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Locating People, Places, and Things:
Situating GIS in the Intelligent Network Landscape

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Abstract
This paper discusses Geographic Information Systems (GIS), particularly in the context of intelligent networks. It begins by examining some of the fundamental characteristics that help define GIS, followed by an overview of how GIS is currently being utilized by the providers of intelligent networks themselves. Yet it is beyond these types of applications, and more in terms of the everyday user, where GIS is in many ways evolving most rapidly. The intersection between GIS with intelligent networks, and the emerging ubiquity of location-aware devices, is further helping to define GIS as an especially powerful tool.

Introduction
In a broad sense, a Geographic Information System – or GIS as it is commonly referred to – is a tool that allows for the storage, processing, and analysis of spatial data (DeMers, 1997; Tomlinson, 2003). At the same time, and especially in the contemporary context, the term GIS defies any singular definition. Once primarily the domain of skilled users and dependent upon at least a relatively high level of computing capacity, GIS functionality is now present in many people's daily lives, including in common mobile telecommunication devices. In short, in today's world GIS has a vast array of applications and different types of users, and it is ever-evolving.

Furthermore, GIS has increasingly grown to utilize, and benefit from, intelligent networks. These networks provide a key platform for much of the data that is utilized and shared in the use of GIS applications. Moreover, the phenomena of GIS itself encompasses various elements that help define the concept of intelligent networks, including the ability to share information between users; offer critical information in relation to research, planning, and real-time decision-making; and allowing for the generation of automated information.

With these and other issues in mind, this paper considers GIS largely in the context of the intelligent network environment. It begins by discussing some of the fundamental characteristics that help define GIS. It then follows with an examination of how GIS is being utilized by the providers of intelligent networks themselves. Yet it is in terms of the everyday user where GIS is perhaps having its most profound effects, and where its functionality is most rapidly evolving. Helping to propel such use has been the growing availability of location-aware devices, including cell phones and laptops, concomitant with the increasingly widespread nature and enhanced capacities of intelligent networks. Thus, the latter half of this paper is primarily dedicated to assessing what might be referred to as the consumerization of GIS technologies. As will be discussed, the widespread consumer use of GIS applications presents not only significant opportunities, but various social implications that are worthy of important consideration as well.

Defining "GIS"

When first developed GIS was something that could simply be described as software combining cartographic and analytical technologies using digital data. However, any simple definition of what GIS is today would belie its complexity. The boundaries of what GIS entails have expanded dramatically since the technology was first developed in the early1960s. At one level, much of what GIS is currently used for remains the same functional and analytical tasks for which it was initially designed: as a system, broadly speaking, that allows users to capture, store, query, edit, merge, overlay, and share spatially referenced, digital data. Yet given its growing range of individual applications and host of different types of users, no accounting can offer an exhaustive overview of the technology's current functions.

To provide at least some working definition of the concept, the nature and functionality of GIS can in part be understood through examining each of the individual, though interrelated, words that the term entails. *Geographic* implies an emphasis on location, typically pertaining to the earth's surface, though in some instances, such as in relation to certain types of natural resources or climate for example, below or immediately above the earth's surface as well. Virtually any type of phenomenon has some element of location associated with it, and therein lies much of the value and power of GIS as a resource and tool.

The geographic elements of a GIS are based upon latitudinal and longitudinal coordinates on the earth's surface. Defined by these coordinates, this information can be incorporated into a GIS as discrete points, lines, or polygons, or what is otherwise referred to as vector data. The use of GIS can also involve raster data, which involves a matrix of cells, with each cell representing a specific portion of the earth's surface. This sort of dataset is especially useful for storing topographic features. Though a discussion of such matters could essentially be limitless, examples of location-oriented phenomena that can be incorporated into a GIS, particularly in the form of vector data, range from service market areas to sewer lines. Raster data can allow for three-dimensional visualization of phenomena ranging from city skyscrapers to mountainous terrain.

GIS: "Information" and "System". The next component of the term GIS – *information* – embodies the attribute data that is linked to and stored in association with the more strictly geographic data. A rather simple though perhaps widely known example of this matter would be an online map generated through the website hotels.com, where users can move their cursor over a given hotel on a map and have not only a sense of the hotel's location, but attributes such as its nightly rate and guest ratings. In short, the attribute data incorporated into a GIS is indexed to the geographic coordinate-based data as previously described. The information aspect of a GIS, then, implies not only the base geographic information associated with a particular phenomenon in space, but attribute variables that further defines characteristics of the phenomenon as well. As was the case with the more strictly geographic elements of a GIS, the types of attribute data that can be stored within a GIS could be a matter of endless elucidation. This is in part due to a GIS being a relational database technology. Utilizing information that is indexed by location, a GIS can draw upon a virtually limitless number of data sets.

As a relational database, GIS allows for managing and analyzing immense volumes of data, including in unique ways, which in part speaks to the matter of GIS as a *system*. Through the storage and use of digital information in a computer based environment, including one that can draw upon a range of resources through telecommunications networks, GIS can be understood as a system that has the capacity to store vast amounts of geographic-based information, including at various scales and from various sources. It can combine what would otherwise be discrete sets of geographic data in virtually limitless ways. Along with assorted analytical and modeling techniques, a GIS can be used to extract new, unique, value-added information.

GIS as an Analytical Tool. Whereas traditional cartography – which is essentially the antecedent to GIS and indeed remains a key use for GIS – involves the production of a single map with a fixed amount of information, GIS can be understood as a resource that allows for vast storage and hence myriad combinations of geo-spatial information. Rather than simply presenting information in a conventional, cartographic sense, a GIS offers opportunities for the ongoing storage, updating, and analysis of information, resulting in a range of applications serving various consumer, business, and policy-based interests. Along with the technology's increasingly underlying presence in the everyday lives of many individuals, more actively technical users of GIS include academic researchers; a range of businesses and industries, including utilities; the military; and government. It is somewhat common for local governments in the U.S. to have a GIS staff person, for example, and GIS is indispensible to industries that rely upon network-based infrastructures, such as utilities and telecommunications providers. GIS also tends to be widely used in various other areas as well, including natural resource and environmental management; urban, regional, and transportation planning; and law enforcement crime prevention.

Analytical operations that can be used in these and other aforementioned areas range from relatively conventional data queries based upon single attributes, to far more advanced analyses. Over time, and especially over the past decade, the boundaries have expanded and indeed blurred in relation to the capacities and functionalities of GIS. Even the more conventional uses have seen rapid changes in matters such as the ability to incorporate extremely large datasets, analytical techniques, and how information is presented. For example, visualizing and analyzing time series data through a GIS is now a somewhat common application, as is three-dimensional analysis. The growth of both publicly and commercially available data has helped to fuel the changes in GIS use and functionality.

GIS Data Availability. The availability of GIS data can vary dramatically depending upon the given country or region in question. In general, GIS data can be freely available, typically from government sources, or proprietary. Proprietary data, however, is often commercially available. GIS data available through government sources has somewhat invariably been collected in relation to regulatory and authoritative concerns. GIS data that is freely available through U.S. government websites includes Federal Communications Commission (FCC) data. The FCC offers a range of telecommunications and media-related data, such as in relation to the location and attributes of cell towers and broadcast television market areas (FCC, 2011).

The U.S. Census Bureau's website includes a vast range of demographic and socioeconomic data (U.S. Census Bureau, 2011), while the United States Geological Survey (USGS) offers terrain data that can be extracted at various scales (USGS, 2011). Through various techniques, such as drawing upon information included in paper maps or satellite imagery, individual users can also somewhat easily create their own GIS data. Similarly, Global Positioning System (GPS) devices allow for the collection of data in the field.

GIS and Intelligent Network Management

From a strictly telecommunications network standpoint, GIS has a range of technical, management, business, and policy applications, only a few of which will be discussed in detail here. That only some of these applications are described below speaks to the range of tools and functionalities available through using GIS, not only in a telecommunications network management context, but in other contexts as well. Many typical users of the Internet are already at least generally familiar with some of the applications that can be beneficial to telecommunications network providers. For example, users of MapQuest or similar websites are undoubtedly familiar with the 'network analysis' functionality associated with driving directions, which is based upon an algorithm designed to identify the shortest route between two places. This least cost path type of analysis has similar applications in telecommunications network planning and routing, as well as in areas such as first responder planning.

Digitizing Network Information. In terms of network management, GIS can serve as a comprehensive database that stores network location and attribute data, thereby enhancing a telecommunication provider's physical asset management. As somewhat alluded to in the previous section, through the process of "digitizing" a user can transfer information from paper maps into a GIS; utilize aerial or satellite imagery as a basis for mapping infrastructure; or utilize a GPS device to collect information about the location of network assets. Many telecommunications providers have either digitized or are in the process of digitizing their networks in a GIS (e.g., Pereira, M., Almeida, G., & Junqueira, A., 2004; ESRI, 2005).

Given that network deployment must necessarily begin with mapping out location, GIS allows for key, location-based information to inform the process, while digitizing information about proposed or deployed network assets means that such information can immediately become part of a given provider's network inventory. Once information is digitized, GIS is a platform that can provide a reliable and up-to-date inventory of network asset location. It offers the opportunity to view and assess a network at different scales and in relation to all or specific assets. Attribute information included in a GIS can include information about network configuration, utilization, life span, maintenance history, and maintenance needs.

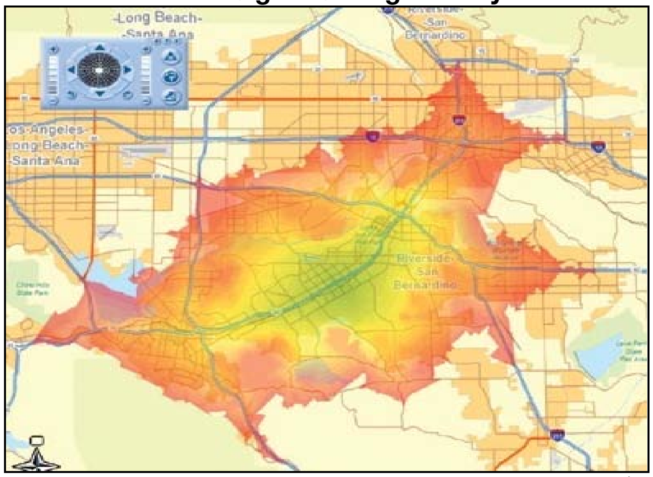
Moreover, through the use of intelligent networks and contemporary interfaces that offer ease of access to a GIS database, virtually any user within a company can readily access network information. This can allow, for example, maintenance activity to be incorporated into a GIS database in real time from the field. In terms of optimizing investment returns, and to use fiber optic network rollouts as an example, a GIS can incorporate and support the analysis of information related to rights of way, the determination of closest facilities, and path analysis, including through modeling various combinations of such information. It further provides opportunities for analyzing and predicting revenues associated with potential infrastructure rollouts and related equipment requirements, such as through examining characteristics of a market service area, such as homes or businesses passed, and characteristics associated with potential growth in demand.

Wireless Networks and GIS. While virtually all of the aforementioned telecommunications network management issues apply to wireless networks, GIS offers particularly enhanced applications when it comes to wireless network planning and analysis, including point-to-point as well as point-to multi-point networks. Data modeling in a GIS allows for three-dimensional analysis that includes line-of-sight analysis; viewshed analysis; best coverage prediction; and determining levels of signal strength for particular locations. Viewshed analysis, for example, can calculate variations in signal strength across an entire 360-degree landscape, which can be essential in the efficient and strategic deployment of wireless broadband networks (See Figure 1). As previously indicated, three-dimensional modeling in a GIS employs raster datasets.

Raster data is especially useful for displaying and analyzing features of the earth's surface, accounting for issues such as topography, elevation, and visibility. Data such as building structures, which can also be key factors in affecting signal propagation, can also be incorporated into these models.

Other key functionalities of three dimensional modeling in relation to wireless technologies include identifying and assessing the location of frequently dropped calls or service; assessing the visibility of proposed radio communications towers from an aesthetics standpoint; modeling subsurface terrain; and market analysis. Moreover, collecting data through using GPS technology enables wireless providers to evaluate virtually any given location for siting telecommunication antennas, including existing structures at that location as well as potential sites for new towers. In short, GIS can be a key part of any telecommunication provider's overall strategy. Among other things, its utilization can reduce and optimize costs on capital expenditures, provide crucial information in relation to network planning and reconfiguration, and allow for various elements of quality control.

Figure 1:
Wireless Signal Strength Analysis



Source: Environmental Systems Research Institute[1]

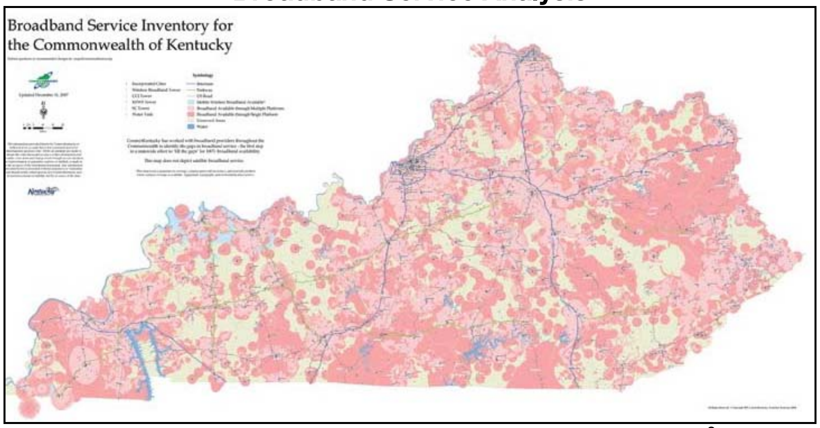
GIS in relation to Other Telecommunications and Media Issues: GIS has also been at least somewhat utilized in academic and policy related analyses, including in relation to the types of issues, such as service availability patterns, as discussed in the previous section. Relatively straightforward use of GIS can lead to nonetheless substantive evaluations of issues such as the geographic digital divide. These and similar types of analyses can be found in at least some scholarly research (e.g., Grubesic & Murray, 2002; Wood, 2008), as well as in policy-based studies and related information (Glasmeier et al., 2003; Connected Nation, 2011).

Figure 2. provides an example of a relatively straightforward broadband service analysis that may be applicable in policy and research-based contexts. The mass media has historically used maps as a basis for presenting and communicating information. It currently utilizes GIS to not only present basic maps to the public, but for newsworthy types of analysis as well (Sui & Godchild, 2001; Murray & Tong, 2008). Media outlets where GIS is of particular relevance include *The Weather Channel*, which relies upon GIS to analyze weather activity and to present forecasts (Monmonier, 1996). The rapid growth of publicly available as well as proprietary geospatial datasets has increasingly facilitated the mass media's use of GIS applications over the past few years (Murray & Tong, 2008), and Google Earth is now a fairly common tool used by some media outlets for reporting on the location of news stories.

As will be discussed in the following section, recently emerging, media-related applications of GIS include the ability for users of mobile devices such as cell phones to access information and entertainment related to their real-time location.

Figure 2:

Broadband Service Analysis



Source: Environmental Systems Research Institute[2]

Applications for the Everyday User

Using GIS traditionally required advanced knowledge and substantial computing resources. However, and particularly through online access to a range of free websites, virtually any user with access to the Internet and basic web navigation skills can now utilize some GIS applications. Thus, many of the web-based GIS applications that are now available have developed in conjunction with the increasingly widespread deployment and capacity of telecommunications networks.

Web-based, user-friendly GIS access began with relatively simple functions from companies such as MapQuest (www.mapquest.com), which offered users the opportunity to create reference maps at any desired scale. More advanced applications that included time and distance calculations between locations based upon route optimization algorithms, were also a part of these web-based services. These applications were nonetheless simple to use, and offered new and unique value to users. Rooted largely in GIS and related technologies such as satellite imagery, websites such as Bing (www.bing.com) and Google Earth (www.google.com/earth) now offer functionalities that include three-dimensional visualization and streetside video. Yet perhaps the greater value of these types of sites comes from the location-based attribute data that is made available to users by hovering a mouse over an object. This seemingly basic application reflects one of the original purposes of GIS, and in many instances remains one of its primary values to everyday users.

Another, web-based mapping functionality that has evolved from traditional GIS involves the ability for users to create unique, thematic maps, such as maps that depict the incidence of socioeconomic phenomena across locations. A key, enhanced functionality of these types of sites is that they allow users to determine for themselves the geographic scales and classification categories in creating maps. The U.S. census website (www.census.gov) offers these types of opportunities. Again, these and similar sites offer user-friendly access to relatively conventional, yet distinctive, GIS functionalities. Each of the aforementioned applications are relatively simple to use, requiring virtually no knowledge of GIS functionality, and it is safe to say that the majority of users of many these types of sites have never heard of GIS per se.

A range of other GIS-based applications, many of which are no doubt taken for granted by their users, are now available through the Internet as well, including weather maps with animated radar, and real-time traffic information. Social media websites allow users to identify and contact individuals based upon location or proximity. GIS can also play a role in the targeted information that has now become a common output associated with basic web searches. Location-based, targeted information can be automatically generated by search engines and websites through identifying a user's location in conjunction with online behavior patterns. The content can range from being highly generalized to highly personalized, based upon an individual user's preferences and fixed location, such as a home or business. To that end, personalized and targeted information can be generated and accessed in relation to the mobility patterns, and real-time locations, of individuals as well.

Mobile GIS. Amidst the new opportunities made available through GIS, it is the intersection between geographic information, intelligent networks, and location-aware mobile devices that is at the cutting edge of evolving GIS-related applications. These applications are increasingly having a more profound effect upon everyday lives as well as business and industry interests.

GPS, GIS, wireless telecommunications networks, and mobile devices such as cell phones and laptops, allow users to not only identify their current location, but to incorporate their location in relation to real-time decision making. This includes identifying the location of fixed phenomena, such as restaurants or public places, as well as mobile phenomena, such as the current location of friends. Similarly, users can have immediate access to place-based information while on route to a given destination. All of these scenarios create possibilities for generating information that can be actively shared with other people in real time, and that can be stored over the long-term as data.

The relatively widespread consumer use of mobile GIS technologies was initially most evident in car navigation systems, which merged GIS functionalities such as mapping, information access, and route optimization capabilities with GPS technology. Location-aware handheld devices began to emerge around the turn of the century. Mobile GIS applications are based upon location sensing technologies that include GPS, triangulation of the known coordinates of wireless base stations, and other radio communication identification techniques, some of which can be used indoors. Modern day location sensing technologies can achieve levels of accuracy down to a few centimeters, though such precision may not always be necessary depending upon the function.

The benefit and long term relevance of mobile GIS applications is perhaps best considered through, and largely being determined by, what has rapidly become the widespread use of mobile devices, including GPS enabled cell phones and laptop computers. The International Telecommunication Union (ITU) estimated that in 2010 the number of mobile cellular subscriptions worldwide exceeded 5.3 billion, representing a more than doubling of such subscriptions over a five year period (ITU, 2011). Meanwhile, approximately 80 percent of currently manufactured cell phones are being equipped with GPS, reflecting a dramatic rise in the availability of this technology in mobile devices (Rebello, 2010). It is in this context that a host of new possibilities have emerged, where personalized information associated with location-related behaviors, mobility patterns, and preferences, is stored as data.

Business and Industry Applications in the Mobile Environment. A host of other applications are being derived from the intersections of these technologies as well, ranging from radio-frequency identification tagging that can assist with recovering stolen assets, to entertainment functions that include playing location-based online games. Business and industry users stand to particularly benefit from modern day location-based technologies. Industry analysts suggest that 80 percent of company-based data is location-oriented (Tsai, 2010). In relatively simple forms, the intersection of GIS and GPS technologies allows for applications that include the real-time tracking of parcels, personnel, and fleet. This can include active as well as passive data collection, which is stored and can eventually be used for issues such as improved efficiency of logistics.

More complex as well as relatively more uncertain business applications, given evolving consumer preferences and regulatory policies, involve the future of location-based marketing and sales. Mobile marketing can occur in the form of alerts, coupons, and advertising. This sort of marketing can be based upon a consumer's real time location, known preferences, and purchasing habits. It can also be based upon real-time data such as impending weather, traffic flow, and a company's current inventory. Thus, not only do everyday users have increased access to location-based information, but information about consumer location-based behavior is now being generated in conjunction with a range of other personalized data. How consumers situate themselves geographically is a key variable that can inform business-related decisions and analysis. Yet how much of this type of data will be readily available to business and industry interests in the future remains somewhat uncertain. Perhaps more importantly, the utility of having this type of information will in many instances be dependent upon businesses having the capacities to incorporate and effectively analyze such data. In many instances successfully benefiting from the vast amount of location-based consumer information that is being generated will require business interests taking an active, knowledgeable approach to harnessing and analyzing location-based consumer information.

Caveats and Further Considerations. The boundaries between GIS, intelligent networks, mobile devices, and the access and generation of information have become fully blurred. Possibilities clearly exist for location-based information to simply add one more dimension to a sea of superficial, rather than substantive, content available to, if not foisted upon, users. Various psychological and social costs may stem from information overload, especially if much of the information is useless. "Opting-in" regulatory measures, where users must actively determine whether or not they will receive information from a given entity, may help curb these types of problems. Perhaps larger concerns relate to privacy and security. With always on, location-sensitive devices, users can be tracked, are perhaps in a constant state of having their privacy or security breeched, and at the very least can be generating ongoing, real-time information about themselves, including their location and behaviors, which they otherwise might not want to share. As is the case with opt-in agreements, regulatory and technical approaches exist in relation to such matters. Again, uncertainties remain as location-based applications have only recently started to see a dramatic growth in use across the wider population.

From the standpoint of more actively applied uses of GIS, an array of key concerns also exist. The use of GIS without knowledge of fundamental issues associated with, for example, cartographic design and statistical data analysis, can be problematic. Given the increased ubiquity and ease of use of GIS technology, those creating and sharing GIS-based information may lack knowledge related to essential principles that should inform the process. Maps are extremely powerful tools when it comes to presenting information. Yet how information is presented, such as in terms of classification thresholds used to define variables, has a strong effect upon how map information is presented as well as perceived.

Another seemingly simple, though absolutely crucial, issue to understand involves cartographic projection, which entails the determination of how the earth, a three-dimensional object, is depicted on a two-dimensional medium. Positional accuracy is essential, yet can be a major problem, when using GIS data. This accuracy relates directly to how data is projected. A two-dimensional representation of the earth's surface cannot simultaneously fully preserve accuracy in terms of shape, distance, area, and direction. Different projections serve different user-needs, and there are literally hundreds of different projections. Conducting an analysis that involves combining layers of GIS data that have been projected differently can lead to serious inaccuracies. Engler & Hall (2007) suggest that both proprietary and publicly available datasets quite often do not include essential meta-data, such as information about projection. Similarly, if users are not considering the age of a dataset, or are unable to ascertain when the data were collected, there are clear possibilities for working with inaccurate information, including the location and attributes of a particular phenomenon.

Conclusion

GIS is difficult to define as any singular system or phenomenon. The technology has evolved over the past 50 years to become a functional part of many people's daily lives. The range of possibilities associated with GIS is now largely a function of the technology's intersection with intelligent networks, mobile devices, and web-based applications. The use of GIS once largely depended upon particular skill sets as well as having sufficient computing and related resources. Many aspects of the technology are now available to virtually any individual that has access to a computer or who owns a mobile broadband device.

GIS has historically been a crucial tool for businesses and government entities with clear location-based considerations, such as utilities and urban planners. Telecommunication systems are highly spatial in nature. They are closely linked to geographic elements such as distance, place, and terrain. Because of this, GIS has historically been, and remains, an important if not essential tool when it comes to issues such as telecommunications network planning and for analyzing network performance. Across a number of industries and for an array of other interests as well, GIS is an invaluable and often unsurpassed tool for examining spatial patterns, solving certain types of problems, ascertaining markets, and for a range of other analytical purposes. It will continue to be utilized in various private sector, government, and research-oriented contexts.

GIS is also a technology that people not only use and often fundamentally rely upon in their daily lives, but that can provide as well as assimilate highly personalized and unique information from any given user, including based upon their changing, real-time location. Through the combination of personalized information that is stored as data, along with information about the real-time location of a user, suggestions can be made, or information generated, based upon user-identified preferences as well as previous patterns of behavior. Ranging from the basic to the relatively more advanced, the various dimensions of GIS, its use, and its intersection with related technologies, result in there not only being somewhat limitless applications of the technology, but helps to define GIS as a powerful tool. This influence extends into areas where GIS can be understood to have a unique role in enhancing the functionalities of intelligent networks themselves.

Notes

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