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Mobile advertising will become more pervasive and profitable, but not before addressing key technical and business challenges.

BY SUBHANKAR DHAR AND UPKAR VARSHNEY

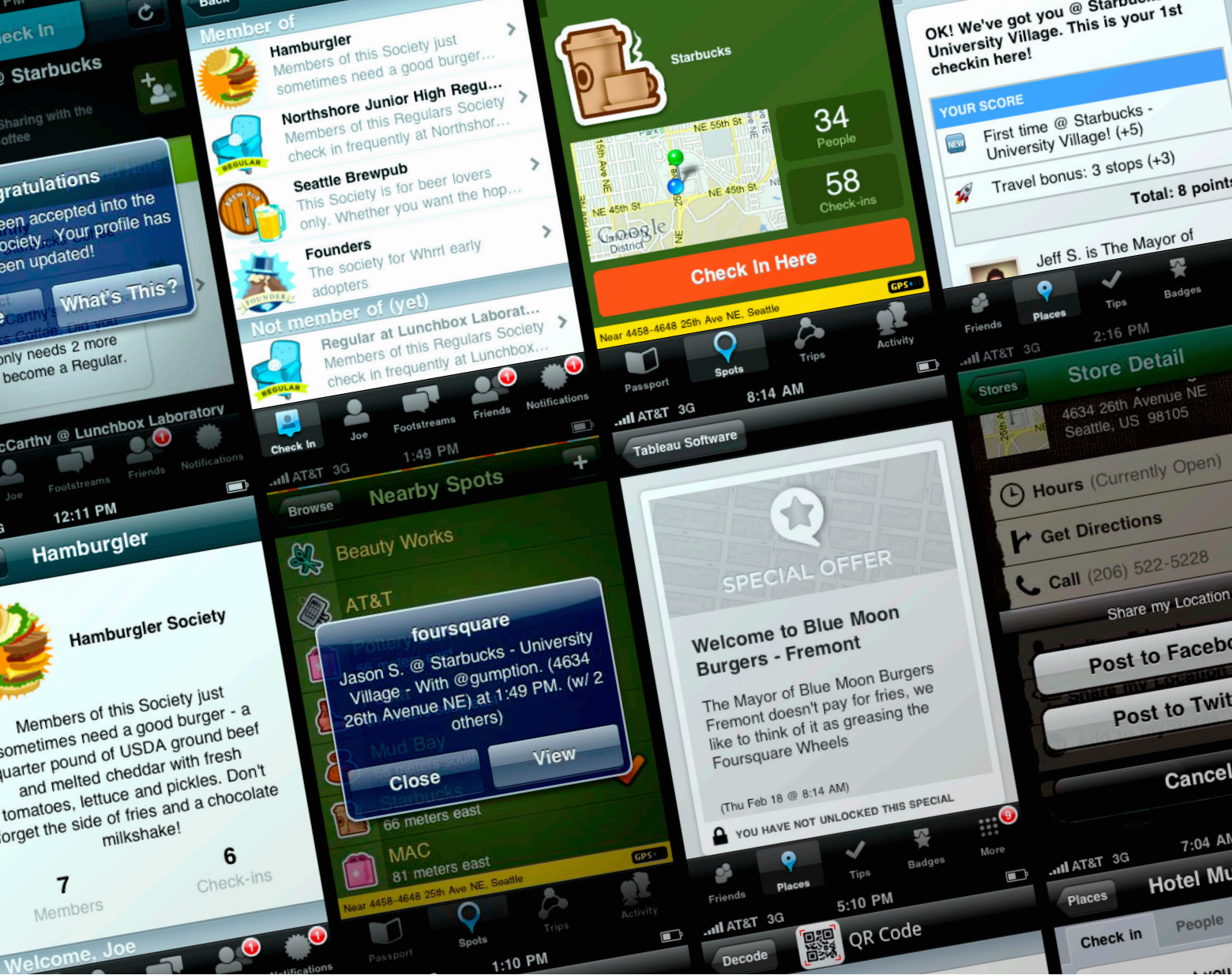
Challenges and Business Models for Mobile Location-based Services and Advertising

LOCATION-BASED SERVICES HAVE attracted considerable attention due to their potential to transform mobile communications and the potential for a range of highly personalized and context-aware services. Since the days of early location-tracking functionalities introduced in Japan in 2001 and in some U.S. networks, location-based services have made considerable progress. E911 requirements for wireless cellular networks in the U.S. have also enabled location-based functionalities using variations of triangulation, GPS, and cell-ID technologies. In addition to the current and emerging satellite-based systems, such as GPS (U.S.), GLONASS (Russian), GALILEO (EU), and COMPASS (China),[30] which will provide wider coverage to benefit location-based services. In some cases locational information can also be derived and utilized from sensors, RFID, Bluetooth, WiMax, and Wireless LANs.[7,31,32] These systems can be used standalone or supplement the coverage for location tracking in indoor environments, where satellite coverage is intermittent or inaccurate.

The potential for location-based services is evident from powerful and ubiquitous wireless devices that are growing in popularity.[8,23] Many surveys predict billions of dollars in revenues for mobile advertising.[27] Mobile Network Operators are well positioned to take up a significant percent of this advertising revenue as they negotiate deals with content providers. Recent deals between media companies, advertising agencies and Internet/software industry also demonstrate significant optimism for future growth.[4,19] However, there are many challenges that have slowed down the deployment, offering, and wide-scale adoption of location-based services. The challenges

» key insights

- Professionals should be aware of technical- and business-related challenges as they develop solutions for location-based services.
- Location-based mobile advertising has potential to generate significant revenues leading to successful business models.
- Awareness of multiple business models that can play key roles in mobile advertising—and how these models compare to one another—would be essential in the successful deployment of location-based services.
- In addtion to the current issues, professionals should also consider the imminent challenges as the develop and implement location-based services.



Location-based advertising and services for mobile devices continue to escalate, but not without overcoming some technical hurdles.

include emerging technologies, suitable applications, and business models. This article addresses both technical- and business-related challenges in location-based services, specifically in mobile advertising. We also address how location-based mobile advertising can generate revenues and sustain successful business models.

Location-based Services

Location-based services (LBS) can be defined as services that depend on and are enhanced by positional information of mobile device.[6] A LBS is a mobile information service that extends spatial and temporal information processing capability to end users via Internet and wireless communications.[5,16,22] Location-based services are the key enabler for a plethora of applications across different domains ranging from tracking and navigation systems to directory services, entertainment to emergency services, and various mobile commerce applications.[14,16] Although, several different types of LBS are possible, we present some of the examples and their requirements in Table 1. Here, we also introduce quality of service for LBS. The QoS can be expressed in locational accuracy required, response time, and reliability of operation. These attributes could offer some guidance to network designers and operators on the need of applications and the functionalities required in location-aware network infrastructure. Several LBS are illustrated in Figure 1 and a range of technologies that can be used in various combinations to create location-aware network architectures are illustrated in Figure 2.

The key characteristics of location-based services can be derived from the applications earlier. To implement LBS properly, the middleware should be designed to include the major characteristics of the applications.[10,18,21] Some of these characteristics are shown in Table 2. The different LBS can be classified under multiple categories of person or device-oriented, push vs. pull, direct vs. indirect profile, among others.

The organizations that play significant roles in the development of LBS standards are the Open Mobile Alliance (OMA) and Open Geospatial Consortium (OGC). In addition to these, there are several other organizations that provide important components of the LBS standards infrastructure.[25,26]

The most important specification that OMA has come up with is MLP (Mobile Location Protocol). MLP en-

SCREENSHOTS BY JOE MCCARTHY

ables LBS applications to interoperate with wireless network regardless of its interfaces (GSM, CDMA etc.) and positioning methods. MLP defines a common interface that facilitates exchange of location information between the LBS application and location servers in wireless networks. It also supports the privacy of user providing access to location information only to those who are authorized users. Hence OMA is the key enabler of mobile service specification standards that support the creation of interoperable end-to-end mobile services.

The Open Geospatial Consortium (OGC) is an international standards organization responsible for the development of standards for geospatial- and location-based services. To complement Location Interoperability Forum's (LIF) advanced MLP services, OGC has come up with OpenLS Services that addresses the geospatial interoperability issues. Key services handled by OpenLS specification are coordinate transformation, Web Mapping, Geography Markup Language (GML), geoprocessing and Web integration. The OpenLS platform provides open interfaces to LBS core services such as route determination, directory, location utility (geocoder that obtains *x, y* co-ordinates from address, and reverse geocoder that obtains address from *x,y* co-ordinates), presentation (display showing map, point of interest), and gateway (find position of mobile terminal 'from the network'). OpenLS Abstract Data Types (ADTs) are the basic information constructs used by these core services. ADTs are 'application schemas' of well-known data types and structures for location information encoded in OGC's XML for Location Services (XLS). These schemas encode location information, for example, route summary and route geometry, route instructions, location, area of interest, and point of interest and address.

Figure 1. Several location-based services.

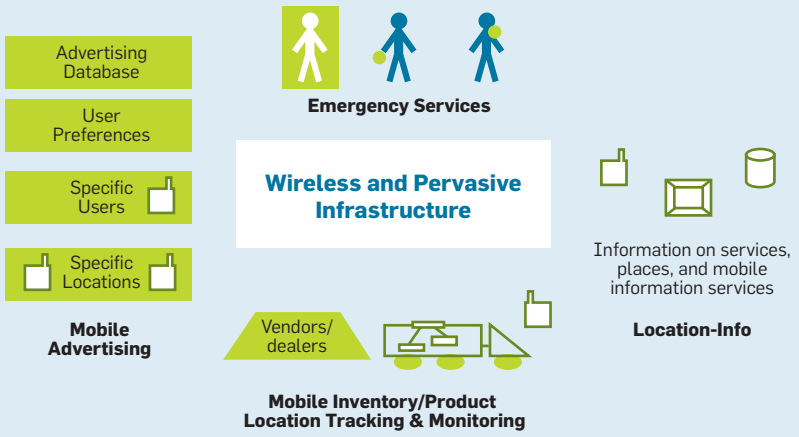
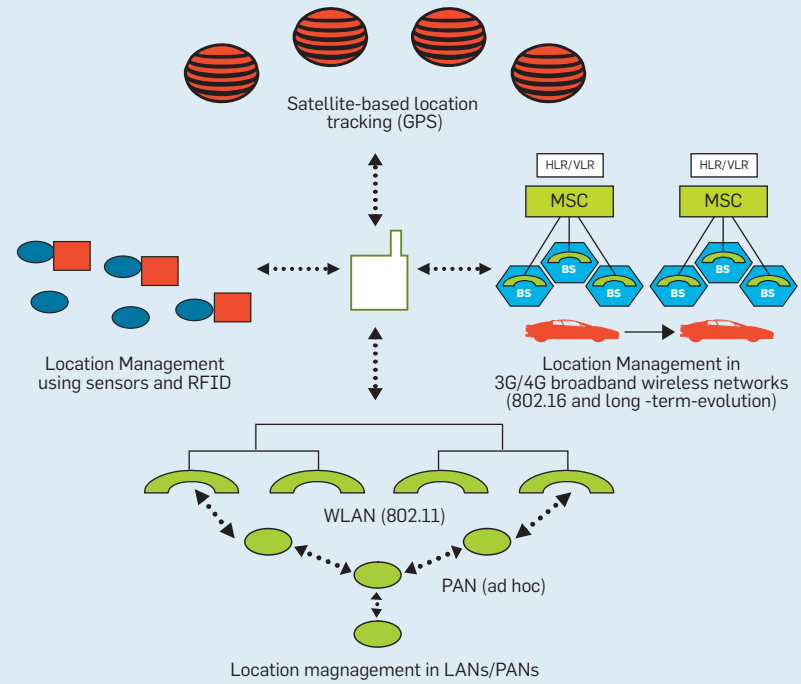


Figure 2. Various technologies for location-based services.



The specifications of OpenGIS are geared toward the development of interoperable solutions that "geo-enable" the Web, wireless, and location-based services. These specifications enable developers to make complex spatial information accessible to help deploy various services and useful applications. In order to make spatial standards interoperable with communication standards, such as, to integrate LBS into Internet, Web and wireless, OGC coordinates its activities with several organizations including OMA, IETF, W3C, OASIS, ISO, Parlay.[6]

Parlay is a consortium that develops open APIs based on their Open Systems Architecture (OSA) for mobile networks that provides functionality for authentication, authorization, and access to network services. APIs for OSA/Parlay enable service implementations within existing fixed and mobile telecommunications networks. This architecture/framework complements the GeoMobility Server, described here.

The GeoMobility server provides the basic functionalities on which location-based applications are built (the OpenLS Core Services). It provides subscribers with various location-based application services and content. By using open interfaces to access network location information, this server

allows applications to access a set of core services known as the OpenLS Core Services. To summarize, the GeoMobility server provides

- The Core Services and their OpenLS interfaces along with the OpenLS Information Model, consisting of Abstract Data Types (ADTs).
- A set of applications build upon the Core Services and accessing them through OpenLS interfaces.
- Content such as map data, points of interest, routes, and so on used by the Core Services; this content can also be hosted on other servers and accessed through the Internet.
- Various supporting functions for personalization, context management, billing, and logging.

LBS Market Overview

Although the market has taken longer to materialize than many predicted a few years ago, individual and corporate customers are now beginning to purchase location-based emergency services, advertising, games, and other location-based services. They look to their telecommunications carrier companies to provide timely, personalized information delivery in ways that provide new efficiencies, convenience, safety measures, and work flows.

Carriers want cost control, predictability, rapid rollout, and easy migration. They want all of their service offerings to be well integrated with their management information systems for billing, accounting, customer service, maintenance, and so on. They want to be able to pick and choose from a broad field of platforms, applications, integration services, and devices. The providers of these products and services in the value chain want to succeed by focusing on their strengths and by building one and selling it many times rather than building everything differently for every customer.

Besides overcoming technological and ethical barriers, marketing location-based services has been a challenge to operators. One major challenge has been that the new applications were relying on technology that was very slow in penetrating the market. As a result, the industry now often talks about location as a means to enable services as opposed to location-based services.

The location market is developed

Table 1. Location-based services.

Location-Based Services	Applications	Required Quality of Service (QoS)
Information/ directory services	▸ Dynamic yellow pages that automatically informs consumer of location of nearest hospitals, restaurants, shopping malls and theatre, and ATM ▸ Nearest parking lot, drug store or gas station	Location accuracy of a tens of meters Response time of few seconds Need for high reliability (98%–99%)
Tracking and navigation services	▸ Tracking of children, locating lost pets, ▸ Locating friends in a particular area ▸ Tracking stolen vehicles, asset tracking ▸ Dynamic navigational guidance ▸ Voice-enabled route description	Location accuracy of few meters Response time of few seconds Need for very high reliability (Goal should be 100%)
Emergency services	▸ Roadside assistance ▸ Search and rescue missions ▸ Police and fire response ▸ Emergency medical ambulance, E911	Location accuracy of a tens of meter Response time of few seconds or less Need for very high reliability (Goal should be 100%)
Location-based advertising	▸ Wireless coupon presentation, targeted & customized ads ▸ Marketing promotions and alerts ▸ Customer notification and identification in the neighborhood store	Location accuracy of few meters Response time of a minute Need for high reliability (98–99%)

Table 2. Characteristics of location-based services.

Types of LBS	Characteristics
Person-oriented LBS	▸ Consists of applications where a service is user based ▸ User usually controls how location information is collected and utilized
Device-oriented LBS	▸ Applications are external to user ▸ Person or the device located is not controlling the service
Push versus pull-based applications	▸ Push-based: information delivered to the mobile terminal (end user) automatically when certain event occurs ▸ Pull-based: Mobile terminal (end user) initiates the request
Direct versus indirect profile	▸ Based on how the user profile is collected: directly from the user during the set up phase, by tracking the user's behavior pattern or from third parties ▸ Security and privacy issues become critical to maintain user trust and to avoid fraudulent activities
Availability of profile information	▸ Profile information requested on the fly or already available to the LBS
Mobility and Interaction	▸ Range of mobility scenarios exist based on combinations of mobility of users and network components ▸ The level and type of interactions depend the mobility scenario
State of interaction	▸ Stateless interaction: Each request is an independent transaction unrelated to previous request ▸ Stateful interaction: The LBS preserves the state across service requests (beneficial to for forecasting future transactions, requests and behavior)
Static versus dynamic information source	▸ Static: Data about historical buildings and landmarks, places of attraction, hotels and restaurants, maps ▸ Dynamic: Information that changes with time (weather, traffic and road conditions)
Source of location information	▸ Location information provided by the user or the network infrastructure or by a third party.
Accuracy of location information	▸ Depending on the positioning technology used in the network infrastructure, different accuracy for localization request of mobile terminals result.

around both business and consumer services and can be broadly grouped into a vertical and horizontal service sphere.

The vertical market is characterized by users drawn from industry environments where the management of mobile location information is and has always been an integral part of the business. The vertical market segment has been the historic base of the mobile location services industry, and many players in it developed proprietary systems for localization long before LBS achieved today's general commercial availability.

In contrast to the vertical market, the horizontal market is characterized by users drawn from industry environments where the use of mobile location information is a new and added value to existing services.

Mobile Advertising

The mobile advertising market is poised for tremendous growth as it continues to exploit some of the appealing features of mobile devices as follows:

- Portability: The devices are small in size and fit into the pocket.
- Personalization and Instant Access: The devices are associated with the identity of the user and the applications are personalized based on the user input. The mobile devices also receive instant access from their users most of the time.
- Mobility and Wireless Internet Connectivity: Most of the mobile devices will have Internet connectivity via wireless links.
- Location-aware: Most of the devices will have some built-in navigational systems like GPS.
- Context-aware: Many applications running on the device are context-aware. For example, in case of search, the advertisements will be displayed based on user's preferences.[13]

All these appealing features coupled with enterprise applications have increased the adoption rate of these devices and as a result of this usages of these devices are growing rapidly. Hence it makes business sense to use the mobile devices as another platform for advertising, which can be customized based on the user's profile and preferences. The users can also select the types of advertisements they would like to receive on their mobile devices. This information would be saved on a server and the advertisement would be sent accordingly. During the first time set up the subscriber will have the opportunity to provide his preferences for the type of ads to be received and displayed on his mobile device. For example, after the customer logs in, he would be prompted with choices in several areas of interests such as specific type of restaurants, currently screened movies, nearby shopping malls, and so on. Several different types of advertising services and their infrastructure requirements are presented in Table 5.

Emerging Business Models

With the deployment of a variety of location-based services coupled with growing consumer appetite for mobile devices fueled by broadband wireless technologies, there are substantial opportunities for revenue generation in this nascent and growing market mobile advertising. Mobility and location-based services combined with context-aware advertising create opportunities for targeted marketing and revenue generation.

As the competition of voice-based mobile services becomes stiff, the network operators seek to increase their market share and generate additional revenue through data services including LBS. The network service provid-

Table 3. Various consortia/organizations for location-based services.

Consortium	Description
Open Mobile Alliance (OMA)	▸ Key enabler of mobile service specification standards that support the creation of interoperable end-to-end mobile services ▸ Consists of nearly 200 organizations including world's leading mobile operators, device manufacturers and network service providers. ▸ Addresses all the key elements of the LBS value chain which also includes those that are addressed by Location Interoperability Forum (LIF) and Wireless Access Protocol (WAP) forum. ▸ LIF and WAP are now part of OMA
Open Geospatial Consortium (OGC)	▸ An international standards organization responsible for the development of standards for geospatial and location based services
Parlay	▸ Consortium that develops open APIs based on their Open Systems Architecture (OSA) for mobile networks which provides functionality for authentication, authorization, and access to network services.
W3C	▸ World Wide Web Consortium provides guidelines for mobile web best practices including navigation, page layout and content.[28]
Internet Engineering Task Force (IETF)	▸ Working Group provides guidelines for applications and services related to LBS
Organization for the Advancement of Structured Information Standards (OASIS)	▸ A global consortium that drives the development, convergence and adoption of e-business and web service standards including LBS and Mobile Web.

Table 4. Various location-based protocols and standards for development of LBS.

Protocols and Standards	Description
Mobile Location Protocol (MLP)	▸ An application-level protocol for obtaining the position of mobile stations (mobile phones, wireless personal digital assistants and so on) independent of underlying network technology. ▸ Serves as the interface between a Location Server and a Location Services (LCS) Client. ▸ Defines the core set of operations that a Location Server should be able to perform
OpenLS	▸ To complement LIF's advanced MLP services, OGC has come up with OpenLS Services which addresses the geospatial interoperability issues
Geopriv	▸ A standard for the transmission of location information over the Internet and is being developed by IETF.[33]

ers play an important role and actively or passively shape the business landscape. There are three types of business scenarios that evolve around the role of network service providers.[22] These are network service provider-dependant business scenario, network service provider-assisted business scenario, and network service provider-independent business scenario.

In the network service provider-dependant business scenario, the network service providers play a dominant role and collect the most of the revenue. These typically generate and own the location data and use this to provide LBS to the consumers. The network service providers use their infrastructure and marketing channel to give access to LBS thereby providing services to a select customer base. In this scenario, the network service providers keep the major portion of the revenue.

In the network service provider–assisted business scenario, the network service provider does not necessarily own or control the location data. The data will be available to location-based service providers either on a given rate or for free. The network service providers act as transporters of the data and voice. They get revenue by selling airtime usage or charging the volume of data packets transmitted.

In the network service provider-independent business scenario, the location data does not necessarily reside on the network service provider's network. The data may come from an independent vendor. As an example, some location-based service providers may use GPS technology and use the data to provide various services to the consumers. The network service providers generate revenue by transporting the LBS data through their network. The location-based service providers may charge the consumers on pay-per-use basis or on a monthly subscription fee.

In order to support various business models, flexible platforms are being developed for AAA (Authentication, Authorization, Accounting) functions and charging. For example, the OSA/Parlay framework proposed in Koutsopoulou et al.[9] provides a platform for charging, billing, and accounting functionality for various LBS-related business models. The user is authenticated and authorized by the 3 GPP AAA Server/Proxy located within the operator network. The Open Mobile Alliance (OMA) is working to standardize Push-to-Talk over Cellular (PoC). The IMS Core also handles AAA functions and triggering of personal and group instant talk sessions.

Another interesting scenario that is gaining popularity is that of OEMs creating development platforms for independent application developers. The developers sell their applications through OEM's authorized stores and share revenue with OEMs and not WSPs. A good example will be Apple's iPhone. Apple has created the Apps store that allowed independent developers to create applications and share revenues with Apple and not the WSPs.[29]

There are a few business models that appear to be viable in the current scenario.[1,11,22] These business models have three major aspects, namely revenue sharing; hosting and advertising.[7] In revenue sharing, every party that contributes to a service takes a part of the service fee, which is based on a partnership agreement. The hosting service provider charges a fee to the LBS service provider for infrastructure and management of these services. The fee can be a fixed monthly rate or based on the usage of data. Advertising in the mobile environment is still in its infancy and is not well established like the World Wide Web. The various business models are presented in Table 6.

Challenges Ahead

Although a great deal of work has been done in location-based services and mobile advertising, there are several major challenges. Mobile multimedia advertising is yet to take off for various reasons. The pricing of the data traffic along with the limitations of small

Table 5. Types of advertising services and infrastructure requirements.

Advertising Services	Description	Infrastructure Requirements	Specific Challenges/Issues
Click-to-Call	▸ A call back number will be provided which is hyperlinked by the advertisers. ▸ When clicked, the customer will be directly connected to that particular advertiser.[17]	A set of generic network and terminal functionalities including standardized toolkits, micro-browser, protocols and application interfaces providing basic transport and control mechanisms.	Network carriers may charge for the call, which is an additional cost to the user.
Short Message Service (SMS) or Multimedia Messaging Service (MMS)	▸ The advertisement provides an option where the customer can enter his number to avail the services of the advertiser. ▸ Once the number is entered, the advertiser would send the text information through SMS and any video clippings through MMS to view.[10,15]	A set of generic network and terminal functionalities including standardized toolkits, micro-browser, protocols and application interfaces providing basic transport and control mechanisms.	For MMS, the bandwidth requirements are significantly higher and smart phones are necessary. 3G/4G network infrastructure will be quite appropriate. MMS will cost more than SMS as network operators may charge higher.
Voice calls	▸ The advertiser will call the customer and inform him of his services. ▸ The customer will receive a call, which will let him know about all the promotions and sales that are going on while he is shopping in a mall.	A set of generic network and terminal functionalities including standardized toolkits, protocols and application interfaces providing basic transport and control mechanisms.	User may not want to receive calls from advertisers.
Location Finder	▸ The advertisement provides the link to find their facility. ▸ Suppose the customer gets an advertisement of the Pizza Hut, it would also provide a link to find their location.	Generic network and terminal functionalities including standardized toolkits, micro-browser, protocols and application interfaces providing basic transport and control mechanisms including navigational tools like GPS.	Accurately determining the location can be challenging.

screens and in many cases limited bandwidth make it difficult for advertisers to take full advantage of location-based context-aware advertising. However, the adoption of LBS is expected to change in the future with the deployment of 4G networks and attractive pricing of these services.

Pricing. Pricing for LBS poses a big challenge to all the players in the mobile ecosystem including customers, advertisers, and marketing vendors—as well as advertising service agencies. The pricing for voice and data services including applications differ considerably. The network operators generally have per-minute and flat rate charging models for voice services and open-ended pricing models for data services. Currently, the consumers have to pay on the basis of airtime and amount of data, and this has not been widely accepted by consumers. The future high speed networks (4G and higher) could create new market opportunities with simple and attractive pricing model.

It is evident that when considering pricing and deployment issues, content providers will have greater flexibility and bargaining power when consumers can access their services and applications directly without any restrictions or charges from the network operators. Content providers who plan to generate revenue through location-based advertising and promotions that will drive traffic to a storefront face some serious pricing challenges. How much the customers are willing to pay for the LBS and how to best attract customers with promotional offers with bundled services in a mobile environment are not yet tested. Prices for location-based services will significantly affect the adoption of these services and create consumer demand. Consumers look for simplicity, transparency and value for the charges they pay for these services.

Transaction-based (per-usage fee) and subscription-based fees are likely to appeal to most of the consumers. For example, consumers are unlikely to pay a high subscription fee for an emergency road service that is not used on a regular basis. However, some may use this service as necessary using pay per use model.

Personalization and context-awareness. The advertising contents should be personalized, or matched to users' preferences and profile.[12] For Push advertisements, can Spam law prohibit sending any message unless opted-in by the users? Assuming that user has agreed to or has subscribed to location-based services, the vendors can send targeted advertisements such as discount ads based on consumer's location to encourage them to purchase certain products or services. If given the permission to access the consumers recent search pattern, the advertising companies can use the data and target those advertisements that are

Table 6. A comparison of several business models.

Model Type	Key Features	Comments
Subscription-based	*Fixed subscription:* Based on a monthly charge with unlimited usage *Limited subscription:* A combination of basic monthly charge (based on a fixed amount of content consumption) plus extra charges based on additional consumption beyond the fixed amount. *Event or transaction-based charging:* Charge is based upon the use of a particular service on content (multimedia message (MMS) or downloading a song) *Session-based charging:* Based on metering during continuous usage of the service or content, such as streaming media services with charges for usage or time	Content providers have to work with WSPs who take control of major revenue and decide what applications and services they deploy.
Safe income	Based on subscriber fees and content providers' placement fees. Fees are derived from businesses that want placement of their ads with top priority and distribution across the WSP's network. Businesses do not share any revenue that content providers earn through the distribution of ads over the WSP network.	A hybrid model without one provider controlling network access and WSPs have less control over revenue generated by the content providers.
Diversified revenue	A combination of high quality content, applications and services and provides a bundled offering that is quite attractive to subscribers. Revenues are generated either through placement of ads or by receiving a share of advertising revenues and transaction fees. The content and service providers use WSPs distribution channel to receive these fees directly.	A more flexible model which has more upside potential for additional revenue generation. Collaboration among WSPs and content provides are necessary to provide a variety of services to the customers. Has some merit over others because it helps to generate additional revenue, with little effort of WSPs for media sales.
Outsourced media sales revenue	Revenue is derived wholly through sharing of all advertising and m-commerce revenue generated over the WSP distribution channel. Requires significant commitment and effective use of mobile advertising from WSPs. It is not only important for the WSPs to track the ads they serve on their network for appropriate revenue sharing, but also to monitor the occurrence of ads they serve to their customers based on their profiles, preferences and characteristics.	WSPs may decide what ads to serve to their customers based on their profile and user preferences. A greater commitment to wireless advertising from WSPs is necessary.
In-house sales revenue	Requires WSPs to have an in-house dedicated team focused on media sales, processing and management of mobile ads. Fully dependent on advertising and m-commerce transaction fees for mobile content acquisition and subscriber access.	In this case, a complete technology solution is required to support mobile advertising in ad development, management and services associated with it.
Advertising by keyword auctioning[24]	Auctioning of keywords in dynamic web search will be adapted in the mobile search business and a variety of strategies being considered. Keywords will be used to provide location-based context-aware advertisements.	An unproven model that requires some suitable adaptation of online advertising platforms of the traditional web. It is not clear exactly how the revenue will be split among the WSPs and other players in the mobile ecosystem.[7]

relevant to that particular user.

If user pulls information (thus opts-in) about his/her choice of products or services within his/her neighborhood, the ads will be delivered to the consumer which becomes less intrusive. This however results in a higher cost as pushed ads are less expensive than delivered pulled ads.

Privacy. Mass adoption of location-based services will depend on how well network operators protect privacy of consumers. Unsolicited mobile advertising is generally considered intrusive and some consumers dislike marketing efforts that encroach their privacy. LBS service providers must understand the fine line between personalization and addressing privacy concerns. In order to provide personalized context-specific LBS, customer data from several sources should be collected and analyzed. However, the personal data of the consumers should be properly managed and appropriate security measures should be taken. The mobile devices are such that they can be personalized to high degree and hence there is a huge potential of providing personalized LBS services on demand. Protecting consumers' privacy is going to be quite important as these services are rolled out. Hence, LBS service providers will have to make these services on a permission-based opt-in basis and educate the consumers about its consequences as location information is a sensitive issue.

Business models and adoption. Adoption of LBS will largely depend on how the network operators charge for value-added mobile data services. The success of mobile advertising will depend on the volume of traffic using the wireless network and associated location-based services. With this nascent and emerging market comes some uncertainty, which may cause low advertising revenues initially. Although there are quite a few location-based services currently available, the use of wireless data services is far below the expectation particularly in the U.S. Consumers view these services as 'nice to have' rather than 'must have' and are not willing to pay the additional fee for many of these niche services. As the market matures and the services become more affordable and wireless Internet services become pervasive, the adoption rate will increase and consumers will realize the value of the LBS. The other factors which may increase adoption may include a satisfactory level of privacy, increased availability of location-based applications, and future introduction of location-awareness in social networking environment.

New and suitable applications. As LBS mature, a plethora of smart phones along with applications that utilize geo-location are emerging. Network service providers will be able to maximize their revenue by retaining and using the location data to develop customized services for their clients on demand. These kinds of value-added services will give competitive advantage and help them gain market share. However, it is well known that content development is not their expertise. Hence, strategic partnerships with specialized content providers and developers will be quite important. One of the major issues with location-based services has been that very few "suitable" applications were available to users, but with Apple's iPhone devices many more applications are becoming available.[29] For example, Motorola has launched a smart phone called Droid that is powered by Google's Android OS, which has voice-enabled navigational tools and personalized maps that will provide directions from source to destination. Another interesting application is Life360's Mobile Emergency Network that uses Android OS and GPS technology. In addition, voice activated location-based search is also becoming available on these smart phones.

Utilizing location-based mobile marketing, businesses can quickly reach out to potential customers. Augmented reality coupled with LBS has lots of potential for mobile marketing in the social networking scenarios. For example, the Twitter 360 iPhone app combines Twitter's new geo-location APIs along with the iPhone 3GS's compass feature and augmented reality to create an application that businesses could easily take advantage of.

Technological Challenges

There are several approaches to determine the location. These include GPS, Wi-Fi (wireless LANs), cellular (2G/3G/4G) networks, sensors, and RFID. GPS uses a constellation of 24 MEO (Medium Earth Orbit) satellites and can offer accuracy of tens of meters. Several different wireless LANs are in use that can offer location accuracy in the order of hundred meters. Cellular networks may use one of multiple techniques including base station triangulation or variations of GPS for accuracy in hundreds of meters. Smaller devices that use RFID and sensors can support accuracy of a meter or less. GPS and its variations are primarily outdoor location technologies, while wireless LANs are primarily indoor. These technologies must be used together to support many applications. For example, moving from outdoor locations to indoors may require handoff from GPS to an indoor location technology such as wireless LANs, RFID, or sensor networks. There is need for additional work, including development of middleware, to support these handoffs among multiple diverse technologies with different frequencies, protocols, and location accuracy.

Connectivity, power, download speed, screen size. Other challenges include dynamic location changes, cost of communications, battery and computing power, continued wireless connectivity, download speed, and smaller screen size and lack of standards.

With limited bandwidth and slow data rate, the user will be reluctant to accept ads on their mobile devices. This will have an adverse effect on advertising performance. The slow download speeds could be addressed with increased penetration of 3G/4G networks. Also, the presence of multiple incompatible locational technologies may create dilemma for many smaller mobile advertising companies including start-ups.

The screen size poses a significant challenge to mobile advertisers as it may be difficult to display information that is rich in content and graphical in nature. Mobile advertising agencies must be innovative and create effective ads that are suitable for the small screen. There are several portable mobile devices ranging from cell phones and PDAs with varying screen size. In general, a PDA's screen size is larger than that of a cell phone. Hence, the ads have to be tailored based on the end user device. In order to avoid this situation, mobile device manufac-

turers must come up with industry standards and guidelines so that the mobile advertising community can effectively use their platform to potential customers. In addition, formatting of texts, font sizes and graphics will be displayed differently or may not be well displayed on different devices. Currently well-defined standards and regulations for format, content, payment are necessary for the mobile advertising industry to grow and attain its full potential. Without such standards and regulations, mobile advertising businesses, location-based service providers, and all other players in this ecosystem will face an uphill task to succeed. Hence, content has to be adapted according to terminal capability. The World Wide Web consortium is developing guidelines for Mobile Web best practices.[28] The recommendations are for developers and the goal is to improve end users experience.

Conclusion and Future Trends

Mobile advertising and other location-based services have the potential for becoming more pervasive and resulting in significant revenue for service providers, wireless carriers, and applications developers and integrators. However, many challenges must be addressed including developing acceptable standards for mobile advertising, addressing security and privacy concerns, enriching users with rich multimedia content, providing end users with value-added location-based services along with performance guarantee. The use of context-awareness and personalization in LBS could lead to highly effective advertising and high level of customer satisfaction. Another interesting application in the recent years is the design and development of large-scale real-time location-based information system.[3,20]

Many emerging trends will impact the future of location-based services. These include the integration of new functionalities in hand-held and wearable communications devices, increasing number of applications that are beginning to utilize location-data and awareness to improve their effectiveness, use of location-awareness in mobile and on-line games, and, increased number of wireless and mobile networks that either have built-in location awareness or are undergoing through the add-ons for improved and accurate location-awareness. The user privacy will be improved by anonymous versions of some location-based services, which may be able to "cloak" the users' locations or decrease the locational accuracy to essentially "hide" the users with higher privacy needs. Use of public displays in more effective interactions with "not-so-private" advertisements either by users or by the infrastructural sensing of users' proximity to ambient displays could become a major improvement over current technological limitations of mobile devices. The incorporation of location-awareness in social networking applications could result in further advancement of viral advertising, where advertisements may spread based on targeting of users in some locations with certain profile. This could further be combined with data mining techniques which will allow near-future prediction of users' locations. The use of computational techniques to "best-match" billions of potential advertisements to billions of mobile users in potentially millions of locations globally will lead to an unprecedented multifold increase in both the effectiveness and the market size for location-based services. C

References

1. Banjo, D. *Charging for Mobile Content, Content Networking in the Mobile Internet*. S. Dixit and T. Wu, eds. Wiley, 2004.
2. Barbeau, S.J., Labrador, M.A., Winters, P.L., Perez, R. and Georggi, N.L. A general architecture in support of interactive, multimedia, location-based mobile applications. *IEEE Communications Magazine 44*, 11 (Nov. 2006), 156–163.
3. Cai, Y and Xu, T. Design, analysis, and implementation of a large-scale real-time location-based information sharing system. In *Proceeding of the 6th International Conference on Mobile Systems, Applications, and Services* (June 2008).
4. Delaney, K. How Yahoo plans to get things going on the go. *Wall Street Journal*. (Jan 8, 2007).
5. Hazas M., Scott J. and Krumm J. Location-aware computing comes of age. *IEEE Computer 37*, 2 (Feb. 2004).
6. Hirsch, F., Kemp, J. and Ilkka, J. *Mobile Web Services: Architecture and Implementation*, John Wiley & Sons, 2006.
7. Issel, K. and Mrozik, J. A mobile data service framework and its business models. In *Proceedings of the 6th ACM International Conference on Advances in Mobile Computing and Multimedia*. (Nov. 2008), 322-325.
8. Junglas, I. A. and Watson, R. T. Location-based services. *Commun. ACM 51*, 3 (Mar. 2008), 65-69.
9. Koutsopoulou, M., Kaloxylos, A., Alonistioti, A. and Merakos, L. A platform for charging, billing, and accounting in future mobile networks. *Computer Communications, 30* (2007), 516–526.
10. Küpper, A. *Location-Based Services: Fundamentals and Operation*. John Wiley & Sons, 2005.
11. Mohamed, Y.H., Gao, Z.J. and Shim, S. Wireless advertising's challenges and opportunities. *IEEE Computer 36*, 5 (May 2003) 30-37.
12. Mokbel, M.F and Levandoski, J.J. Toward context and preference-aware location-based services. In *Proceedings of the 8th ACM International Workshop on Data Engineering for Wireless and Mobile Access* (June 2009), 25-32.
13. Mahmoud, Q.H. Provisioning context-aware advertisements to wireless mobile users. *IEEE International Conference on Multimedia and Expo*. (July 2006), 669-672.
14. Mohapatra, D. and Suma, S.B. Survey of location based wireless services. *IEEE Intern. Conf. on Personal Wireless Communications* (Jan. 2005), 358-362.
15. Ralph, D. and Graham, P. *MMS: Technologies, Usage and Business Models*. Wiley, 2004.
16. Rao, B. and Minakakis, L. Evolution of mobile location-based services. *Commun. ACM 46*, 12 (Dec. 2003) 61-65.
17. Rashid, O., Coulton, P., Edwards, R. Providing location based information/advertising for existing mobile phone users. *Personal and Ubiquitous Computing 12*, 1 (Jan. 2008).
18. Schiller, J. H. and Voisard, A. *Location-based Services*. Morgan Kaufmann Publishers, 2004
19. Sharma, A. AOL Targets Cellphone Ads. *Wall Street Journal*. (May 16, 2007).
20. Steed, A. Supporting mobile applications with real-time visualisation of GPS availability. In *Proceedings of Mobile HCI*. Springer, 2004.
21. Sun. The Java ME Platform-The Most Ubiquitous Application Platform for Mobile Devices; http://java.sun.com/javame/index.jsp
22. Unni, R. and Harmon, R. Location-based services: Models for strategy development in m-commerce. In *Proceedings of Intl. Conf. on Technology Management for Reshaping the World* (July 2003), 416- 424.
23. Vascellaro, J.E. Air War: A Fight Over What You Can Do on a Cellphone. *Wall Street Journal*. (Jun 14, 2007).
24. Vickery, W. Counterspeculation, auctions and competitive sealed tenders. *Journal of Finance*, (1961), 8-31.
25. Virrantaus, K., Markkula, J., Garmash, A., Terziyan, Y.V. Developing GIS-supported location-based services. In *Proc. of First International Workshop on Web Geographical Information System*, (Kyoto, Japan) 423–432.
26. Wierenga J. and Komisarczuk, P. SIMPLE: Developing a LBS positioning solution. In *Proceedings of the 4th International Conference on Mobile and Ubiquitous Multimedia* (Dec. 8-10, 2005).
27. Wireless News, Analysis: are mobile ads the next gold rush? (Feb. 9, 2007); http://wirelessfederation.com/news/category/informa-telecoms/ (retrieved on June 20, 2007).
28. Mobile Web Best Practices, http://www.w3.org/TR/mobile-bp/
29. Malik, O. iPhone is Boosting Demand for Location-based Services; http://gigaom.com/2009/04/27/iphone-is-bossting-demand-for-location-based services/
30. Deng, Z., Zou, D., Huang, J., Chen, X. and Yu, Y. The assisted GNSS boomed up location based services. In *Proc. of IEEE Conference on Wireless Communications, Networking and Mobile Computing*, 2009.
31. Rashid, O., Coulton, P., Edwards, R. Providing location based information/adverting for existing mobile phone users. *Personal and Ubiquitous Computing 12*, 1 (Jan. 2008) 3-10
32. Sanchez, J., Cano, J., Calafate, C. and Manzoni, P. BlueMall: A Bluetooth-based advertising system for commercial areas. In *Proc. 3rd ACM Workshop on Performance Monitoring and Measurement of Heterogeneous Wireless and Wired Networks* (2008), 17-22.
33. Tschofenig, H, Schulzrinne, H., Newton, A., Peterson, J. and Mankin, A. The IETF Geopriv and Presence architecture focusing on location privacy. Position paper. *The W3C Workshop on Languages for Privacy-Vacancy Policy Negotiation and Semantics-Driven Enforcement* (Oct. 2006).

Subhankar Dhar (subhankar.dhar@sjsu.edu) is an associate professor in the Department of Management Information Systems at San Jose State University, San Jose, CA. He is supported by a Lucas Fellowship Grant.

Upkar Varshney (uvarshney@gsu.edu) is an associate editor in the Department of Computer Information Systems, Georgia State University, Atlanta, GA.