology, to maximize customer value and profits"*. On the other hand, m-Commerce is denoted as a subset of m-Business that involves commercial transactions, i.e. the exchange of goods, tangible or intangible, for money. Selling books and CDs over the Internet is a well-known example of m-Commerce, whereas a service for locating a person having a heart attack and sending an ambulance to him/her would be considered as an m-Business rather than m-Commerce service [65].

The application areas of m-Business include: i) Sales Force Automation, ii) Field Force Automation, iii) Warehouse and Stock Management, iv) Asset Management, v) Fleet Management, vi) Wireless Operations, vii) Customer Relationships [62]. In these application areas, there exists a considerable diversity of associated business processes, as opposed to the case of m-commerce where the involved business processes are more limited (advertise and present products and services; accept customer order; accept payment and deliver goods).

The direct goal of the application areas listed above is not profit, in the monetary sense of the term; much as in the case of m-commerce applications, profit is generated indirectly. The direct goal of these applications are, in accordance with the category of application, to increase productivity and customer

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satisfaction [76], achieve cost reduction, improve the quality of provided services and communicate better image to the client [19], support traceability of the items [77], achieve better asset management [1], provide more effective services [1], [12], [19]. Therefore, the utilization of context for m-business applications should be done with the aim of increasing the aforementioned benefits of using these applications.

Additionally, many of these applications are generally targeted to corporate employees, rather than the general public. This limits the need to maintain loyalty of m-application users, since the corporate employees do not have the option to use a competitive application (this is also true for m-government services [71], since the governmental organizations are typically the sole providers of the specific services). Thus, the limited application target group modifies the characteristics of the context to be taken into account in the following respects:

- *the computer literacy of the application users varies less*: since the organization/enterprise can (and typically will) train its employees on the use of the m-commerce applications, all users of the m-business application will have a minimum degree of computer literacy and skills. Contrary, the m-commerce applications are usually addressed to the general public, in which case user training is not feasible and the applications must be crafted to be used by people having the absolutely necessary computer skills.
- *the emotional aspect of the user is of less importance*: enterprise employees are expected to perform regardless of their current emotional situation (compared to consumers).
- *the end-user access devices are bound to vary less*: enterprises and organizations in many cases supply their personnel with PDAs or smartphones, through which they access the m-business applications. The provided access devices are ordered in bulk, therefore within an enterprise the different types of end-user access devices through which the m-business application will be used is limited to 1-5 [enterprises will typically order such devices in bulk, probably differentiating according to the employee's rank (e.g. managers are bound to get a more fully-featured PDA as compared to entry-level workers) and/or

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the department that employees work in (e.g. workers in the delivery fleet department may need better GPS devices than workers in the warehouse)], while in the m-commerce the number of end-user access device types will be significantly higher.

- *a considerable amount of data needed by the m-business applications is known in advance*. This allows this data to be pre-loaded to the end-user access device (when the user has access to the corporate network), to save communication costs for fetching this data through mobile telephony networks. The need to fetch data through mobile telephony networks can be limited to receiving information that has been modified since the pre-loading. Similar practices can be followed for returning data to the enterprise information system (e.g. store the received orders in the end-user access device and off-load them to the enterprise information system upon return to the office). On the other hand, provisions for maintaining the confidentiality of the pre-loaded data must be employed, to avert their leakage e.g. in the case of end-user access device loss or theft.
- *privacy concerns are limited*. The organization will be entitled to maintain in its human resource management system a great deal of personal information for the m-business application users, which can be used for implementing adaptivity in the m-business application. Moreover, some information that users would want to maintain as private in the m-commerce domain (e.g. their current location) would not be considered as private in a number of m-business application (e.g. the location of a truck and hence its driver in a fleet management application). This simplifies the design and development of the applications by removing restrictions on where processing will take place and which data will be available to the various modules.

8.2 Context Management for m-Business Applications

Similarly to the case of m-commerce applications, the identification, management and exploitation of *context* constitute recurrent and interdependent processes in m-business applications' lifecycle, and there is a need for theoretical framework for the management and standardization of these processes. The

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Conceptual Model presented in section 4 (which includes a computer-oriented definition of context information) and the methodology discussed in section 5 for the definition of context information and its capturing on extended UML diagrams, may be applied to m-business applications with some differentiations.

To begin with, the definition of context presented in paragraph 4.1 should be altered so as to reflect the goal of adaptation of m-business applications as follows:

'Context information of an m-business application is every piece of information which may be used to characterize a state of an entity that can be considered to be relevant to the interaction of the user with the particular application. The entity state may be either static or dynamically changing, while the relevance of the entity to the user-application interaction can be derived from the potential to exploit the information describing the entity state to optimize this interaction, so as to maximize the benefits that derive from the use of the application.'

The modification of the definition is important, since it allows to include more context factors in an m-business application as compared to an m-commerce one (any factor maximizing *the benefits* vs. maximizing the *commercial value*). The formal definition of context presented in subsection 4.2, however, is generic and independent of business goals and application requirements, and hence remains unaltered in the domain of m-business applications.

The categories of context information presented in Figure 1 (user domain, environment domain, computing domain and application-specific domain) remain, although special attention should be given to (a) the location and time and (b) the application-specific context. This is affirmed by research works analyzing mobile businesses models and processes [11], [25], [38], [73], where the emphasis in the process analysis for adaptivity modeling is placed on the elements of *who*, *what*, *when* and *where*, with the first three elements being directly coupled with the application functionality (*what*) and the business rules for data access (*who*, *when*) and the fourth being related to the user location.

Taking into account the differences between m-commerce and m-business applications presented above, the methodology presented in section 5 can be altered in the following ways:

- in step 1, enterprise administration and business analysts will specify the m-business services that are needed to promote the

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goals of introducing the m-business application (c.f. subsection 8.1). For each one of the innovative services, the aspects of context that may be exploited are identified at a high level. Identification of business processes needing to be redesigned and/or re-implemented to foster mobility is also performed at this stage.

- In step 2, the research designs for assessing the success of the m-business application is performed. Perceived usability of mobile business services, perceived fit for mobile working context and perceived impact on mobile work productivity are subjective metrics that can be collected through questionnaires [76]. However a number of objective metrics (e.g. mean time to service a customer request) can be also collected through the system. These metrics should be identified in this stage to allow for incorporation of appropriate monitoring mechanisms, collecting data needed for the assessment, into the m-business application.
- In step 3, the services identified in step 1 are mapped to tasks that should be incorporated into the m-business application.
- steps 4-11 effectively remain the same; the involved actors will however take into account the differentiations regarding the m-business application user computer literacy (more complex operations may be included without the risk of the user being driven away), the uniformity of end-user access devices (e.g. it can be assumed that the end-user access device is equipped with a GPS receiver, that the screen resolution is at least 320 x 480 etc), the fact that some data can be pre-loaded to the system (thus communication costs can be reduced) etc. The emotional aspect of the user is also bound to receive less attention.
- step 12, pertaining to the privacy concerns may be skipped or significantly limited to only consider maintenance and processing of sensitive data.
- steps 13-14 remain the same.
- step 15 will have to be substituted by a step where the assessment of the application's effectiveness will take place in reference to the enhancement of the advantages offered. Based on the results of this

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assessment, enterprise administration and business analysts will revisit the relevant aspects of the m-business application, triggering the re-execution of the appropriate steps of the methodology.

The recording of context parameters may be implemented with the use of context-aware UML case and class diagrams, as described in subsections 5.1 and 5.2. The architecture described on a high level in paragraph 6 may be used in web-based m-business applications, allowing the management of context to be conducted by resource-rich servers.

9 Concluding Remarks

Studying user/consumer behaviour in the context of m–commerce applications, coupled with the study of his/her environment, allows us to delimit and specify the context information that is of value for a particular m–commerce application. In the m-commerce domain, the exploitation of this information for delivering innovative and enhanced services offers a competitive advantage for attracting new and maintaining existing customers.

The present study attempts to approach users interacting with an information system provided through a mobile setting, also as consumers conducting commercial transactions (e.g. information search, decision making process, buying, etc.) through a mobile retail interface. In the era of multichannel retailing, mobile commerce provides a promising and highly evolving retail channel offering to users/consumers with opportunities which never existed before. In other words, since the user of a mobile information system (e.g. a mobile commercial application) is at the same time a consumer interacting with a mobile retail channel, it is suggested that the investigation of his/her behaviour should adopt an interdisciplinary research approach (i.e. Information Systems and Marketing in the case of the present study).

The proposed methodology takes into account the concerns for information privacy, formulating a holistic view under which the benefits and risks from using additional information element to deliver richer services are assessed and allowing thus marketing experts and business analysts to make informed decisions regarding whether it is actually beneficial to use particular private/sensitive data or not. In summation, building bridges among different disciplines contributes to the provision of more integrated and robust research

outcomes. This is the case and one of the main contributions (in terms of research methods) of the present study. The present study also considers the differences between m-commerce and m-business applications and proposes an adapted methodology to better suit the needs of m-business applications' lifecycle.

Additionally, the development of a formal framework for the representation of the context-related concepts, a methodology for context identification and the context-aware UML use case and class diagrams to serve as a tool for documenting context factors and characteristics are presented in this paper, aiming to facilitate the development of context-aware mobile commerce applications. Also, the design of a subsystem that will manage context can be standardized, since it constitutes a standard and repetitive process for each mobile commerce application. Moreover, the encapsulation of the content management logic and procedures into a separate subsystem results to a number of advantages, regarding its manageability, maintainability and speed of application development. However, there is a need to appropriately design in detail the subsystems that will manage context information for m-commerce applications. To that end, future research is strongly encouraged to proceed towards designing such systems.

Finally, future research could apply and test the research framework and/or the m-commerce information system (when implement) provided by the present study in practice. To that end, future research could employ either lab or field experimental settings through which researchers can manipulate one or more of the context's variables in order to test cause-and-effect relationships (i.e. effects of manipulation on consumer/user behaviour) through a causal research design. As far as the selection of the manipulated, independent (moderating factors) and dependent variables is concerned, there is a plethora of available combinations (supported by theory) that could set the basis of the corresponding research hypotheses formulation. Indicatively, relevant theory towards supporting the corresponding research hypotheses could be derived through Information Systems, Marketing, Environmental Psychology and e- and m-Commerce disciplines/research domains.

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