17 MOBILE SYSTEMS DEVELOPMENT: A Literature Review

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Abstract   *This article reviews 105 representative contributions to the literature on mobile systems development. The contributions are categorized according to a simple conceptual framework. The framework comprises four perspectives: the **requirements** perspective, the **technology** perspective, the **application** perspective, and the **business** perspective. Our literature review shows that mobile systems development is overlooked in the current debate. From the review, we extend the traditional view on systems development to encompass mobile systems and, based on the identified perspectives, we propose core characteristics for mobile systems. We also extend the traditional focus found in systems development on processes in a development project to encompass the whole of the development company as well as interorganizational linkage between development companies. Finally, we point at research directions emerging from the review that are relevant to the field of mobile systems development.*

Keywords   Mobile systems development, software development, literature review, mobile requirements, mobile technology, mobile applications, mobile business

1   INTRODUCTION

Information systems development has been researched for decades both from the viewpoint of software engineering and the viewpoint of the information system in use

in organizations. In this article, we address the branch of systems development dealing with developing mobile applications. The present advances in mobile technologies necessitate a rethinking of systems development for this particular domain (Krogstie et al. 2004). Traditional software engineering has much to offer mobile systems development, but the limitations caused by the uniqueness of mobile applications are not clear. The organizational approaches to information systems development or approaches directed at developing Web applications for the consumer market may also have much to offer mobile systems development, but again, these limitations are not clear.

In this paper, we review the literature on mobile systems development (i.e., the research literature that purport to address mobile systems development and mobile applications, irrespective of whether these applications are for the consumer market or for organizational purposes). We do this to sort out what characterizes mobile systems development and the contributions that have already been made in this domain.

The next section outlines our research approach. In section 3, we present the perspectives we have found and how the literature fits into these perspectives. In the discussion in section 4, we elaborate on the structure of the research knowledge on mobile systems development and, in particular, we discuss what is unique about mobile systems development compared to traditional systems development. In section 5, we conclude the article.

2   RESEARCH APPROACH

Along the lines suggested by Webster and Watson (2002), we have pursued a structured approach to selecting articles and we have used a concept matrix to arrive at a conceptual structuring of the domain of mobile systems development.

2.1 Article Selection

We have systematically searched journal articles through the Danish Article Database Service, a portal to all major journals either published by or indexed by Wiley, Siam, Emerald, Blackwell, ACM, IEEE, Kluwer, Elsevier, Proquest, JSTOR, ArticleFirst, EBSCO, FirstSearch, or Ingenta (to name a few). We have also systematically searched conference proceedings indexed by ACM, IEEE, and AIS. We have further searched through conference proceedings on mobile systems, m-commerce, and systems development that we otherwise came across. We have focused on contributions with title, abstract, or keywords hinting that they would be relevant for this literature review and only contributions thus relevant have been reviewed in detail. We have limited our search to contributions dated 2000 or later. In effect, contributions were included in the literature review if they satisfy two criteria:

- They mention mobile systems one way or the other in the title, abstract, or keywords.
- They are relevant for the task of development.

2.2 Conceptual Structuring

The structure of the literature review in the following section was developed through a concept matrix. The conceptual structure emerges from the review. The categorization of contributions is not based on an *a priori* conceptualization. The first-level categories are the primary concern of each contribution as we assess it (e.g., a contribution on how to prototype a wireless LAN is categorized as having a primary concern for requirements). The other first-level categories that emerge from the literature are technology, application, and business. The review reveals in this way four first-level categories, thus providing four primary *perspectives* on mobile systems development.

At the second level, we focus on the concepts addressed in each contribution as we assess it, for example, a contribution (Pedersen and Ling 2003) within the business perspective is categorized at the second level as providing an adoption and diffusion study. The review reveals 8 second-level concepts thus providing 8 areas. The areas are modeling techniques; design studies; wireless communication; architecture; security; application; adoption and diffusion studies; and business models and strategic alliances.

3   PERSPECTIVES

The relevance of the different discourses within the existing research on mobility has been considered by applying a systems development lens. We end up with 105 articles revealing four perspectives (first-level categories) in total covering 8 different areas (second-level concepts) of the literature on mobile systems development. The reviewed contributions and their distribution on perspectives and areas are shown in Table 1; the numbers in brackets are the number of contributions in this area.

We suggest that the four perspectives all have a role to play or influence the practice of mobile systems development. It should be noted that in the following presentation only a representative subset of the articles are used.

3.1 The Requirement Perspective

The *requirement* perspective is here applied as a category comprising two areas within mobile systems development: (1) the literature on modeling techniques for designing architecturally sound mobile systems and (2) the large number of studies focusing on design and human-computer interaction (HCI). In mobile systems development, both research directions play an important role in getting the requirements right for mobile systems.

Table 1. The Distribution of Papers in Each of the Perspectives and Areas

PERSPECTIVES	AREAS	REFERENCES
Requirements	Modeling techniques **[4]**	Drosos et al. 2004; Sauer 2004; Smith 2000, 2004
	Design studies **[26]**	Ahlström et al. 2002; Andersson et al. 2004; Andreasson et al. 2002; Brunnberg 2004; Condost et al. 2002; Dahlbom and Ljungberg 1998; Esbjörnsson 2001; Forsberg 2002; Gallis et al. 2001; Gustavsson et al. 2001; Hardless et al. 2001; Kjeldskov and Graham 2003; Kjeldskov et al. 2004; Lindroth 2002; Lindroth et al. 2001; Lundin and Magnusson 2002; Lundin and Nuldén 2004; Messeter et al. 2004; Nilsson 2001; Olsson 2004; Pareto and Snis 2004; Pica 2002; Östergren 2004; Smith-Berndtsson and Åström 2001; Weilenman 2001; Xu and Teo 2004
Technology	Wireless communications **[18]**	Carneiro et al. 2004; Chen et al. 1998; Gao et al. 2004; Hang et al. 1997; Hsieh and Sivakumar 2004; Hu and Zhang 2004; Huang and Zhuang 2004; Iraqi et al. 2000; Jiang and Zhuang 2004; Kim et al. 2003; Lindgren et al. 2003; Lu et al. 2004; Mahadevan and Sivalingam 2001; Mohapatra et al. 2003; Niebert et al. 2004; Wei and Gitlin 2004; Wu and Chuang 2001
	Architecture **[17]**	Braun et al. 2004; Bruno et al. 2001; Cannataro and Pascuzzi 2001; Dahlberg et al. 2001; Davies et al. 2002; Fife and Gruenwald 2003; Jing et al. 1999; Karimi and Krishnamurthy 2001; March et al. 2000; Metafas et al. 1996; Pierre 2001; Pitoura and Bhargava 1994; Sanneblad 2001; Schoeman and Cloete 2003; Shih and Shim 2002; Straub and Heinemann 2004; Thorstensten et al. 2004

PERSPECTIVES	AREAS	REFERENCES
	Security [18]	Bahl et al. 2002; Bierman and Cloete 2002; Capra 2004; Dogac and Tumer 2002; Gupta and Montenegro 1998; Køien 2004; Lange-heinrich 2001; Mishra et al. 2004; Park et al. 1998; Phillips et al. 2002; Ravi et al. 2004; Schwiderski-Grosche and Knospe 2002; Sklavos et al. 2005; Tang et al. 2003; Tang and Veijalainen 2001; Wang and Pang 2003; Weippl and Essmayr 2003; Yang et al. 2004
Application	Application [6]	Christensen et al. 2002; Lipic and Osmano-vic 2001; Olla and Atkinson 2004; Raati-kainen et al. 2002; Senn 2000; Varshney and Vetter 2002; Yen and Chou 2000
Business	Adoption and diffusion studies [7]	Aarnio et al. 2002; Fogelgren-Pedersen 2002; Ling 2000; Ioanna et al. 2004; Naruse 2003; Pedersen and Ling 2003
	Business models and strategic alliances [9]	Alphonse 2004; Barnes 2002; Haaker et al. 2004; Olla and Patel 2002; Pedersen and Methlie 2004; Sabat 2002; Siau et al. 2001; Tsalgatidou and Pitoura 200; Van de Kar et al. 2003

3.1.1 Modeling Techniques

Because of the advances in wireless technologies, the level of complexity for the underlying system architecture rises. Furthermore, as complexity rises, time-to-market is as important as ever. This calls for a powerful modeling and design methodology ensuring robust and rapid development.

The increased complexity leads to at least four desirable capabilities within modeling and development of mobile systems: controllable abstraction, reusability, analysis of capabilities, and a high level of abstraction (Metafas et al. 1996). Considering these desired capabilities we may say that this "implies the need for an object-based approach" (Metafas et al. 1996, p. 123). These modeling and architectural considerations seem to have been agreed upon in the later contributions within this field. Smith (2004) proposes an extension of the specification language Object-Z (Smith 2000) to enable scalable and intuitive implementation of mobile applications. The Object-Z specification language is an object-oriented approach. Smith (2004, p. 193) argues that the properties of "inheritance and polymorphism allow us to exploit commonalities in mobile systems by defining more complex models in terms of simpler ones." Similar attempts at applying object-oriented approaches to modeling of mobile systems have been proposed. Drosos et al. (2004) apply an extension of the unified modeling language (UML), namely UML-R (unified modeling language for real-time). The obvious benefit of UML is the already predominant use of UML in practice, implying that the applicability of UML must be conceived as high among designers. To test the

applicability of UML-R, Drosos et al. evaluate a development project applying the UML-R design language. The evaluation showed a reduction in development time and the methodology also proved to be highly beneficial as a tool for abstraction when several development teams collaborated in codesign of the resulting mobile system.

3.1.2   Design Studies

We treat design studies and mobile HCI under the common area of *design studies*. The huge interest in research on design and use of mobile systems dates back to the late 1990s. Dahlbom and Ljungberg (1998) proposed *mobile informatics* as a new research direction within IS. The core of mobile informatics is the exploration into how mobile work may be supported by wireless technologies and how users apply these. The contributions within design studies have been many.

Another, related school of thought is the research discourse of mobile HCI. One of the research areas within mobile HCI shares strong relations with mobile informatics, even though the term *usability test* is used more frequently in mobile HCI. In mobile HCI, there is an interest in evaluating the research approach by which evaluations of usability are carried out. Kjeldskov and Graham (2003) provide a review of the applied mobile HCI research methods. The review indicates that the laboratory testing approach dominates the mobile HCI domain even though the real-world context obviously cannot be compensated for in such settings. Consequently, they advocate for an increased interest in more context-rich research approaches (e.g., field studies or case studies). However, a recent study (Kjeldskov et al. 2004) shows that a usability test in a laboratory may be just as effective.

3.2 The Technology Perspective

The continuous advances of wireless technologies imply a complex and uncertain area for development companies. Developing mobile systems, therefore, necessitates in-depth analysis and consideration of what technology to use as the foundation for coming mobile systems. The *technology* perspective covers broadly the technical contributions adding to an increased body of knowledge on how to understand, exploit, and deal with the new technological capabilities from a technical viewpoint, and the issues and challenges emerging from these wireless innovations. Pierre (2001) contributes to the field by providing an overview of the predominant concepts and nontrivial areas (e.g., cellular systems, network infrastructure, application architecture, and security). Our literature review has revealed contributions in the three areas: wireless communications, application architecture, and security.

3.2.1   Wireless Communications

In this context, wireless communications covers research on or strongly related to cellular systems and network infrastructure. The increasing number of new or improved wireless network technologies is immense. The primary challenge is no longer just to go wireless, but seems to be "the ability to provide seamless and adaptive quality of

service in such [a] heterogeneous environment" (Gao et al. 2004, p. 24). Currently, this field seems to attract particular interest both in practice and in research. Examples of some the latest contributions are a discussion of the challenges of mobile *ad hoc* networks (MANETs) and future directions and challenges (Mohapatra et al. 2003), a presentation of challenges and solutions in an attempt to solve the interoperability problems in the UMTS network (Kim et al. 2003; Niebert et al. 2004), a proposed a framework for integration of cellular wide wireless area networks (WWAN) and wireless local area networks (WLAN) (Wei and Gitlin 2004), and attacks on the challenges associated with turning the 4G platform into an open architecture including different wireless networks (Carneiro et al. 2004; Jiang and Zhuang 2004; Lu et al. 2004).

3.2.2 Architecture

The architecture is an essential area for development organizations. If we are developing location-based services, which imply an enormous load of requests on the underlying database management system, what architectural implications does this have? The architectural challenges have received a great deal of attention (see Davies et al. 2002; Jing et al. 1999; Pitoura and Bhargava 1994; Sanneblad 2001; Schoeman and Cloete 2003; Shih and Shim 2002). Two examples of studies in which a specific system architecture has been discussed and elaborated are Schoeman and Cloete (2003) and Shih and Shim (2002). Schoeman and Cloete discuss the architectural requirements for a mobile agent system. They contribute by developing a framework adding to an increased understanding of the architectural requirements and issues related to designing and implementing a mobile agent system. The other example represents system architectures within mobile commerce. One of the complex issues for architectures in mobile commerce is that of ensuring correct management of monetary transactions (Dogac and Tumer 2002; Shih and Shim 2002). Shih and Shim propose a scalable framework based on the Java Intelligent Network Infrastructure (JINI) capable of handling complex business transactions from a varied set of services.

3.2.3 Security

Another important area within mobile systems is security. Security in mobile systems exists at many levels; for example, security in wireless networks, security in embedded systems (Ravi et al. 2004), security in mobile agent systems (Bierman and Cloete 2002), security in mobile commerce systems (Schwiderski-Grosche and Knospe 2002), and security in the shape of engineering trust (Capra 2004) ensuring user integrity in mobile information sharing environment (Phillips et al. 2002). The contributions provided by this debate are of outmost relevance and importance to mobile systems development.

3.3 The Application Perspective

The *application* perspective covers articles with the aim of classifying and categorizing existing mobile applications and markets/sectors in which these may be of

particular interest. The main contribution of this research is an increased insight into and understanding of the various classes and types of applications that exist as potential future business objects (Lipic and Osmanovic 2001; Olla and Atkinson 2004; Senn 2000). Varshney and Vetter (2002), for instance, propose a framework for classification of different types of mobile applications and end up with 10 different classes, including mobile financial applications, mobile advertising, and mobile office. Raatikainen et al. (2002) take a different path and discuss the requirements for future middleware (i.e., a set of generic services above the operating system) in order to support mobile applications. Yen and Chou (2000) take the discussion a step further and address the question of business application, managerial issues, and future developments.

3.4 The Business Perspective

The *business* perspective comprises the following two areas of research: (1) adoption and diffusion studies and (2) business models and strategic alliances. Both of these areas may play a significant role when companies consider the business potential of a mobile system. What is the potential with respect to adoption and diffusion of the product on the market? Is it necessary to initiate strategic alliances in order to ensure a solid product and minimize the costs of failure and how are such strategic alliances handled? These are just some of the questions that are relevant in the business-oriented considerations that to some extent steer and influence the development activity.

3.4.1   *Adoption and Diffusion Studies*

Adoption and diffusion studies, in general, constitute a broad research area. In recent years, there has been an interest in applying models from this research discourse on the area of m-commerce (see Aarnio et al. 2002; Fogelgren-Pedersen 2002; Han 2002; Ling 2000; Naruse 2003). The studies are broadly categorized as either diffusion studies, adoption studies, or domestication studies (Pedersen and Ling 2003). In diffusion studies, the focal point is how adoption of, for example, mobile systems takes place at the macro level (Pedersen and Ling 2003). That is, how segments or groups of end-users adopt technology. Adoption studies represent a more individualized focus and are interested in the adoption at the micro level, for instance, individual user adoption (Pedersen and Ling 2003). In the last category, domestication studies, the focus is on the use of technology and its socio-technical consequences. The focus on socio-technical issues associated with technology use is not limited to either defined end-user groups or individual users (Pedersen and Ling 2003). Domestication studies are, therefore, not limited to either a macro or micro level focus. In this way, domestication studies of end-users' habits and use patterns share concerns with design studies (section 3.1).

3.4.2   *Business Models and Strategic Alliances*

In an environment characterized by much uncertainty, such as the mobile industry, there has been a trend toward strategic alliances also refereed to as value chains (Barnes 2002; Haaker et al. 2004; Kar et al. 2003; More and McGrath 1999; Pedersen and

Methlie 2004; Sabat 2002;Tsalgatidou and Pitoura 2001). The emergence and organi-
zation of such interorganizational networks requires that "multiple actors have to
balance different design requirements, strategic requirements, and business logics to
create a win-win situation, in which each actor has an incentive to cooperate" (Haaker
et al. 2004, p. 1). Actors in these networks may be technology platform vendors, net-
work and infrastructure vendors, application developers, or content providers (Sabat
2002; Tsalgatidou and Pitoura 2001).

In a case study of the business model applied in the design and launch of i-mode's
ringtunes service, Kar et al. (2003) propose four elements that together represent the
business model for the ringtunes service concept. The four elements are (1) service
formula, (2) network formation and coordination, (3) enabling technology, and
(4) revenue model. The literature within mobile commerce seems to agree largely on
these dimensions as constituting elements of a business model (see Haaker et al. 2004;
Pedersen and Methlie 2004). According to Kar et al., the service formula is concerned
with defining the service strategy for adding value to the end-customer (e.g., what and
how content is to be offered). The network formation and coordination—or the govern-
ance dimension (Pedersen and Methlie 2004)—defines the rules of engagement in the
interorganizational alliance. Finally, Kar et al. emphasize the importance of getting the
technological issues solved and reaching, for all parties, an acceptable revenue model.

4. DISCUSSION

The literature review reveals the current state of the mobility debate and also its
contribution to mobile systems development. The distribution of the reviewed articles
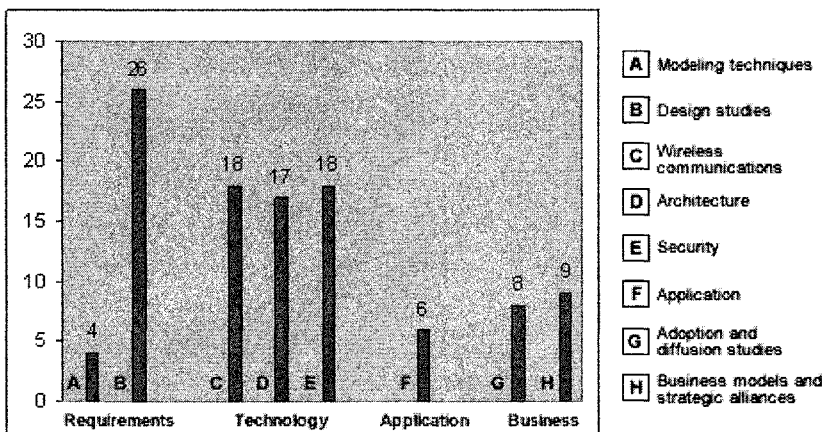on the different perspectives is depicted in Figure 1.

Figure 1. Histogram of the Different Perspectives
and the Distribution of Articles

Interpreting the distribution of contributions brings forth several issues. Clearly, the distribution shows an overweight of technology-related contributions. The three areas within the technology perspective represent 50 percent (53 papers out of 105) of the articles in this review. Arguably, we may say that the mobility debate so far has been largely technology-driven. The strong focus on technology is an obvious indicator of continuous development and innovation within this field, which reflects somewhat immature technologies, but also emphasizes a strong demand for more robust and flexible mobile technologies.

The requirements perspective shows an uneven distribution between the two areas (modeling techniques and design studies; see Table 1). Modeling techniques are covered in only four articles whereas design studies are covered in 26 articles. Both areas are important in a mobile systems development context when trying to understand the requirements. However, the current state of the research literature reveals that much needs to be done in the area of modeling techniques in order to develop a sufficient body of knowledge of how to actually model these systems. The role of modeling techniques should not be underemphasized as these contributions are necessary as a first step toward conceptualizing mobile systems from a development perspective. In a discussion of the characteristics of mobile systems, Krogstie et al. (2004) propose model-based techniques as a way forward to understand the particularities of these systems. In general, the implications of mobility have been extensively studied, taking many different perspectives. The varying types of contributions may all have a role to play in mobile systems development, but the limitations are unclear. As a first step, we propose an extension of the scope of traditional systems development that may contribute to a framing of mobile systems development.

The literature review shows that the scope of mobile systems development is an extension of the scope of traditional systems development.

From the literature on mobile systems development, it is easy to get the impression that all that has been learned and written about traditional systems development is neglected as it is hardly mentioned in the literature we have reviewed. It is, however, necessary to look at the recent research on mobile systems development as an extension of the existing body of knowledge on systems development (see Figure 2).
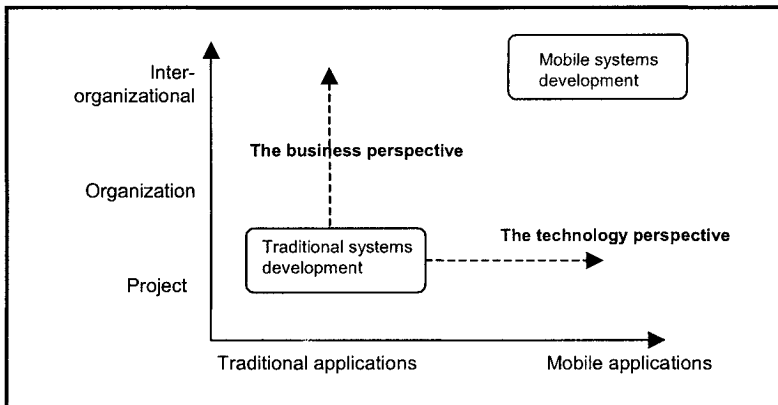

Figure 2. The Extended Scope of Mobile Systems Development

Traditional systems development tends to focus on methodologies and techniques that are focusing on stationary information systems in organizations, enterprise resource planning systems, and, lately, Web information systems. The particulars of the mobile technologies as outlined in the technology perspective (section 3.2) extend the scope (horizontally in Figure 2) because of the focus on mobile wireless communications, application architectures, and security. The technology perspective has immediate implications for the requirements perspective (section 3.1) as that is directed at modeling techniques and design studies. It is striking that very little research has been directed at establishing requirements that do not merely reflect the mobile technologies, but also the organizational and social context of mobility. The technology perspective has also immediate implications for the application perspective (section 3.3) with its outline of the different types of mobile applications and their uniqueness.

Traditional systems development tends to focus primarily on the task of development at the level of the project and very little on the task of development at the level of the company or at the level of inter-organizational development. The tremendous focus within mobile systems development on the business perspective extends the scope toward higher organizational levels (vertically in Figure 2).

Business models and strategic alliances have been of some concern in traditional systems development. The increasing complexity of the task of developing mobile systems and its character in terms of both task uncertainty and business risks makes it less likely that these complexities can be handled at the level of the development project. Mobile systems development thus often involves several development projects in several development companies. Collaboration between some of these is then organized in strategic alliances (Haaker et al. 2004). Hence, the concern for strategic alliances becomes crucial in mobile systems development. Strategic alliances are not new to systems development, but seem to be more common among mobile development companies, although so far there is little research documenting this.

The increased technical complexity in mobile systems and the increased complexity of business models may well lead companies to enter into strategic alliances. Strategic alliances, on the other hand, do not reduce the complexities per se. The partakers in the alliance exercise specialization of development capabilities and competencies as well as specialization of system components or provided services. Effectively, that can increase the process complexities, as the complexity of the added collaboration also needs to be handled.

We propose that strategic alliances stand out as a unique characteristic of mobile systems development and thus deserve further attention in the pursuit of framing and understanding the implications of this concept.

5   CONCLUSION

In this paper, we have reviewed 106 papers and their contributions to mobile systems development. The review shows that the field is still at an early stage.

We found that little research addresses mobile systems development directly. The reviewed literature is relevant to mobile systems development, but not central. Traditional systems development may have much to offer, but is largely directed at the project level. The technological challenges in mobile systems development are signi-

ficant, but research in these areas is not well connected to the development tasks. Strategic alliances and interorganizational development surface as one of the characteristics of mobile systems development, but remain a significant challenge for future research.

Effectively, we propose to view mobile systems development as an extension of traditional systems to encompass these new challenges.

Further research is needed in order to understand the implications of the technological challenges and challenges stemming from business models and strategic alliances on mobile systems development.

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