Spatial Data Infrastructure – An Integrated Architecture for Location Based Services?

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ABSTRACT

Trends in wireless communication towards the development of smaller, faster, cheaper devices are contributing to a radical change in the spatial information user base. With the ability to access information using a mobile phone or a Mobile Internet enabled Personal Digital Assistant, combined with the capability to determine the position of mobile devices, a range of applications known as Location Based Services (LBS) are emerging. These services provide relevant information to users based on the position of their mobile device. This information can be both spatially and non-spatially related, but must be presented in a useful way. The broader issues of LBS, that revolve around enabling a range of users to access spatial information, can be considered under the domain of Spatial Data Infrastructures (SDI). Since the SDI components of people, data, access networks, policy and technical standards parallel the issues of LBS, it is proposed that the SDI concept be augmented to support the development and deployment of wireless LBS applications. This paper describes a proposed case study approach for LBS development so as to determine how SDI needs to adapt in order to support these emerging applications.

Key words: wireless communication, spatial data infrastructure, location based services
Introduction

With the ability to communicate over great distances wirelessly, society has rapidly embraced wireless communication and integrated it into daily life (Katz 1994; Pandya 2000). The introduction of the mobile phone provided a sense of freedom and security not offered by the fixed line telephone; people were able to make and receive calls whilst moving. In fact, the number of people making calls to emergency numbers recently in the United States of America led to the development of a mandate to determine the location of mobile phone callers, so that appropriate services could be dispatched promptly and accurately to the site of the emergency (FCC 1999).

The drive to determine the location of mobile phones and the ability to send and receive data over the telephone network has spurred a new range of applications that are enhanced through location information. For example, services such as emergency roadside assistance, early warning evacuation, E911 (safety); traffic monitoring, news updates, weather updates, store/business locators (information); fleet management, package tracking (tracking); location sensitive billing, location based commerce (commerce) can all benefit from the use of position information of the service user or a target of interest. Classified as Location Based Services (LBS), these applications typically provide mobile phone users with a filtered (in terms of both time and geography) set of information with the intention of supporting dynamic, spatial decision making. LBS rely on spatial and non-spatial data presented in an appropriate form to users. To achieve this, issues of policy, standards and access must be resolved. These issues have typically been associated with and explored within the Spatial Data Infrastructure (SDI) context.

The environment created by an SDI enables users to access and retrieve datasets easily and securely. Whilst typically infrastructures have been developed for government jurisdictions to facilitate data sharing and reuse, organisations are increasingly realising the value and benefit in establishing a formal SDI for their company that is compatible with local and state government initiatives. Considering the similarities between SDI and
LBS, it is proposed that an SDI could be developed to support LBS. However, the current SDI model may require modification if it is to be used for this purpose.

To be effective, an SDI must be designed with the user in mind, and LBS applications are no different. The ability to access spatial information on a mobile phone has meant that the potential user base of spatial information has rapidly increased to approximately 50 million people worldwide (Goldman et al. 2001). Many of these users may not be skilled in the use and interpretation of spatial information (for example, orientation issues pose a particular difficulty to mobile users presented with navigation information – which way is ahead, north, etc.) so care must be taken to provide information that is meaningful and relevant. Additionally the limitations imposed by wireless communication methods and mobile devices on the quantity and format of information that can be transmitted may also impact on the SDI model definition.

**Location Based Services**

Location Based Services exploit knowledge about where a mobile device (and its user) is located. This location knowledge is used to provide relevant, contextual information to users. A result of the convergence of information systems, (wireless) communication mechanisms and positioning technologies (Figure 1), LBS offer a personalised approach to data access.

![Figure 1 - The convergence of technologies enables Location Based Services](image)
Whilst the Internet evolved to form an environment of geographic anonymity, services available on the Mobile Internet are capitalising on the fact that users will be accessing them using portable devices and will be at a specific location at the time of access. The position of a mobile phone can be linked with information systems and therefore provide information related to the user’s position. Limiting content is a necessity in a wireless communication environment where bandwidth is limited and mobile devices have restricted processing power and areas for display. Additionally the Mobile Internet is moving away from the traditional Internet model of a static information repository, with real-time, dynamic information regarded as highly desirable by mobile users.

Even though there are many datasets available that could contribute to location based services, individual LBS developers must organise data provision or access agreements. The current lack of coordination in the provision of data sets and organisation partnerships is likely to lead to a duplication of effort and resources. The establishment of SDI guidelines for LBS could minimise such duplication by allowing LBS developers access to accurate state government data sets (for example road networks and cadastral information). An SDI of this nature would allow organisations to maintain their individual commercial interests as, for example, proprietary data sets could be integrated with state data sets, but relieve them from costly maintenance and data generation procedures for such data that is not related to the organisation’s core function.

As noted by Coleman and McLaughlin (1998), ‘Perhaps even more than the mapping and GIS products with which we are familiar, positioning ‘appliances’ will drive the requirements, demands and practices of spatial information users over the next decade’. Mobile phones are becoming ‘positioning appliances’, and their connection with the Mobile Internet (with underlying information systems and wireless communication methods) are placing new demands on spatial information providers to meet the needs of new spatial information users.
**Spatial Data Infrastructure Architecture**

Emerging from the increased use of spatial information and the associated need for cooperation between data users and producers, Spatial Data Infrastructures are becoming an important tool to assist with decision making and spatial analysis problem solving for both the public and private sectors. Whilst there are many definitions for SDI relative to their contexts, Rajabifard and Williamson (2001) explain their underlying principle as providing an environment which enables a variety of users to access and retrieve complete and consistent data sets easily and securely. The ability to share data within large government organisations, and amongst external corporations has minimised duplication saving resources, time and effort. The Property Information Project (PIP) undertaken by the Victorian State Government is one example where partnerships have led to more productive and more efficient data collection practices, refer to Jacoby et al. (2002) for details of this initiative.

Overarching the varied users and purposes for which SDI have been constructed, a number of common elements have been identified: policy, technical standards, access networks, fundamental data sets and human resources (Coleman & McLaughlin 1998). The interrelated nature of these elements is fundamental to the cohesive nature of the infrastructure (refer to Figure 2) and are the linking features for SDI of differing scale.

![Figure 2 - Nature and Relation between SDI Components (Rajabifard & Williamson 2001)](image)
As identified by Chan et al. (2001) this ‘component-view’ model of SDI is a static representation and fails to convey the dynamic nature, complexity, hierarchical structure and the role of partnerships, all of which are also fundamental to the design and establishment of an SDI. This representation is adequate to describe the concept required to support the data sharing and access environment proposed by SDI, however from an implementation perspective more detail is required. The modelling of SDI at the implementation level is a focus of current research initiatives (refer to the work undertaken by the Centre for Spatial Data Infrastructures and Land Administration http://www.geom.unimelb.edu.au/research/SDI_research/).

Considering the advances in the wireless communication area, the SDI model may need to be modified in order to continue to facilitate the exchange and sharing of spatial information. The interrelated and cohesive nature of the infrastructure means that each of the five components must be examined to gain an understanding of requirements in the context of wireless spatial information dissemination. As an example, access mechanisms via a mobile device that is capable of tracking a user’s location impact on privacy issues of both the user and the data they are accessing.

Specific guidelines for the format and/or storage mechanisms of data may need to be incorporated considering the wireless communication methods and their limitations (in comparison to fixed wire methods). The policy component will have to examine privacy issues in response to community concerns regarding the positioning of mobile devices (particularly mobile phones) and the use of this information. Encompassed within the technical standards component are issues of metadata, and methods of ensuring the quality of data provided to users. All of these issues must be considered in conjunction with recognition of the dynamics of the people accessing, using and producing spatial information. Additionally, guidelines for the components must be relevant to the hierarchical nature of SDI and be applicable at each level from corporate through to global.
Spatial Data Infrastructures hold the potential, and have already begun, to make spatial information more readily available. The specific infrastructure requirements necessary for ensuring that SDI data is accessible over wireless devices however are still to be determined.

**Spatial Data Infrastructure As A Foundation For Location Based Services**

As described above, SDI facilitates spatial data use. They must be designed with users in mind to support the data flow from data producers and value adding agents, to the users.

In order to gain a better understanding of the issues involved for LBS deployment and how an SDI could support this endeavour, a prototype LBS is under development. The prototype is intended to act as a test bed, the use of which will help to determine what infrastructure is required for wireless location based services.

The prototype application is a public transport information service that can be accessed via a WAP (Wireless Application Protocol) enabled mobile phone or Personal Digital Assistant. The public transport information application lends itself well to a location based service. Current methods by which prospective public transport patrons can plan their journeys are limited by ‘static’ mechanisms – commuters must be physically at a stop/station to use trip planners or obtain real-time vehicle arrival information, or must plan their trip before leaving a fixed Internet connection. Providing public transport information wirelessly facilitates mobile spatial decision making by providing users with access to timely and location specific information.

Whilst public transport patrons have varied demands and requirements, the prototype will only accommodate a small range of these. However, it is anticipated that these will be sufficient to demonstrate some potential real-world uses of this form of service, and of other similar information provision LBS. Four potential use scenarios have been considered for the prototype. A prospective public transport patron may want:
a. the service to determine an appropriate mode and/or route for their journey (which may include route or mode changes);
b. to specify a particular mode of transport that they wish to use for their journey;
c. to look up current timetable information for a regularly travelled route; or
d. to plan a trip, or investigate trip alternatives, well in advance of travelling.

Whilst the use cases describe four functions that the system is expected to be able to perform, there are many commonalities between the user requirements in each case. The requirements (shown in Table 1) relate to the information that the user needs in order to make a decision in relation to the use of public transport for their journey. Considering that a user’s journey will not be restricted to public transport travel alone, due to the non-coincidence of journey origins and destinations with public transport stops/stations, pedestrian navigation information may also be of use.
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Use Case</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pedestrian journey description</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Origin of journey (may correlate with position of mobile device when the</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>service is accessed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination of journey</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Textual information describing journey from origin to first public transport</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>embarkation point</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textual information describing journey from final public transport</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>disembarkation point to destination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrian route map (beginning and end of journey)</td>
<td>✓*</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓*</td>
</tr>
<tr>
<td>Pedestrian journey duration</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Public transport journey description</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode identifier</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Embarkation identifier (stop number or station name, platform)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Disembarkation identifier (stop number or station name, platform)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Route identifier (number and/or name)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Direction of service (inbound/outbound) (important for trams/buses –</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>inherent in the train route identifier)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scheduled departure time at disembarkation point</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Expected departure time at embarkation point</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Scheduled arrival time at disembarkation point</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Expected arrival time at disembarkation point</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Indication of route/mode interchange</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Public transport journey ‘snap shot’ maps (of embarkation and</td>
<td>✓*</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓*</td>
</tr>
<tr>
<td>disembarkation points, including mode/vehicle interchanges)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Journey duration (including connection waiting times if necessary)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Zone/Fare information</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Legend:
Use cases: a. immediate journey planner, b. journey planner using a particular mode of transport, c. time table lookup and d. trip planner.
✓ necessary requirement
✓* optional requirement (depending on mode, or time of service access)
✓* ‘nice to have’ requirement
- not applicable

It is anticipated that the development of the prototype, and its use as a test bed, will enable a number of issues to be discovered that relate to SDI components (as shown in Table 2). An incremental approach has been adopted for the development of the prototype. The increasing functionality and complexity of subsequent versions will allow a variety of issues (in addition to those shown in Table 2) to be addressed. Whilst it is expected that some issues will be relevant to all versions of the prototype, the variation between versions will allow these issues to be explored in greater detail.

Whilst all of the five SDI components are critical to the success of an SDI, it is likely that their interconnected nature will mean modification to one component will require
modification of other components. It is expected that the test bed will reveal both quantitative and qualitative information that can be used to define the guidelines for each of the components in the context of LBS.

Table 2 - SDI Observation Criteria (version 1)

<table>
<thead>
<tr>
<th>People</th>
<th>Data</th>
<th>Standards</th>
<th>Policy</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>End User</td>
<td>Content Request handling</td>
<td>Standards/format Request</td>
<td>Personalisation</td>
<td>Data volume</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td>handling</td>
<td></td>
<td>Data content</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interoperability</td>
<td></td>
<td>Scalability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quality Metadata</td>
<td></td>
<td>Response time</td>
</tr>
<tr>
<td>Integrator</td>
<td></td>
<td></td>
<td>Privacy</td>
<td>Scalamility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Personalisation</td>
<td>Response time</td>
</tr>
<tr>
<td>Data Provider</td>
<td>Content Standards/format</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resolution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In relation to the access network component, the test bed will be able to be used to assess data volumes and speed of transmission, data formats, scalability, request handling and potentially charging methods. For the policy component, issues of data access and pricing, data transfer, custodianship, metadata, standards, privacy and the use of ‘digital personae’ information will be investigated. Standards will encompass aspects such as reference systems, data models, data dictionaries, data quality, data transfer and metadata as well as highlight whether additional standards are required for LBS. Included within the data component are issues of data format, data models and data quality (of prime importance to mobile users are spatial and attribute accuracy, temporal accuracy and logical consistency).
Specifically, it is anticipated that the test bed will have the potential to:

- assess the scalability of a public transport information LBS;
- explore feasible data quantities for current network and transmission mechanisms, and hence provide an indication of how much information can be disseminated to mobile users;
- investigate information delivery using different forms of media, and their associated data volumes;
- explore the efficiency gains in user interaction times through the use of personalisation or profiling;
- provide an environment in which to test current standards in the context of a route finder LBS and highlight areas which require specific or additional standards for the wireless delivery of spatial information; and
- explore the integration of relatively static information (road network, cadastre, etc.) with real-time information (location of public transport vehicles) and the delivery of this information in relation to a user’s location and service access time.

Whilst specific requirements or guidelines for the SDI components will be revealed by the use of this test bed, the test bed will not have a direct influence or facilitate determination of policy statements. Rather, the test bed will demonstrate the implementation of policy statements derived from existing implementations and literature. Broad policy guidelines may result, but their adoption will remain with specific implementations.

The issues revealed through the use of the test bed will help to determine in what ways the current SDI model is lacking in its ability to support wireless spatial information dissemination applications (such as a location based public transport information service). An augmented SDI model could then be designed and used as a guide by government and industry for future LBS application development.
Conclusion

The continuing challenges presented by technological advancement have been a significant driver for the spatial information industry. This has continued with the recent convergence of positioning technologies, wireless communication and information systems. With wireless communication and information access methods expected to continue to evolve and play an increasing role in society, and the strong focus on mobility that wireless communication implies, it is critical for the spatial information industry to develop an infrastructure that meets the needs of the new user base.

Location Based Services are often cited as one service likely to drive the development of the Mobile Internet. Irrespective of the range of services encapsulated by the broad ‘Location Based Services’ term, all require spatial data management capabilities to link position information with other data sources. An infrastructure to support the development and deployment of such applications would be particularly useful.

It is important now, in the early days of the combination of these technologies, to establish guidelines for the necessary infrastructure to support the dissemination and use of spatial information that can be accessed by mobile devices. The prototype under development as part of this research is anticipated to help establish some of the requirements for such an infrastructure. The mechanisms that will enable mobile users (who may not be skilled spatial information users) to transparently gain access to appropriate sections of larger databases need to be determined in order for LBS and wireless spatial information access to be feasible.

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