A multi-layer approach to the study of inter-organizational wireless infrastructure

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ABSTRACT
The supply side of the pervasive commerce market will rely on a mix of wireless technologies that include public cellular and wireless networks as well as the wireless networks owned and operated by individuals and organizations. The integration of these diverse networks constitutes a significant milestone in the evolution of toward pervasive commerce. This research reports on results from a trial involving public cellular/private wireless network integration. Based on insights derived from the trial we propose a multi-layer approach to the study of inter-organizational systems, which facilitates the study of integrated wireless infrastructures in a way that incorporates the findings of the extant inter-organizational systems (IOS) literature from the management information systems (MIS) field.

General Terms
Management, Performance, Design

Keywords
Pervasive commerce, wireless infrastructure, inter-organizational systems.

1. INTRODUCTION
Continuous innovations in wireless and mobile technologies have allowed the integration of networks in order for end-users to seamlessly roam across different networks. The possibility of integrated wireless infrastructure is based on two technological developments: wireless local area networks (WLANs) deployed by individuals and organizations and advanced cellular technologies (3G) deployed by cellular telecommunications firms. Combined, these technologies enable users to have the highest bandwidth and the highest degree of mobility, providing the basis for pervasive commerce.

While providing great opportunities for end-users, integration of these networks -owned by different parties- will present challenges at both the technical and organizational level. As a new type of inter-organizational system, issues like control and coordination of technical and administrative tasks will challenge current practices by both organizations employing WLANs and cellular operators. This study aims to map these challenges and moreover will focus on how innovative integrated wireless infrastructures will in itself constitute a new branch of research on inter-organizational systems (IOSs).

To date IOS research, conducted primarily in the field of management information systems, focuses on an application-oriented IOS, such as American Airlines' SABRE system and American Hospital Supply's ASAP. These systems typically require a high degree of coordination at the application level, while the typically fixed infrastructure for the shared application is managed separately by each organization and in some cases a third party telecommunications firm. However, as new wireless technologies emerge the demand for integrated infrastructures will grow, particularly as users will require seamless roaming across networks and with user-defined profiles that make network access transparent to the end user. Such integrated infrastructure will require information sharing and coordination across organizations, and in turn will challenge traditional conceptions of inter-organizational systems.

This possibility of seamless roaming between networks and its impact on organizations is the subject of this research. In particular we seek to understand the following questions: how can the study of integrated wireless infrastructure best be carried out? What does inter-organizational infrastructure integration mean for organizations? Can IOS constructs from management information systems be applied? To address these questions we begin with an analysis of the IOS literature and an overview of concepts that apply to the area of infrastructure integration. We will then turn to the description of a trial to integrate a university WLAN and a network operator's 3G cellular network. We provide an analysis of the issues such an integrated infrastructure raises for the organization. Drawing on lessons from the trial, we next propose

a framework for studying integrated organizational infrastructure. Finally, we will apply this framework to create a research agenda for inter-organizational wireless network infrastructure and discuss the implications for pervasive commerce.

2. The study of wireless infrastructure integration

Pervasive commerce will require integrated wireless network infrastructure that enables users to seamlessly roam, accessing the network that provides the appropriate functionality (bandwidth, security) at the appropriate price. This seamless integration will create both technical and organizational challenges, as it requires information sharing between the organizations and individuals that operate the networks. While the technical challenges have been addressed by the computer science and telecommunication fields (see e.g. Luo et al., 2003), the organizational issues have received less attention.

The organizational issues these integrated infrastructures will create have both intra- and inter-organizational components. The study of inter-organizational relations and information technology has been a topic of research in the management information systems community that has developed its own conceptualization of the term 'inter-organizational system (IOS)'. In the following paragraphs we described this literature and its value for the study of integrated wireless infrastructures.

2.1 IOS literature and approaches

The term IOS was born in the early 1980s, when Barrett and Konynski used the term "inter-organizational information sharing system" with its distinguishing feature being an automated information system that allows information to be sent across organizational boundaries (e.g. Applegate et al., 1996; Cash & Konynski, 1985; Johnston & Vitale, 1998; Kumar & Dissel, 1996; Hong, 2002). While this definition would not appear to exclude infrastructure such as wireless networks, it has predominantly been applied to study of cross-organization *applications*.

The research on IOS can be delineated by either its theoretical underpinnings or the topic of study. Theoretical bases include economic approaches such as transaction cost economics, incomplete contracts, adoption and resource dependence theories, as well as social and behavioral approaches that deal with inter-organizational relationships, power issues and commitment, in addition to work that integrates both of these approaches (Chatterjee and Ravichandran, 2004; Ibrahim, 2003). A more clear delineation can be made when considering the topics studied, where five categories emerge: (1) organizational requirements, (2) interdependence: the role of power and trust, (3) aligning IOS with business function, (4) factors influencing adoption of IOS, and (5) impact of IOS on organizational activities and inter-organizational relationships. Studies regarding organizational requirements examine resources, organization-wide changes, implementation challenges, etc. (see also Gunaserkaran & Ngai, 2004; Pant et al., 2003; Van der Aalst, 1999). Studies focusing on the interdependence among businesses and its effect on IOS deployment deal with issues such as commitment among firms, trust, and power(see also Hart & Saunders, 1997; Wehmeyer et al., 2001). Research concerned with aligning IOS with business function deals with how business networking affects the design of IOS (e.g. Alt & Fleisch 2001), and how business strategy and workflows affect IOS requirements (e.g. Santarek, 1998; Hong, 2002). Factors influencing the adoption of IOS seem to entail the largest stream of research concerned with IOS, examining both the nature and process of adoption. (see also Premkumar & Ramamurthy, 1995; Soliman and Janz, 2004; Zhu et al., 2002). Finally, research related to the impact of IOS on the organization deals with the ability of IOS to fundamentally affect governance structure of interfirm relationships and coordination (e.g. Hill & Scudder, 2002; Nevodic-Budic & Pinto, 2001).

2.2 IOS and wireless network integration

This review of the IOS literature indicates that while there are similarities between current conceptualizations of IOSs and network infrastructure, differences do exist. In the following sections we describe these similarities and differences as well as their implications for the use of IOS constructs for the study of integrated infrastructure.

As described above IOS are predominantly seen as application level systems, with idiosyncratic protocols, formats, and services. Thus, while the general term inter-organizational system could apply to integration of wireless network infrastructure across organizations, the latter more specifically relates to integration of infrastructure upon which many different applications can be used. Despite this physical difference the processes share some similarities. First, both types of integration cross organizational boundaries and hence require trust and ongoing coordination. Furthermore, in both cases the ultimate goal is to enable the sharing of information.

While these similarities are significant there are important differences. First infrastructure integration is less idiosyncratic in its technology and in the relationships between firms. While IOS are often customized for specific inter-organizational relationships, or in the case of more standardized solutions are industry-specific, infrastructure integration solutions are more universal in that they involve relations between public infrastructure providers and organizations and the technology used relies on only a few standards that typically enjoy worldwide compatibility. Second, while IOSs are mostly concerned with continuous transactions with similar structures, the same cannot be said of integrated infrastructure. While information transfers over integrated infrastructures should be uniform after the implementation phase, continuing coordination for maintenance could vary significantly from organization to organization and from one period of time to another. Third, application and infrastructure integration are likely to involve different parts of the organization. While infrastructure integration will mostly involve the IT staffs of the various organizations, application integration also involves the part of the organization that uses the application. Fourth, we find that while application integration is driven by the many factors discussed above, wireless infrastructure integration is likely to be driven by end user needs. While superior support of end users may be part of a competitive advantage this is likely to be a secondary consideration. The fifth difference between application and infrastructure integration is that infrastructure integration may make application integration easier and thus is likely to precede it. Finally, while conceptualizations of IOSs treat the technology as a black box, conceptualizations of integrated infrastructure are likely to tie organizational implications with technical issues.

Thus, it is clear that the study of wireless infrastructure integration will include some of the same constructs as an application-oriented IOS study, in the former the technology is more likely to be in the forefront. Given calls for greater integration of technical issues in the extant IOS and broader management information systems literatures, this could have far reaching benefits. In the next section we present our case study of a wireless network IOS which highlights the importance of both technical and organizational issues for this crucial step toward pervasive commerce.

3. The trial

This trial of wireless network integration involved a cellular network operator, a university, and a cellular network equipment vendor in The Netherlands and occurred in the spring of 2004. The project was sparked by the construction of a 3G testbed network at the university campus, which upon integration with the university's WLAN, provided the perfect laboratory for the equipment vendor to test its recently developed SmartClient/SmartServer software. The software was designed to facilitate seamless roaming between networks by providing information about network availability as well as facilitating integrated authentication – a key feature required for seamless roaming. In the following sections we describe the testbed network and roaming software as well as their limitations vis-à-vis a commercially viable configuration. Next we discuss the organizational processes required to establish the current configuration and finally we discuss some of the likely processes that would be required in a fully commercial implementation.

3.1 The network and software

Due to particular configurations of both the 3G cellular and WLAN networks the trial focused on wireless internet access. The access was accomplished predominantly via laptops, which was favored based on the cellular network (namely the lack of a WAP gateway connection) and the lack of available and adequate mobile handsets. To connect to the TUD WLAN, users required a laptop, a wireless network adapter (802.11b or PCMCIA card), client software (802.1x or VPN client), plus a service account from a Dutch institute of higher education. In the Netherlands all of the universities and junior colleges are provided Internet access through one organization, SURFnet. SURFnet has arranged authentication of WLAN access such that students, faculty and staff, namely anyone granted an account at any institution can have access to the WLANs at any other institution. This is possible through a system of integrated authentication.

Integrated authentication is just one of several challenges of integrating heterogeneous networks. Additional issues include the physical challenges of seamless vertical handovers across WLAN and 3G radio technologies, security, and unified accounting and billing. To solve some of these challenges the SmartClient and accompanying SmartServer software were developed.

The Smart solution includes both client software to be loaded onto mobile devices such as laptops, PDAs and phones as well as server software to be controlled by the cellular network operator. The server segment of the solution, known as the SmartServer, provides a common backend infrastructure to the cellular network provider for the integration of billing as well as authentication of 3G and 802.11 WLAN networks. On the client side (laptop, PDA, etc.), the SmartClient is installed with either a dual mode 3G-WLAN wireless access card or separate 3G and WLAN wireless access cards. This loosely coupled architecture allows independent deployment of 802.11 and 3G/2G cellular networks.

An important component of an integrated architecture is the integrated authentication. WLAN authentication can be accomplished through the use of an authentication, authorization and accounting (AAA) server, which typically makes use of the RADIUS protocol, and hence is referred to as a RADIUS server. The trend in fixed network authentication has been toward centralized authentication using a RADIUS server and when the need to authenticate WLAN users arose the 802.1x standard and the existing RADIUS infrastructure worked well together to fulfill this need. Authentication in the WLAN environment requires that information be shared between the RADIUS server, the WLAN access points, the client (end user) and the user database (list of authorized users). While centralization of authentication and hence the required information flows has been taking place *within* organizations, thus allowing employees to login from a variety of locations, it is only now starting to take place *across* organizations. The SURFnet configuration is an example of such an inter-organizational authentication process. The SURFnet configuration makes use of RADIUS proxies, which enable the chaining of servers and are particularly useful when the access points, the authentication server owner and user database are controlled by different organizations. For the cellular network, authentication is accomplished through information sharing between the SIM card located on the users' device and the Home Location Register (HLR), which is a server operated by the cellular network operator.

While a commercial configuration, meaning one where the cellular operator owned both the cellular and WLAN infrastructure, would place control of the RADIUS server with the cellular operator, the configuration used in the trial was somewhat different. In the trial there was no integration of the mobile operator's authentication center and the vendor's SmartServer and SURFnet's Radius server. In other words, the SmartServer was not connected with the mobile operator's HLR and Authentication Center. Thus, instead of having to coordinate authentication with the mobile operator, the inter-organizational coordination around authentication occurred between TUD, SURFnet and the equipment vendor. In the future it is possible the number of organizations involved would be reduced.

3.2 Organizational processes for the trial

The organizational processes required to set up and maintain the integrated infrastructure during the trial can be broken into three categories: deployment of WLAN with secure access, installation of mobility software and devices (SmartClient, 3G card, SIM dongle), and configuration of shared authentication.

Our findings concerning the organizational implications of integrated infrastructure are based on our participation in managing the trial as well as 8 semi-structured interviews with the various firms involved in the trial and with users, members and leaders of the IT organization at the university. To understand organizational implications driven by end user needs, end user experience data was also gathered. The end users consisted of 9 people affiliated with either the university, the mobile operator or the equipment vendor. They were allowed access to the networks for a one month period. Access to the networks was made with

laptops; some participants were provided with Tablet PCs, while others used their own laptops.

The first organizational process for the trial was the provision of the WLAN network. While this process was well under way when the trial began the infrastructure and processes established in the rollout were vital to the success of the trial. The university decided to implement a centralized WLAN deployment where the university, rather than college-level IT departments, was responsible for setting up and managing the network. Centralized deployment was key for integration for several reasons. First, the list of users of the system needs to be shared externally and having the list centrally managed helps facilitate sharing across organizational boundaries. Second, access points must be named and having this function centrally managed helps establish unique and systematic naming that facilitates fault detection. In some integrated systems the names of access points must also be shared. Third, the university chose two authentication techniques, namely Virtual Private Network (VPN) access or 802.1x. The software for authenticated access is made available to users via a website and thus helps establish a standard implementation that is widely deployed. To facilitate this deployment the helpdesk is available to handle installation problems. These systems helped to establish an easy-to-use WLAN infrastructure for the university which served as an important platform for launching the integrated infrastructure. One aspect of the system that was not centralized was dealing with firewalls. Users of WLANs on campus sometimes find they are unable to access the same files as from their desktop. This usually occurs because the user was unable to establish a connection through a college-level firewall.

The second organizational process was oriented to preparing end users for integrated mobile access. These procedures would be very much related to the existing mobility management processes of an organization[1]. The process of installing the software was managed by two employees of the university. One was specifically assigned to this project but worked only part time, and the second was a member of the university's IT staff. The IT staff member became involved when IT staff participating in the trial decided they could install the hard and software themselves and then problems arose.

The installation process began with the SmartClient software, which came with detailed installation procedures that were reported to be easy to follow. Despite the clarity of the manual, the software required a particular configuration of the Windows operating system and due to the variety of models of the mobile devices, being various laptop and tablet PCs, with various versions of the Windows operating system, the installation of the SmartClient was challenging. There were many problems encountered, some of which required the time consuming reinstallation of the operating system. Addressing the problems in the SmartClient installation required extensive coordination between the TUD staff and that of the equipment vendor. While many issues were handled via the phone and email, some problems required face to face visits.

Once the SmartClient was loaded the 3G card and SIM dongle, which enabled an authenticated connection to the 3G network, were installed. The 3G card also presented problems as in some cases the drivers interfered with those for the Windows operating system. The 3G card was a commercially available product and thus it was necessary to contact the company to get advice on how to overcome the problems.

The third organizational process for the trial was establishing and maintaining shared authentication. In this trial the university already had a centralized authentication system managed by SURFnet. While the technical process of establishing shared authentication is rather straightforward, the inter-organizational coordination can be challenging and hence a major step had already been achieved. However, given the trial architecture a connection between SURFnet and the equipment vendor's authentication server was still required. Establishing this connection went smoothly due to the specific directions provided by SURFnet. The only problem encountered in the setup was due to a discrepancy in the naming of a subdirectory. While the initial setup and operation went smoothly, there were coordination issues that arose in the ongoing operation. For example, when a problem occurred in the vendor's server it was not clear who was responsible or what action to take. The vendor could only try a series of repairs and when they failed they called SURFnet and discovered the problem had been related to the interconnected systems.

3.3 Lessons for organizational wireless infrastructure integration

As these systems are rolled out organizations and mobile operators should take note of the following insights generated by this trial. First, the participants found prior experience with the WLAN helpful for both end users and IT staff. Second, if infrastructure integration requires any additional software or hardware, it is helpful if the existing end user hardware and software configurations are standardized. This may be impossible for hotspot providers but organization may be able to make steps toward this goal. Finally, for organizations considering integrating infrastructures through an agreement with the mobile operator, it may be wise to consider the existing relationship if there is one. Answers to questions such as 'How responsive are they concerning problems with existing voice service?' may be telling. If the answer is not positive it may be worthwhile to ask if the integrated service will be handled by the same part of the operator's organization.

For mobile operators offering integrated access services there are also insights that have arisen from the trial. Due to the inter-organizational coordination required in setting up organizational and end user systems it was suggested that mobile operators offer a certification program. The certification program would provide training to a member of the client organization who would serve as their organization's point person for problems that appear to be in the operator's domain. This benefits both the client organization and the operator as it creates a person familiar with both systems. Furthermore, it was suggested that a mechanism be developed by which these certified employees could share

[1] As organizations deploy mobile technologies they are likely to find that management of mobile devices is more difficult than desktop hardware and software. In addition to issues such as loss and theft of mobile devices, IT managers must contend with managing software upgrades for a wide variety of devices, which may only arrive in the office infrequently. For further discussion of these issues, particularly in the realm of small firms see Maitland (2004).

solutions with other organizations. The idea here is that organizations may face similar problems and the solutions are likely known by other client organizations.

Establishing such a program would do more than create a bridge between the organization and the mobile operator. It would also indicate that customer service would be taken seriously and that the operator was opening up its tight control over their network by letting others understand some of the technical and organizational functions and processes. Integrated authentication requires mutual trust, which will be required for sharing sensitive information such as user lists. This may require operators to relinquish some control. If operators are unwilling to work together with organizations on integrated infrastructure, organizations may find it easier to simply bypass the mobile operator altogether. Such a solution is being proposed as will be discussed in the next section.

For both the operator and the organization the process of integration can go smoothly if it is well thought out, as the integration between the university and SURFnet demonstrates. While the initial implementation is one hurdle to cross, there is a need to consider the dynamic nature of integrated authentication. For some organizations, particularly small ones, authentication may be a new function and hence they may be unfamiliar with the process. Thus, it is important to think about the mechanisms by which user lists, access point lists, and other crucial information will be shared between the organization and the mobile operator. Also, the potential inter-organizational effects of system upgrades, security management systems, and emergency procedures should be considered. In all these cases, both technical and inter-organizational relationship factors will have a role to play.

3.4 3G/WLAN integration in the broader context of integrated access

The trial provided a unique opportunity to observe the organizational implications of integrated 3G/WLAN infrastructure. In an interview, the university's CIO indicated that integrated authentication is integral to supporting ubiquitous computing for students as well as faculty and staff. Otherwise, she contends, access to public and private networks will continue to be segregated, with consequent inconvenience for end users. The CIO maintains this view of ubiquitous access despite being unclear as to how exactly the university would integrate mobile computing into its educational systems. This appears to be a detail to be worked out.

The opportunities for convenient, seamless roaming and unified billing make integrated hotspot and public mobile infrastructure integration the most promising wireless infrastructure integration business model. However, organizations of all types that operate their own wireless infrastructure may also find their users clamoring for this type seamless access. On the other hand, since organizations rarely charge users for WLAN access the benefit of unified billing will not accrue to these users or their organizations. Despite this, if seamless roaming becomes the norm it is something that organizations will likely be pressured to offer. Such undertakings require that an organization trust the mobile operator to protect the organization's sensitive intranet resources. Furthermore, the degree of an organization's decentralization in management of wireless infrastructure will influence the cost/benefit calculus of such a solution. Applications of such as strategy, such as the availability of WLAN access in public places such as sports stadiums and airports, are beginning to give users a taste of pervasive access. However, the access experiences tend to differ greatly and the next step toward pervasive commerce is to provide the same access experience whether it is at the office, at home, at the airport, or at the park.

The solutions differ in terms of locus of control and include (1) operator driven integration solutions, (2) third party solutions and (3) solutions that can be deployed by organizations themselves. Operator driven solutions often enable operators to deploy WLANs that are pre-integrated with their 3G networks. Equipment vendors offering such solutions include Nokia[2,3], Ericsson[4], and Alcatel[5]. Conversely, Research In Motion's (RIM) BlackBerry[6] service, which provides end-to-end security from an organization's information system and end-user devices, represents a third party solution that integrates a public cellular service with an organization's email system over a secure link. Finally, AT&T is proposing a solution to be deployed by organizations. Instead of using secure end-user devices, the AT&T solution[7] uses client software, which has the information to automatically authenticate and access pre-assigned wireless networks. The list of usable networks is decided by the organization and the communication is secured end-to-end enabling automatic seamless connectivity between pre-assigned networks. While such a solution gives the organization greater control and eliminates the need to coordinate authentication with the mobile network operator, the need to pre-assign networks limits end-user mobility and convenience.

Thus, it is clear that the trend of integrated network infrastructures that make possible integrated access is on the horizon. What is not clear however is how to approach the study of this phenomenon to better understand its implications for end users, organizations, third party suppliers and the public mobile network industry. More specifically, precisely what concepts and theories can be used to shed light on this phenomenon or does it require new concepts or theory? This question is the subject of the next sections.

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[2] Nokia OWLAN: http://www.nokia.com/downloads/solutions/operators/Solution_Brochure_November_02.pdf

[3] Juha Ala-Laurila, Jouni Mikkonen, Jyri Rinnemaa (2001), Wireless LAN Access Network Architecture for Mobile Operators, IEEE communications magazine, November 2001.

[4] Tomas Boström, Tomas Goldbeck-Löwe and Ralf Keller (2002), Ericsson Mobile Operator WLAN Solution, Ericsson White Paper

[5] Philippe Laine (2003), Public WLAN for Mobile Operators, Alcatel Technology White Paper

[6] BlackBerry: http://www.blackberry.com/

[7] Hui Luo, Zhimei Jiang, Byoung-Jo Kim, N.K. Shankaranarayanan, and Paul Henry (2003), Integrating Wireless LAN and Cellular Data for the Enterprise, IEEE Internet Computing, March-April 2003.

4. Wireless network integration research: A way forward

The wireless infrastructure integration case presented above has generated insights into the study of this phenomenon and provides a basis for making recommendations about future research on this topic. In particular, we propose a framework for studying inter-organizational systems at both the infrastructure and application levels, the makes use of existing research findings as well as moving the field forward. In particular, such a framework should accomplish the following goals. A framework for studying inter-organizational systems should first be holistic in that it takes into account the breadth of the organizational information infrastructure as defined by Ciborra (2000). Such an approach will help researchers view inter-organizational systems as highly complex and interdependent systems. Among other benefits, this view will help assess the applicability of innovations in one area for related areas. Second, the framework should open the black box of technology that currently exists in the IOS literature. Being more explicit about the technical basis of the system under study is likely to lead to more realistic implementation recommendations and a better understanding of organizational requirements. It also facilitates recognition of embedded technologies and provides one way of describing the bounds of the system. Furthermore, explicit consideration of the technology can also help identify critical intra and inter-organizational relations for system design, implementation and management.

A framework for IOS research should also emphasize the organic nature of the growth of information systems. End user innovations and new uses for old systems are important considerations for system design. Furthermore, implied in the organic perspective is a dynamic one. Information infrastructures change over time and consideration of the past, present and future can improve our understanding of these complex systems. Also implied in an organic approach is that standardization of information technologies can be a very difficult challenge and that attempts to control complex systems have advantages and disadvantages. For an in-depth discussion of these issues see Ciborra (2000). Given these requirements we now move to explicate the framework.

4.1 IOS constructs

As a new yet related phenomenon, research on wireless network integration can draw from the existing IOS literature. As indicated in Table 1, we believe that research on wireless network integration can be informed by several areas. As our university trial demonstrates, there are likely to be organizational requirements that will influence the success of a network infrastructure integration project. Furthermore, the level of trust required for sharing authentication information is likely to be high and hence could also determine the success of the endeavor. Trust may also turn out to be one of several factors influencing the adoption of integrated infrastructure, and the integrated infrastructure will likely have broad impacts on the organization and possibly the inter-organizational relationship. The only IOS subject area we do not expect to generate a significant amount of interest is the alignment of the IOS with the business function. Since infrastructure cuts across many business functions this is not expected to be an area of interest, however alignment could be interesting to some as a framework for studying the ability of wireless network infrastructure to meet the needs of a mobile workforce.

Similarly, we find that many of the theories used to study application-oriented IOSs could also be applied to the study of integrated infrastructure. We believe that analogous to the trend in the IOS literature, the emphasis on transaction cost efficiencies for explaining integrated infrastructure adoption has some merits but is likely to miss some of the other factors at play. Adoption theories, particularly those that emphasize comparative advantage, and resource dependency theory that may explain why an organization would opt for operator-oriented solutions as opposed to those that the organization can employ on its own are likely to be applied. Furthermore, behavioral theories, particularly those that emphasize bandwagon effects, are likely to provide a framework for understanding the diffusion of the technology among firms. Naturally, seeing the value in several of these of the theories parallels the trend in the IOS literature of moving towards an integrative framework. The only theoretical perspective that appears unlikely to be applied is that of incomplete contracts because the integration of infrastructure, unlike that of an IOS, is unlikely to lock in a relationship to such a great extent due to the less idiosyncratic nature of the technology.

IOS Research Area / Theory	Applicability to integrated infrastructure
Organizational requirements	Yes
Interdependence: The role of power and trust	Yes
Aligning IOS with business function	Unlikely
Factors influencing adoption of IOS	Yes
Impact of IOS on the organization and inter-organizational relationships	Yes
Transaction costs	Yes, with reservations
Incomplete contracts	Unlikely
Adoption and resource dependence theories	Yes
Social and behavioral approaches	Yes
Integrated theories	Yes

Table 1: Applicability of IOS concepts and theories to integrated infrastructure

4.2 A multilayer approach to IOSs

Given our stated goals and the concepts borrowed from the extent IOS literature, we propose the following framework for the study of inter-organizational wireless infrastructure and application

integration. At its core our framework is a multilayer approach to IOSs, and is shown in Figure 4. Around this multilayer approach traditional IOS research approaches can be carried out as well as new, more broad directions for research. This model is based on the traditional OSI or TCP/IP protocol stacks, shown in Figure 3[8], which have survived for nearly two decades and yet are still relevant today[9].

OSI	TCP/IP
Application	Application
Presentation	
Session	
Transport	Transport (host to host)
Network	Internet
Data link	Network access
Physical	Physical

Figure 3: OSI and TCP/IP protocol stacks

Source: Stallings (2001)

Because these reference models cover both applications and the technologies used to transport data between organizations they provide an important basis for studying inter-organizational systems. While this multilayer IOS reference model (Figure 4) provides researchers with a reference point to discuss the different aspects of the information system, one should note that, as with the OSI and TCP/IP models, these differences are nebulous. For example, the exact boundary between middleware and application software is fuzzy, which reflects what we experience in practice.

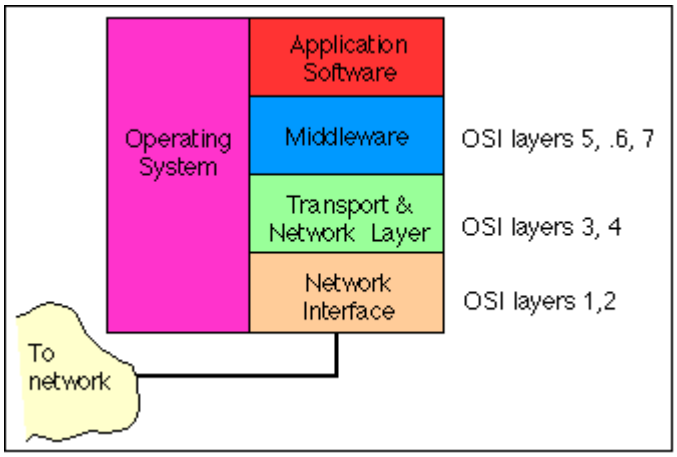

Figure 4: Multilayer inter-organizational system reference model

Source: Fairhurst (2001)[10]

To apply these models it is necessary to consider the information system structure both within and between organizations. Diagrams that represent multiple components of infrastructure at each level and connections across levels, such as shown in Figure 5, help translate the abstract reference model into a model that can be more easily used to understand the relationships between the levels. However useful, unfortunately these diagrams can quickly become overwhelming and it may be necessary to resort back to the more abstract representation such as that shown in Figure 6.

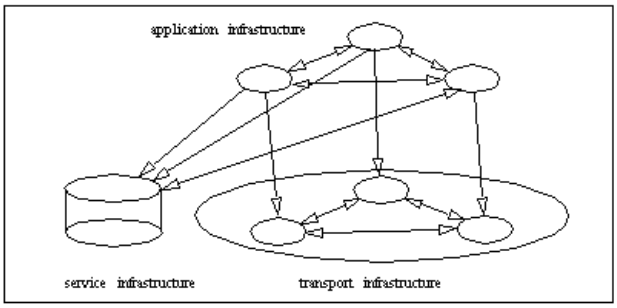

Figure 5: The structure of intra-organizational infrastructure

Source: Hanseth (2002)

Figure 6 depicts by a dotted line the transfer of information as it occurs in an application level IOS, the domain of traditional IOS literature. When drawn in this way, the diagram highlights the limitation of the traditional IOS perspective, which is concerned with only one aspect of the entire inter-organizational information infrastructure. Figure 6 also shows that when network infrastructure integration occurs the inter-organizational relationship may be limited to the end user organization and the public network provider. In this case the integrated system is concerned only with the bottom layers of the model. Furthermore, the diagram also highlights that each organization, whether it is a public or private network owner or operator, has a multilayer system. The fact that the public network operators also have multilayer systems is often overlooked because the upper layers

[8] A similar approach has been suggested by Hanseth (2002) but his multilayer approach was carried out in an intraorganizational perspective with the goal of broadening the research focus.

[9] Here the older OSI model is presented side by side with the new TCP/IP model to show their differences in the number of layers and where layers start and stop. While some argue about the superiority of one model over the other, for our purposes either will do. Here the important point is that a layered approach is a widely used model, has a long history and is still considered useful.

[10] See lecture notes by Gorry Fairhurst http://www.erg.abdn.ac.uk/users/gorry/ downloaded 10-19-04.

of their networks have typically been closed. However, as the meaning of 'public network operator' expands and includes hotspot WLAN providers or third party nodes in peer to peer systems, the full multilayer network of the public network 'operator' may have greater significance for private network owners.

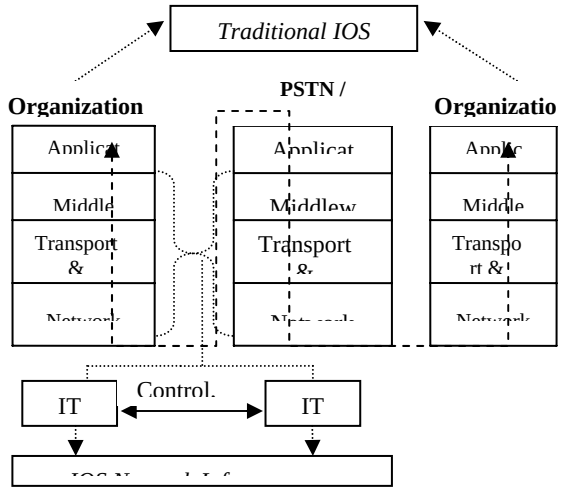

Figure 6: IOS multilayer diagram

This multilayer conceptualization of inter-organizational systems, provides the basis for carrying out research of great significance for pervasive commerce. While it clearly provides a basis for studying wireless network integration, it can also be used to consider the applications needed for pervasive commerce and the technical and organizational dependencies of those applications with other technology owners. As the technologies and nature of human organization change it is important to understand the broader implication of IOSs as they will naturally interact with or perhaps even be the cause of broader societal trends.

4.3 Research agenda for inter-organizational wireless network integration

The following research agenda applies the multi-layer framework presented above to some of the traditional categories of research from the IOS literature. In each case we present insights derived from the university wireless network integration trial and propose research questions that can provide more rigorous investigation of these issues.

Adoption Drivers

Insights: The trial suggests organizational adoption of integrated wireless infrastructure will be driven by demand from end users. Experience with WLAN has shown that organizational users with experience at home push organizations to adopt the technology.

Questions: Will integrated network infrastructure adoption be driven by organizational end users? How is this similar to or different from inter-organizational applications? What types of applications will be required to make full use of integrated wireless infrastructure?

Organizational Requirements

Insights: The extent of previous WLAN experience is expected to play an important role in successful integrated infrastructure implementation. Also a variety of management factors such as the amount of resources allocated to end user support will also play a role

Questions: What will be the organizational requirements for successful integrated network infrastructure adoption? How will heterogeneous hardware and software configurations be handled? How are these requirements similar to or different from those for inter-organizational applications?

Management

Insights: While implementation of an integrated infrastructure poses challenges, the management of such a system is likely to produce a diverse array of challenges some of which may be idiosyncratic to the organization and may change with time. Coordination on tasks such as system upgrades will require ongoing relationships that vary in intensity over time.

Questions: What are some critical mechanisms for managing continued network integration? How are these similar to or different from inter-organizational applications? To what extent will integrated infrastructure become a standard offering (as opposed to more idiosyncratic inter-organizational systems) of mobile network operators? How will such a development affect management, organizational requirements and adoptions drivers?

End users

Insights: Employees' mobility needs vary significantly and thus at first the costs of wireless network integration may not exceed a cost/benefit analysis for many organizations. Furthermore, wireless but stationary network access appeared to be more valuable to many employees.

Questions: How will valuation of mobile and wireless access affect the adoption of integrated wireless network infrastructure? How will the valuation of wireless vis-à-vis mobile affect the types of organizations involved in an inter-organizational integrated infrastructure? How will integrated wireless network infrastructure affect workers' satisfaction, productivity, information processing and decision making? What types of applications does the integrated infrastructure enable?

Intra and Inter-organizational relations

Insights: Integrated access is likely to increase mobility both within and outside the physical space of the organization. Also, in terms of relations between mobile network operators and organizations, integrated infrastructure requires coordination that can both strengthen the relationship and harm it.

Questions: What organizational changes will occur due to integrated wireless access? How will the relationship between the organization and the mobile operator (or other public network provider) change due to the integrated access? Will the number of relationships with public network operators increase? If so, how will organizations manage these relations?

Industry and market implications

Insights: If integrated wireless network infrastructure is adopted widely it may greatly increase the number of network infrastructure related relationships for the average individual and organization. The challenge of managing these relationships is likely to lead to a variety of changes including consolidation of

network infrastructure owners, affiliate plans similar to roaming agreements, or the development of intermediaries.

Questions: Will intermediaries to manage these relationships emerge? Which industries will be the first to adopt integrated wireless infrastructure? For which industries does integrated wireless infrastructure hold the greatest promise? Pose the greatest threat?

Societal implications

Questions: What are the societal implications of mobile workers with integrated wireless infrastructure? How would such infrastructure affect notions of work and private lives? How would private WLANs be integrated into the integrated infrastructure? What would be the implications of organizations providing home based WLANs?

5. Conclusions

The development of a pervasive commerce market will require an integrated wireless infrastructure with seamless roaming. As the research here demonstrates integrated organizational wireless and public cellular networks are one means of creating such a network. Given this is a relatively new phenomenon, a new approach to studying these networks is required. We propose a multi-layer framework of inter-organizational systems as a means of connecting existing IOS research with the study of integrated inter-organizational wireless infrastructures. This framework, together with insights from a university-based 3G/WLAN integration trial, and previous insights from IOS research, were used to generate research questions for future studies of integrated wireless infrastructures. By understanding the answers to these questions we will gain insight into the future of pervasive commerce.

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