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The Next Wave of Nomadic Computing: A Research Agenda for Information Systems Research

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Abstract
A nomadic information environment is a heterogeneous assemblage of interconnected technological and organizational elements, which enables physical and social mobility of computing and communication services between organizational actors both within and across organizational borders. We analyze such environments based on their prevalent features of mobility, digital convergence, and mass scale. We describe essential features of each in more detail and characterize their mutual interdependencies. We build a framework, which identifies research issues in nomadic information environments at the individual, the team, the organizational, and inter-organizational levels, comprising both service and infrastructure development. We assess the opportunities and challenges for research into each area at the level of design, use and adoption, and impacts. We conclude by discussing challenges posed by nomadic information environments for information systems field to our research skills and methods. These deal with the need to invent novel research methods and shift research focus, the necessity to question the divide between the technical and the social, and the need to better integrate developmental and behavioral (empirical) research modes.

Keywords: mobile computing, IS research, information environments

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The Next Wave of Nomadic Computing: A Research Agenda for Information Systems Research

Introduction

Rapid developments in information technology (IT), particularly in communication and collaboration technologies, are substantially changing the landscape of organizational computing. Concepts like pervasive or ubiquitous computing[1], enabled by dramatic developments in mobile and wireless communication technologies, such as WAP[2], Bluetooth™[3], and 3G mobile phones[4], and the continued miniaturization of chips and computing devices suggests the possibility of radically new types of computing services. These services will establish for the first time a truly nomadic information environment. At the same time, handheld computing devices such as personal digital assistants or digital mobile phones will lead to more complete digitalization, miniaturization and integration of diverse sets of knowledge (personal, organizational, public) for knowledge workers. The tools will also offer unprecedented possibilities to access and share information in organizations and communicate them with others on the move. Such emerging environments we call a nomadic information environment. A nomadic information environment is defined here as a heterogeneous assemblage of interconnected technological and organizational elements, which enables physical and social mobility of computing and communication services between organizational actors both within and across organizational borders.

A push towards nomadic information environments is driven by three profound changes in business environments: *knowledge intensity*, *globalization*, and *virtualization*. First, learning, innovation and knowledge have become one of the key issues that concern managers and organizational design in the 21st century. Swift and radical organizational learning and routinization of innovation are the true sources of organizational advantage. Consequently, knowledge has become the critical production factor that underpins these capabilities. At the same time, organizations are becoming increasingly global: companies' value chains are stretched over national boundaries and companies engage in strategic alliances around the globe. Finally, an increasing number of organizations experiment with virtual forms—including virtual teams, organizational memory and virtual communities—to integrate knowledge distributed throughout a global organization. In such emerging net-centric organizations, communication and coordination take place dominantly through computer and communication networks thus

[1] See for example http://www.technologyreview.com/magazine/jan01/buderi.aspThe Evolution of Computing, and http://www.acm.org/technews/articles/2001-3/0131w.html#item19, or its impact on the different industries denoted as "gadget wars" see http://www.acm.org/technews/articles/2001-3/0316f.html#item12

[2] WAP stands for Wiress Application Protocol. It is an open global standard that specifies standards for mobile users information and service access. For more information, refer to http://www.wapforum.org.

[3] Bluetooth™ is a de facto standard for wireless communication among various devices in short to medium distance. For more information, refer to http://www.bluetooth.com.

[4] 3G refers to the third generation mobile phone systems which allow broadband access for enhanced wireless service. For more information, refer to http://www.3gpp.org.

making access to and availability of global information and communication technology a key element in the organizational design and operations.

The spread of nomadic communication technologies, combined with the changes in business environments offers radically different ways in which information can be created, shared, and mobilized in the future. Managerial and knowledge work will not be tied to an office and desktop machines, but will consist of constant and continuous collaboration, communication, and coordination on-the-fly among distributed actors using an increasingly diverse set of computing devices at various levels of organizational action (Bellotti and Bly 1996, Luff and Heath 1998, Mintzberg 1975).

The creation of effective and innovative information environments utilizing nomadic and pervasive technology will set out a research agenda that stretches over several disciplines, and involves multiple levels of analysis. This emerging disciplinary matrix will consist of areas like computer science, human-computer interaction, organizational design, cognitive psychology, ergonomics and economics. In this paper, we present a research agenda for nomadic information environments from the viewpoint of information systems (IS) research. This research agenda is based on our recognition of the unique need of IS researchers to understand how to integrate diverse technological, social and managerial issues while designing, building and managing such environments and services.

In the past, IS research has been often criticized for its lack of relevance (Benbasat and Zmud 1999, Davenport and Markus 1999, Lee 1999, Lyytinen 1999). Often adopting the role of "historians of the recent history," IS researchers have been occupied heavily with the problem-solving concerning the past and the present, rather than creating problems for the future. Because of this, IS researchers frequently examine the development and the use of IT in organizations with old technological paradigms that are viewed irrelevant by the industry, only after the field has moved into new technological regimes with a new set of challenges. Likewise, unless IS researchers become an active voice within the discourse addressing the creation and development of nomadic information environments and its consequences, the IS community will remain to be challenged for its irrelevancy.

The rest of the paper is organized as follows. In the following section, we present some fundamental characteristics of the emerging nomadic information environments. We consider both technical and non-technical features that are necessary to design, build and manage nomadic information environments. Then, we discuss the implications of nomadic information environments for individuals, teams, and organizations, and identify a set of core issues for each of these levels that will guide future IS research. We conclude our paper by discussing three theoretical and methodological challenges that we anticipate in this line of inquiry.

A Framework of Nomadic Information Environments

As noted above a nomadic information environment is defined here as a heterogeneous assemblage of interconnected technological and organizational elements, which enables physical and social mobility of computing and communication services between organizational actors both within and across organizational borders. The novel features of such an environment are its high level *mobility*, the consequent *large scale* of services and infrastructure, and the multiplicity of services in terms of data processes and transmitted—often called *digital convergence (*see figure 1). These three technological drivers—*mobility, digital convergence, and mass scale*—underlie most developments in future computing technology.

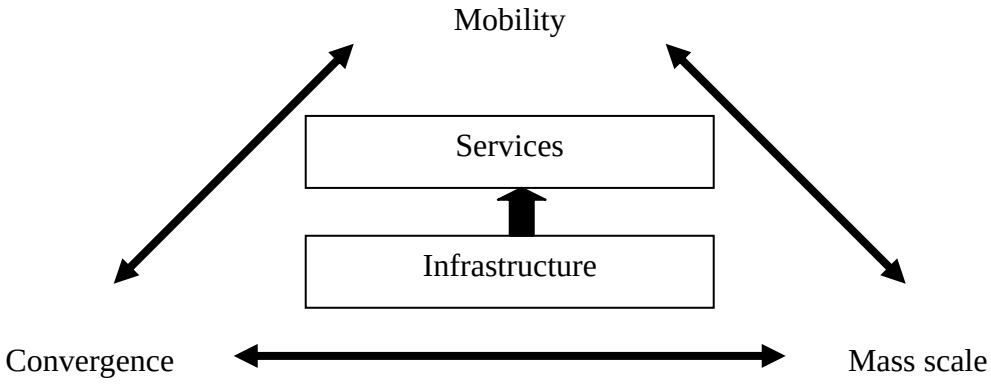

Figure 1. A framework of nomadic information environments

These drivers are distinct in the sense that one can achieve, for example, quite a high degrees of mobility without a full digital convergence (e.g. cellular services or low level mobile data services), or one can provide a high level of digital convergence without a high level mobility. Yet, when put together they become reciprocally influencing drivers that will shape the evolution of future computing environments to become truly pervasive, nomadic, and diverse and flexible in terms of services offered. When taken together, the emerging nomadic information environments are different from the past mobile computing and pervasive computing research (see e.g., Bellotti and Bly 1996, Luff and Heath 1998) that has focused mostly on micro level behaviors and local mobility with separate applications, ignoring so far the issues of large scale design and integration to the existing installed base of services and infrastructure.

When nomadic computing becomes a part of the mainstream, its key technological drivers will both influence and enable developments both in the *infrastructure* and *services*. The infrastructure that enables and constraints the types of services entertained by future users, and the actual services that create the nomadic information environments, as we experience them, will encompass both technical and non-technical (or social) elements and their role and nature may have to be rethought.

Fundamental Drivers towards Nomadic Information environments

Mobility

In the past, services were provided at a stationary location and users had to come to the site to receive the service: in the future, services will come to the users acting in various organizational roles, whenever and wherever they are needed. For example, users can log on to any PC and pick up any phone in the organization and will receive nearly identical services regardless of their physical location. Furthermore, identical or similar services will be provided through multiple devices at different sites and on the move. For example, an intranet portal service can be retrieved from a desktop PC in an office, a mobile PDA at an airport terminal, or a mobile terminal in a car driving 250 kilometers per hour on a German autobahn. The enabling infrastructure will recognize differences in the deployed devices and will accordingly adjust the content and rendering mechanisms to fit the device.

We argue that mobility will be the most distinctive characteristic of future computing environments, enabling nomadic information creation and sharing. Unlike traditional stationary computing technologies that were tied to a physical location, emerging wireless and handheld computing tools can be taken to different places and held in different places at ease, while still providing both access and adequate computational services. At the same time, in order to support all forms of mobility we will observe important changes in terminals. Their size (smaller), shape (more diverse, ergonomic, and stylistic), and functional diversity (from simple mobile phones to portable laptops offering complex virtual reality environments) will be increasingly varied in the future. Moreover, our capability to configure them into varied service platforms will grow rapidly.

The most important feature of these devices is their nomadic nature: they move with us all the time, and accompany us in many types of services. This raises the need to integrate them with other resources while we move around. Luff and Heath (1998) identify three types of mobility that consequently need to be addressed: *micro mobility, local mobility,* and *remote mobility*. Micro mobility refers to the way in which small artifacts such as books and notepads can be mobilized and manipulated "at-hand" and how they relate to our bodily experience. Local mobility involves real-time interactions between people and technologies in the same "location" or "site". Finally, remote mobility supports both asynchronous and synchronous collaboration and information sharing among individuals who move around distant physical locations. While 3G mobile phones and global positioning systems (GPS) are designed to support remote mobility at a global scale and increase the awareness of our movement through physical space, emerging small distance radio-wave technologies like Bluetooth™ support micro and local mobility enabling new forms of information sharing and storage at the personal and team levels with available computing resources (like printers, screens or coffee-makers).

Research within the Computer Supported Collaborative Work (CSCW) field has primarily focused on the "physical" mobility part of nomadic computing (Bellotti and Bly 1996, Luff and Heath 1998). In future, however, it is equally important to consider the "social" mobility while designing services and erecting the infrastructure for nomadic knowledge work. Social mobility refers here to the ways in which and the ease with which individuals can move across different social contexts and social roles, and be still supported by the technology and services. As society and organizations becomes more fluid and dynamic, individuals adopt multiple social roles at an increased intensity and need their information services adjusted accordingly. In new organizational arrangements, it is not uncommon to find individuals who are involved in multiple projects, who hold multiple occupations—many of which are unique—, and who draw upon and are constrained by a set of distinctive social structures. Many times these individuals may not even work at, or for the organization. Organizations' members also participate at increasing levels in inter-organizational task forces, standardization efforts, R&D teams, or marketing campaigns. In such an environment, individuals need to change their roles frequently as they move from one social context to another. Combine this with the need to manage their expanding informal connections to peers and the need to maintain their social relationships with friends and family, one starts to appreciate the complexity of the social worlds that must be organized, enacted and maintained through integrated computing and communication services. Although social mobility can be enabled without physical mobility, these two types of mobility often co-mingle, and increased physical mobility normally precipitates social mobility. For example, when a mobile phone user moves from one location to another, he/she often changes the social context as well (e.g. attends a meeting with a specific role). Since mobility propagates further mobility (Bellotti and Bly 1996), we expect that supporting *simultaneously* both types of mobility will stay as an important research and design

issue when specifying services and building the future infrastructure. Additional research challenges will emerge from the diversity of the types of computing devices that are available, their integration into our bodily experience (smart clothing, even to consider users as cyborgs), and the need to understand information and communication service as a multi-platform engagement.

Digital Convergence

Evolution of computing in the 90's has made the computer a universal media machine thanks to an increased convergence of all physical media to a digital format. In the future, most data will be captured, stored and transmitted in a digital format and thereby many types of information representations can be stored in, transmitted by, and displayed using multiple devices and technology platforms including PC's, mobile terminals or consumer electronic devices like digital TV's. The convergence between mobile phones and personal digital assistants (PDAs) is a good example of such a technical trend. At the same time, several types of data (text, audio, video, etc.) can be transmitted and processed. The increasing use of voice over the IP network is a good example of this trend. Finally, digital convergence permits and necessitates that various devices share information and interoperate seamlessly while producing the service. For example, most PDAs and mobile phones allow users to synchronize their data (like calendars or address books) with PCs, or data services (like directory) with voice services. Interoperability and peer-to-peer computing will become essential elements that enable mobility at the three physical mobility levels, and thus to developing truly pervasive computing environments. That will require the creation of seamless data communication and service protocols between mobile tools and other computing resources embedded in physical environments such as walls, furniture, or desktop computers.

The current trend toward convergence is largely enabled by low cost digitization and open standards. Digital signal processing forms the fundamental enabler of all emerging communication and computing tools that allow diverse devices to share information and multiple types of data to be displayed on the same device. Open standards, such as Bluetooth™, TCP/IP (v6), and WAP, are critical for digital convergence and to support physical mobility. Through such open standards, various devices from competing vendors in diverse technological environments can share information and operate together.

It is important to observe, however, that open data transmission and presentation standards are not enough, if we want to support social mobility. To enhance technology mediated social mobility, organizations and industries need to develop and agree on "social ontologies", which define the significance of social roles, associated behaviors and their linkages with various organizational contexts. Such ontologies will include both technical and social elements. A simple example of a social ontology is the task of granting varying access privileges to different types of users in an intranet based on their organizational position, skill, or experience. In this case, the **types of users** are socially constructed (Berger and Luckmann 1967), while the access privileges and functions themselves are technically defined. Just as the convergence enabled by open standards are essential for physical mobility and interoperability, social ontologies, along with their embedding into the infrastructure and their maintenance through negotiations, is critical to support social mobility and in building nomadic information environments.

Mass Scale

Mobility and convergence implies that the deployment and the use of nomadic information environments will take place in principle at a global level. This, by definition, entails

unforeseen massive scale in service volume, service types and the number of users. Some available statistics may clarify our point here. The number of internet capable mobile devices is expected to reach 1 billion by 2003 (IST-WSI 2000), and the US alone we will have over 300 million Bluetooth capable devices by 2003. In 2000 alone, the market for PDA in the US has grown to $1.03 billion, more than twice the $436.5 million in 1999 (Tam 2001). It is also expected that the amount of data transferred over wireless connection will be c.a. 200 Megabytes per user in a month by 2006[5]. Again, we identify a number of technical and social issues related to the unprecedented mass scale of nomadic information environments. From the technical standpoint, mass scale will require continued attention to interoperability, scalability, reliability and performance of services (March et al. 2000). From the social standpoint, adoption and diffusion patterns, pricing and maintenance, and regulation related to price and content will become major issues that will require managers' and IS researchers attention. While topics related to usability and the adoption of innovations have been one of the main streams of information systems literature (Davis et al. 1989, Markus 1990, Zmud 1984), the extremely large scale and diversity of future information environments will make it difficult to draw solely upon past theoretical models and empirical findings. For example, we need to understand much better the multifaceted relationships between diffusion and adoption contexts, use contexts, and features of the services and technology. Of particular importance is to understand the specific ergonomic and bodily features of embedded or 'at-hand' services and technologies. It is also important to examine their impact on adoption and usability. Moreover, we need to shift from understanding how users adopt and exploit one *specific* application and / or technology in a particular organizational setting to understanding how they use and configure a *varying and dynamic* set of services over time on multiple devices across multiple organizational and physical contexts. The evolution and the avalanche like diffusion of some internet based peer-to-peer services, such as Napster ™, or the immense popularity of short-messaging services in Scandinavia (Kivimäki and Fomin 2001) demonstrate the difficulty of using traditional models to predict the diffusion of such large scale services. Such examples clearly show that how the adoption and the use of such technology is socially formed and evolved at a large scale.

Infrastructure and Services

Nomadic information environments will need to be created on two layers. At a lower layer, the emerging global information infrastructure covering both wired and wireless telecommunications services based on open TCP/IP based protocols is expected to provide a stable platform for nomadic computing on a mass scale. Such an infrastructure will be technically heterogeneous, geographically dispersed, and institutionally complex without any centralized coordination mechanism. Yet, a necessary feature of the emerging infrastructure is that it will have to provide a minimum set of *common infrastructural services like* directory services of users, available services, and social ontologies. A new critical challenge enabled by mobility is to provide location awareness for mobile users. Such awareness cannot be effectively provided without the directory services at the infrastructure level. Furthermore, to support both

[5] For an estimation see Qualcomms analysis of economics of data transfer at http://www.thinkmobile.com/Content/Detail.asp?CTID=1&ID=3272

physical and social mobility, the directory must include information related to social ontologies (with varying levels of detail depending on the use context and role of the user), as well as technical and physical service and location information.

While the emerging infrastructure must be based on a common platform of protocols to ensure stability and persistence, services in nomadic environments will require personalization, dynamic mobility for services and users, and associated channel adaptation. Services must be dynamically configured, modified, and combined to meet the personal needs of the user in the context of physical and social mobility. Information provided by the same infrastructural element like an enterprise planning system or a customer relationship management system has to be customized and combined with personal and public data that are needed by the particular user to meet his/her needs in a given social role.

It is clear that the complexity of nomadic information environments will greatly exceed that of a traditional corporate information management function where much of the computing services have been bound to a specific location, or a set of locations. From the sourly learned experiences over the past two decades of how to effectively manage fixed information services, we can predict that information management in organizations will hit a new complexity wall when organizations migrate to mobile environments. Organizations will not be able to manage the increased complexity of mobile and nomadic services without a sound organizational strategy and supporting infrastructure that spans far beyond an organization's boundaries. Managing infrastructure and strategy options in such an immensely complex environment, which incorporates both extra-organizational and intra-organizational relational structures will become a major research challenge for IS researchers (Sambamurthy and Zmud 2000).

Nomadic Information environments: Opportunities and Challenges

The emergence of mobile and pervasive computing technologies will raise unique opportunities and challenges for IS research. Technical developments in the next decade will allow organizations to create nomadic and pervasive computing environments where distributed information and computing resources, whether held by individuals, or stored within the shared infrastructure, can be enacted and utilized with minimal temporal and spatial limitations. Traditionally, knowledge in organizations has been sticky (Szulanski 1995, von Hippel 1994) and owned by a few individuals and / or locally stored, limiting its application and usefulness. The emergence of mainstream computing has shifted these limitations to some extent, but retained the metaphor of "desktop computing" with a concept of knowledge related to a fixed office environment (Bellotti and Bly 1996). As a result, individuals and organizations have not been able to utilize knowledge when and where it made most sense. A good example can be found in the widely reported failures of shared desktop group calendaring systems. The usefulness of group calendaring systems was severely limited since users had to use their desktop PCs to access these systems and thereby maintain two separate calendars (mobile and fixed). Hence, these tools were not available when they were most needed, i.e., during meetings to coordinate schedules, or to synchronize their calendars automatically on site.

In nomadic environments, in contrast, individuals will be always connected to the global communication and service network. Individuals equipped with mobile communication tools, no matter where they are located, will have access to corporate information and computing resources and users' local resources. Taken together, nomadic information environments will enable unprecedented simultaneous localization and globalization of knowledge whilst individuals utilize tools and technologies to draw upon information resources and services from anywhere, and at anytime (March et al. 2000). This unique feature of a nomadic information

environment offers salient opportunities for IS research. These cover all issues that relate to managing, organizing and sharing information at the individual, team, organizational and inter-organizational levels.

We will build our analysis of research opportunities on a socio-technical perspective of knowledge (Akrich 1992, Akrich and Latour 1992, Latour 1987, Latour and Woolgar 1979) and related literatures that view organization as a distributed knowledge system (Boland and Tenkasi 1995, Hutchins 1995, Weick and Roberts 1993). Thus, below we assume that knowledge in organizations is distributed among human and non-human (or technical) elements, which are at varying levels available either locally, or remotely for organizations' members. Moreover, knowledge in an organization exists not only in individual elements (both human and non-human), but also in the ways in which these individual elements are interconnected either by proximity and physical availability or through virtual connections (Argote and Ingram 2000, Yoo and Ifvarsson forthcoming).

At the individual level, mobile technologies will allow and necessitate the personalization of tools and information transmitted by and stored in various tools at-hand for a specific user. An extreme case of personalization can be found in wearable computers, and the idea of personal area networks (PAN) (IST-WSI 2000). These tools, combined with stationary sensors deployed in the building, can be used to deliver primarily personalized knowledge to users relevant for their context (e.g. location, remote sensing, personal sensing). In such an environment, individuals will interact more extensively with the physical environment through the embodiment of computing tools creating new levels of personal knowledge. For example, the wall of a company's headquarter can have a large public display screen that changes its content depending on the people who are at the wall at that moment, thus supporting both physical and social mobility. If guests to the company are standing in front of the wall, the screen may display greeting information and a building map. If potential customers are standing at the wall, the wall may display key product information that might be of interest to the customer. The same display can be used to perform a videoconferencing, or to project the screen of a mobile PDA for an ad hoc team meeting.

Another important issue is the need to cater for the personalization of information. There are many different levels of personal information, some work related and some completely private and confidential. Since personalization means an integration of different types of personal information onto a single device, it is important that these systems and services provide visibility controls for different types of information. Again, group calendar system combined with PDAs offer a good example. Most calendar systems available on PDAs allow people to guard private information from being shared for group calendaring purposes.

At the team level, nomadic information environments both necessitate and provide awareness of the status of knowledge resources in organizations. As organizations become mobile, the need for awareness of others and what they know becomes increasingly important. In particular, local mobility increases the need for awareness in remote mobility (Bellotti and Bly 1996). Pervasive computing environments equipped with sensors that interact with PAN and GPS can be used to provide essential awareness information, such as location, availability, and changes in the status of organizational actors and persons, to the remote collaborators.

Awareness in nomadic information environments is not necessarily limited to the information about the status and availability of other individuals; it also includes information about the status of technology-mediated knowledge resources. Recently, in the socio-cognition literature, the notion of transactive memory has emerged as an important concept to understand the knowledge and learning in teams (Moreland et al. 1996, Wegner 1987). It is a meta-knowledge about other individual team members' expertise. Simply put, it is knowledge about

who knows what. Similarly, in nomadic information environments, one needs to know where he/she can find necessary knowledge resources to solve a problem. Given that knowledge resources include individuals and technological tools both of which can be mobile, it is extremely important to also create mechanisms through which transactive memory—including both human and technological elements- can improve team performance. At the same time, available services at the team level must provide flexible and encompassing mechanisms for enlisting actors, and coordinating their activities in terms of access rights, transaction completeness and security. These mechanisms should provide awareness of the status of other activities, and offering features like reminders, communication support, etc. that enable teams to coordinate their activities and share ideas across temporal and spatial boundaries (Karsten and Lyytinen 19999). Though there is much past research in such mechanisms, the increased complexity created by simultaneous social and physical mobility will remain a big research challenge for IS researchers.

At the organizational level, the emergence of nomadic information environments challenges both IS researchers and managers to think beyond the traditional distinction between technical (Alavi and Leidner 1999, Davenport and Prusak 1998) and social support of information (Brown and Duguid 2000, Nonaka and Takeuchi 1995, Wenger 1998). As noted earlier, in nomadic information environments, it is becoming extremely difficult to distinguish what is social and what is technical because technical becomes embedded in our everyday operations, and mediates personal and physical experience. Consequently, managers need to think about how to use increasingly varying sources of information mobilization in a complementary way in order to maximize the utility of knowledge resources in organizations. As such, it is becoming a manager's deliberate design choice about how to use and mobilize social and technological resources in organizations.

Finally, an increasingly large number of organizations utilize inter-organizational arrangements such as outsourcing or strategic alliances to maximize the utilization of their own knowledge resources while at the same time tapping into others' resources. Such inter-organizational relationships amplify and make more complex the physical and social mobility issues. For example, in the case of outsourcing, social mobility can cause interesting legal problems for knowledge sharing. Since temporary workers are not a company's official employees, knowledge contributed by and to them on the company's intranet cannot be legally protected through a patent. New social and technical mechanisms need to be developed to facilitate knowledge sharing in firms without jeopardizing their ability to protect proprietary knowledge through such legal devices as patents. Similarly, in the case of strategic alliances developing new standards, there is a tension between guarding private and proprietary knowledge while sharing public information. We see the need to develop new forms of social contracting that can protect private knowledge without constraining emerging business practices enabled by increased mobility.

Research Issues

In the previous two sections, we discussed the dominant features of technical developments in mobile and digital technologies, and the opportunities and challenges these environments will bring about at the individual, team or organizational level. In this section, we will identify a series of research issues that need be addressed by IS researchers within these themes. This we will accomplish by integrating the technological drivers with the individual, team and organizational changes. In particular we will organize the discussion based on the

concept of IS research that it is driven by the rise and consequences of radical improvement in IT- like pervasive computing (King 1993). We can thereby organize our discussion by using the following mission of IS research as a foundation: effective design, use and adoption of IT in organizational contexts (Keen 1991). Accordingly, in table 1, we identify key research issues that deserve IS researchers' attention in future with respect to pervasive computing issues.

IS researchers will have to be cognizant of the design and management issues at the individual, team, organizational and inter-organizational levels related to both emerging services and infrastructure. For services, IS researchers need to address design, use and adoption, and impact of various services at all four levels. For infrastructure, the development and construction (both technical and social) processes of key enabling capabilities on which various services will be provided and the governance and control of these capabilities will be the major issues to be explored by IS researchers. All these issues must be constantly related to three main technological drivers: mobility, mass scale and digital convergence.

	Individual level	**Team level**	**Organizational level**	**Inter-organizational level**
Services Design	• Development of personal, intelligent, mobile assistants • Micro-mobility • Content and medium independence	• Socio-technical transactive memory • Coordination of data and knowledge creation through technical "scripts"	• Enterprise applications and architectures • New workflow and organizational structure • Social ontology models	• Inter-organizational agents • Transaction and coordination mechanisms
Use and adoption	• Use of information channel • Sense-making and enacting in virtual environments • Management of personal information	• Team level adoption and configuration of services • Team process design and maangement – leadership, decision-making, communications	• Organization wide use and adoption of services • Service management and governance	• Industry adoption and network externalities • Emergence, coordination, and control of standards and services
Impact	• Efficiency and effectiveness of decision-making • Information overload • Learning	• Team performance (efficiency and effectiveness) • Team development (trust and learning)	• Organizational performance, and competitive advantage • Organizational learning and agility • Place-less processes	• Emergence of new industry structures and value chains • Transformation of industry structure
Infrastructure Enabling capabilities	• Micro mobility • Synchronization • Peer-to-peer connections • User profiling • Intelligent environments • Directory information	• Awareness support • Simultaneous local and remote mobility	• Integration and maintenance of heterogeneous systems • Partnerships in services • Maintenance of geographically dispersed computing resources	• Standard development • Interoperability
Governance and control	• Access privileges • Security • Privacy • Visibility of personal / public knowledge	• Team level ownership and control of data and information • Access and control of services	• IT services governance • Enterprise architectures • Pricing and control of IT resources	• Regulatory policy and instruments • Pricing • Security and privacy

Fundamental Drivers

- Mobility
- Convergence
- Mass Scale

Table 1. Emergent Research Issues in Nomadic Information Environments

Below we will discuss key research issues at each level for both services and infrastructures.

Individual level

Services. At the individual level, future nomadic environments provide personalization and micro mobility. The design of personalized, intelligent, and mobile services require fundamentally different approaches in user requirements analysis and systems design and development (Banavar et al. 2000, Fricke et al. 2001). We note the separation between content and medium of services as a major challenge in systems development. In the past, system developers can make assumptions about a particular medium by which a particular content will be delivered. For example, users input through CRT terminals; managers receive paper management reports; and people use computers to exchange electronic mail messages. However, in nomadic information environments, such assumptions will not hold. An early example of such independence of content and medium can be found in news service provided through various media by CNN. One can get almost identical contents from CNN via traditional cable TV, their web sites, and wireless devices. As a consequence, design and development of new systems and services need to make a minimum set of assumptions about physical devices to provide a maximum level of personalization and mobility.

In the realm of adoption and use of nomadic information environments, we believe managing personal information access across multiple channels (synchronization and personalization) (Swanson 1987) will be one of the key issues that need to be explored. While the acceptance of IT has been one of the most popular research topics in the past (Davis et al. 1989, Taylor and Todd 1995), the pervasiveness nature of nomadic information environments will present new issues for IS researchers such as integration of software and hardware design with the principles of industrial design and ergonomics (micromobility) (Rhodes 1997, Rhodes et al. 1999, Sawhney and Schmandt 1997), and understanding usability at the new level in mobile contexts with a variety of devices at hand (personalization support)(Dey et al. 1998).

In assessing the impact of nomadic information environments, while most traditional variables such as efficiency and effectiveness will continue to be important, new issues like information overload and learning will become crucial issues.

Infrastructures. To support personal, intelligent, and mobile services, organizations need to build infrastructures that provide various enabling capabilities including micro mobility, synchronization, and directory service (Luff and Heath 1998). The construction of such infrastructure will have both technical and social dimensons at the same time. In the realm of governance and control of infrastructures, the control and ownership of personal and public knowledge across various media in multiple contexts will be a key challenge (Asokan 1994).

Team level

Services. At the team level, the support for local and remote mobility through transactive memory systems, coordination mechanisms, and awareness support will remain major research challenges in years to come (Fagrell et al. 1999). We feel that it is critical to take into account both physical and social mobility while researching these issues and understand mobility as a socio-technical design issue. As noted above there is hardly any research that has touched upon the social mobility, nor is there any research that has studied transactive memories in distributed environments.

Two salient issues for the adoption and use of nomadic information environments at the team level will be team level acceptance of such environments and new team process and configurations. Little research has been done to understand team level acceptance factors related to technology (Fulk 1993, Yoo 1998). Furthermore, given the flexible and pervasive nature of the nomadic information environments, it will be important to understand how and why teams configure these environments differently. Nomadic information environments will also require different team configurations for different tasks such as decision-making processes, leadership, and communications.

The team level impact of nomadic information environments can be assessed both through team performance (efficiency and effectiveness) and team development (trust, cohesion, and learning). While recent research in virtual teams started to deal with these issues (Ahuja and Carley 1998, Jarvenpaa et al. 1998, Jarvenpaa and Leidner 1999, Maznevski and Chudoba 2000), much more research is needed on this topic and in particular how the increased information richness and availability will influence these processes.

Infrastructures. The services of nomadic information environments at the team level will demand novel and scalable infrastructure services that do not exist yet. We also understand poorly how to integrate and co-develop social and technical elements that support and enable both social and physical mobility (e.g., incentives, cultural changes, changes in personal identity as expressed both in the physical and the virtual world). We also lack studies, which examine the usefulness and potential of location awareness to coordinate and mobilize shared information (Schmidt et al. 1999, Schmidt et al. 2000).

The governance and control of nomadic information environments also brings new set of issues in the area of ownership, control, and access privileges of knowledge among multiple team members working on several different projects across several organizations. Since individuals will carry many different roles in different social contexts, providing means by which individuals can share public knowledge with other members of the team while protecting their private information from them will be an important issue of governance and control.

Organizational level

Services. At the organizational level, the development of enterprise application and architectures that will enable new workflow and organizational structure will remain an important issue. At the same time the large scale and rapid rate of change of nomadic computing technology will challenges fundamental assumptions of traditional systems development methodologies. Accordingly, Lyytinen et al. (1998) argue for a substantial and pervasive change in software development content, scope, and organization, which has to be examined by IS researchers. For example, the design of new workflows includes not only technological changes, but also recurrent need for organizational design. In fact, in the future, organizational design will take place through a simultaneous co-evolution and alignment of organizational and technical elements (Chandler et al. 1999, Nadler and Tushman 1997). Furthermore, the development of nomadic information environments at the organizational level requires the development of social ontology models, which involve both technical design and implementation and social negotiation.

The ongoing interest in the adoption and diffusion of services at organizational level by IS researchers will demand fresh thinking and theoretical development. As noted above the issue is not so much how a specific relatively "fixed" technology is adopted, but rather how various services are adopted, refined, configured, reshaped and transferred across social and physical sites and to different access devices. The second issues is the mass scale at which these services

will be utilized and mobilized. This requires both diachronic and synchronic analysis of services and their adoption with relatively large data sets.

The impact of nomadic information environments can be studied not only through traditional organizational performance measures of effectiveness, but also through capability related concepts of organizational learning and agility. In addition, nomadic information environments will permit "place-less" processes and transactions, which calls for new models of organizational actions and behaviors.

Infrastructures. At the level of infrastructure, the maintenance of diverse technical platforms and the construction and coordination of associated social ontologies demands continued attention. While technical issues related to the development and maintenance of heterogeneous, interoperable and distributed computing platforms are receiving an increased attention by IS researchers (March et al. 2000), the behavioral and managerial issues related to social ontology and social mobility have not been widely addressed.

In terms of governance and control, the enterprise wise IT control and governance has been an important issue in the traditional IS literature (Brown and Magill 1994, Brown and Sambamurthy 1999). Given the dispersed and pervasive nature of nomadic computing tools, however, these issues will deserve a new level of attention by IS researchers.

Inter-organizational level

Services. At the inter-organizational level, the development of novel inter-organizational agents and services that enable seamless transactions and coordination will emerge as critical research issues. In the realm of adoption and use, the emergence, coordination, and control of industry wide standards that governs such inter-organizational agents and transaction mechanisms will become important issues for future research (Brunner et al. 2001, Papazoglou 2001, Valera et al. 2001). The impact of nomadic information environments at the inter-organizational level has to be studied by looking at the emergence of new industry structures, service markets and the transformation of existing industry structures (Chandler et al. 1999, Christensen 1997).

Infrastructures. A key and challenging issue for providing inter-organizational nomadic information environments will be the development of infrastructure that provides capability to operate across heterogeneous (both technical and social) networks. The establishment of standard and interoperability will become again a key issue (Jakobs 2000). Finally, in the realm of governance and control, the various regulatory policy and instruments covers pricing security, and privacy concerns will become major social issues that should receive IS researchers' attention.

Conclusion

In this paper, we suggest that recent developments in telecommunications and mobile computing technologies will demand us to rethink some fundamental assumptions underlying past IS research. Such assumptions include: the bodily embedding of computing among and within users is not important in understanding their behaviors; computing takes place in fixed physical sites- ergo sites do not count; we are interested in discrete applications or technologies not in complex environments that enable organizations to mobilize information and its sharing; computing is a remote abstract functionality- not something which concretely moves around and takes place within different contexts and enables new forms of organizational capability and agility; or that technological features of the service and the supporting infrastructure that offers

those services are an important part of the research problem. We believe that questioning some of these traditional assumptions will lead to new and novel problem formulations and will also extend our methodological and theoretical discourses in the future.

Based on our analysis of the key technological drivers, we identified several issues that IS researchers need to carefully investigate in future if we want to offer guidance and provide intellectual leadership in ubiquitous, nomadic computing environments. As our analysis also point out the impact of the pervasive computing concept on our research agenda is pervasive. We will have to return to many of the old and established topics and reanalyze them in the context of new and radical improvements in the services and platforms. Simultaneously, as we pointed out above, many virgin and unexplored territories will be opened for IS researchers, which will reshape our research agenda in the next decade. We believe that the IS research community and IS researchers are perfectly positioned to respond to this challenge and redirect our research agenda based on our intellectual heritage and core capabilities. The key question thatwill face us is: do we want to address this challenge and change our research practices accordingly?

At the same time we believe that the emergence of nomadic computing environments provides a unique opportunity for the IS community to provide an intellectual leadership in shaping how the design and the use of nomadic technology in organizations will take place. There are at least two alternative perspectives that the IS community can provide. First, IS researchers can actively participate in formulating theoretical and practical guidelines of how to design and develop nomadic information environments as socio-technical ensembles, injecting new forms of systems thinking into this process (Churchman 1968). Because IS research community is uniquely positioned between technical and social worlds and their reciprocal interactions, fundamentally concerned with shaping the world through designs, we should be able to locate ourselves at the center of this activity. Second, as we have pointed out above, both the development and the use of nomadic computing are socially constructed and embedded, and therefore all analyses of its use and design must be placed always in a social context. While we maintain the cautious optimism concerning the technology's transforming capability, IS researchers can provide a balanced story of the likely difficulties of designing and the using nomadic information environments. Especially, we should warn and be cognizant of the surprises of technological transformation in terms of unintended social and organizational consequences due to the unexpected interactions between the "social" and the "technical" elements.

Second, the design and the use of nomadic computing tools will shape and be shaped by the value positions held by important actors, including designers, vendors, managers, policy makers, users, etc. The choice and the use of certain technologies are often made to explicitly promote certain value positions in the society (like free speech). In other cases, the use of technology can have inadvertent consequences of promoting certain value positions. The widespread use of mobile tools, for example, will raise unprecedented concerns with regard to security, surveillance and monitoring, privacy, or new time regimes work. We recognize that the IS research community has been often silent to such critical issues. IS researchers, hence, should have the privilege to take a "arms length" look at these issues from a critical perspective (Orlikowski and Baroudi 1991) and critically examine and reveal values and norms that are made privileged through the espoused and actual uses of technology.

We believe that there is enough room in the IS research community to voices of both design activism and critical reflection. Finally, regardless of the perspective that one takes to study nomadic information environments, we can recognize new challenges *in research approaches* that IS researchers need to master if they want to address the research challenges related to nomadic information environments and move forward to carry out research in this emerging field. We will conclude this paper by identifying three such challenges.

First, given the personalized and localized nature of nomadic knowledge and computing, research in this area demands an "up-close" examination of phenomena as it unfolds. This will require us to use more extensively data intensive research methodologies like anthropology, ethno-methodology or action research. Many times investigations will demand access to sensitive and personal knowledge and will have to take into account information access and use as a bodily experience requiring new types of research partnerships and trust. At the same time, given the globalized nature of nomadic information environments, the idea embedded in the traditional data intensive research methodologies of studying *local behaviors* or *meanings* outside the context of a global technology is foregone. Instead, we need to tailor these methodologies so that we can study interrelationships and patterns among various individuals and technological tools dispersed in time and vast geographical space. This paradoxical nature of nomadic knowledge creates a challenging research environment and researchers will need to work on crafting research methodologies and sharpening data collection tools and methods to cope with this paradox.

When researching nomadic knowledge, as noted above, one needs to study the "environments" as opposed to "an application". Past technology acceptance literature (Davis et al. 1989) and the human computer interaction literature (Shneiderman 1980) have mainly focused on the use of a single application, or specific functionality offered by the user interface (like pull-down menus and the like). What we lack in the traditions- both in terms of concepts and theories, and at the level of research methodology- is a deeper understanding of how individuals behave in rich and nomadic information environments enabled and supported by multiple technologies, services and pervasive infrastructure.

Second, as noted earlier, it is becoming extremely difficult to distinguish between social (or non-technical) and technical elements in nomadic information environments when studying information and its sharing. New theoretical and methodological tools need to be developed to adequately address this challenge. While traditional social network analysis has been helpful in understanding the interrelatedness among individuals, it has ignored technical elements mediating, enabling or constraining the social network. One promising approach to overcome this dilemma is to use Actor Network Theory as a methodological tool (Akrich 1992, Akrich and Latour 1992, Latour 1987, Latour and Woolgar 1979). Actor Network Theory considers simultaneously both technical and non-technical elements in the network and their symmetrical relations *cum* inscriptions and thus helps analyze the deep embedding of the technical in to the social (and vice versa). Another challenging theme is to understand better how time and time-space relations become re-organized in nomadic environments, and how the concepts of social and physical co-presence need to be reinterpreted in this new world (Giddens 1984).

Third, many of the technologies discussed above are still in their infancy, though new tools are being developed at a very rapid speed, and at a large scale. This trend challenges the traditional distinction between "technical (or developmental)" research and "behavioral (or organizational)" research in the information systems field. New types of alliances need to be forged and IS researchers should be more actively involved in studies while these technologies are being built and tried out- not after the fact when they enter the market. Because social and technical has become blurred in nomadic information environments IS researchers need to learn better integrate the strands of both technical and behavioral research. Behavioral IS researchers must desperately seek the "IT" in their IT research (Orlikowski and Iacono 2001), while the technical IS researchers must more deeply appreciate how the "social" becomes IT in their IT research. This will require us to be more open and engage ourselves in innovative interdisciplinary research efforts.

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