Location matters: Spatial standards for the Internet of Things

ITU-T Technology Watch Report

September 2013

Precise and accurate location (spatial) information enhance our association with our natural and built environments. This report looks at the global effort to weave different sources and formats of spatial information together so that they can be useful to people wherever they are and whatever they are doing.

The rapid evolution of the telecommunication/information and communication technology (ICT) environment requires related technology foresight and immediate action in order to propose ITU-T standardization activities as early as possible.

ITU-T Technology Watch surveys the ICT landscape to capture new topics for standardization activities. Technology Watch Reports assess new technologies with regard to existing standards inside and outside ITU-T and their likely impact on future standardization.

Acknowledgements

This report was written by staff and members of the Open Geospatial Consortium (OGC), in collaboration with the ITU Secretariat. The OGC is an international consortium of more than 475 companies, government agencies, research organizations, and universities participating in a consensus process to develop open standards for the communication of spatial information.

Please send your feedback and comments to tsbtechwatch@itu.int.

The opinions expressed in this report are those of the authors and do not necessarily reflect the views of the International Telecommunication Union or its membership.

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Technology Watch is managed by the Policy & Technology Watch Division, ITU Telecommunication Standardization Bureau.

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1. An introduction to spatial standards

The Internet provides communications infrastructure for countless networks of freely associating human beings but, beyond that, the Internet increasingly enhances our association with our natural and built environments. This connection to the real world depends on open *spatial* standards.

Applications like 'friend finder'[1] and location marketing[2] are important market drivers for defining and documenting the mobile Internet and the associated standards infrastructure enabling location-based services (LBS). More importantly, information sharing on a global basis about the natural and man-made environments is crucial to solving humanity's most critical problems.

This report has two central aims:

1) Help stakeholders understand location standards – or more broadly, spatial standards – for *Social-Local-Mobile* markets and the *Internet of Things* (IoT).
2) Bring home the message that these standards can only fulfill their potential if stakeholders support cross-participation of standards developers in the working groups and technical committees of multiple standards organizations.

Information so often includes *where/place* information that spatial (location) interoperability requirements are discussed across a number of standards development organizations (SDOs). The principal geospatial standards organizations are the Open Geospatial Consortium (OGC) and Technical Committee 211 of the International Organization for Standardization (ISO/TC211: "Geographic information/Geomatics").

OGC, ISO, ITU-T and other SDOs are cooperating in areas of common interest, but more can be done at the working group and technical committee level where engineers representing different countries, companies and standards bodies can build a strong international ecosystem of spatial standards.

In this report we look at the global effort to weave different sources and formats of spatial information together so that they can be useful to people wherever they are and whatever they are doing. More than 20 years of standards work has gone into making these resources usable together in applications. Much has been accomplished but much work remains, and readers will see why the remaining work requires communication and collaboration by a diverse collection of SDOs as well as how this can be achieved.

1.1 Getting location anywhere

In the past 25 years, performance of silicon integrated circuits has increased by a factor of more than 1,000, and wireless data speed has increased by a factor of 100,000, from 100 bps to 10 Mbps. Nokia anticipates that by 2020 the average mobile user will consume one gigabyte of data per day.[3]

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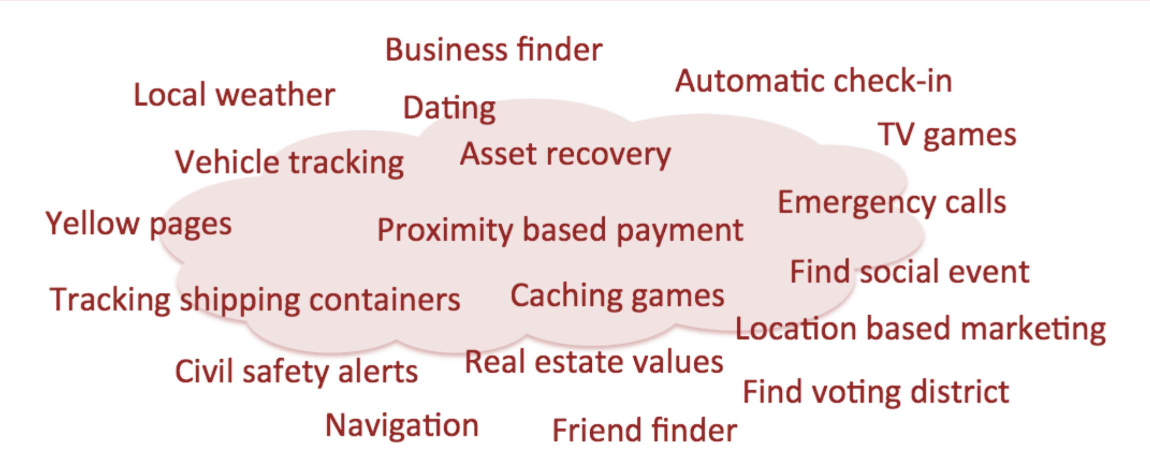
[1] See, for instance, Locaccino, a location-centered social application that was developed in the Mobile Commerce Lab at Carnegie Mellon, http://locaccino.org/

[2] See Wikipedia, http://en.wikipedia.org/wiki/Proximity_marketing, or ITU-T Technology Watch Report on Digital Signage, http://itu.int/en/ITU-T/techwatch/Pages/digital-signage-standards.aspx

[3] Nokia Siemens Networks, http://www.nokiasiemensnetworks.com/news-events/press-room/press-releases/mobile-operators-could-you-be-profitable-providing-everyone-a-gigabyte-a-day-of-personaliz

Figure 1: Some of the many LBS applications delivered via the Internet



In many parts of the world, wireless mobile devices provide not only voice communication but also Web access and access to observations from onboard sensors, cameras, high-resolution displays and information tools and, of course, *location-based services.* While the consumer rarely sees the raw location data, the services that location enables (such as navigation or friend finder) are highly visible and very important to the consumer. Costs and power requirements are falling, network coverage is expanding, and the number of *apps* is exploding.

Wireless mobile devices are not only consumers of data; they are also producers of data. Within the top software layer of the telecommunications stack, different kinds of data such as text, imagery and video all require their own collections of standards. The case is similar for spatial data, with different collections of standards required by *geospatial* data referenced to the Earth's surface and *engineering data* referenced to, for example, a building's engineering coordinate system.

The Pew Research Center’s “Internet & American Life Project” found that, by February 2012, almost three-quarters (74%) of smartphone owners were using their devices to get directions and other location-related information (up from 55% in May 2011).[4]

That study was published more than a year ago. Today all new smartphones are location-enabled through onboard GPS chips. The ubiquity of these chips in mobile devices is proving to be a major market driver for wireless mobile devices. Mobile devices that can report their location to applications play leading roles in fields as diverse as transportation, emergency response, disaster management, environmental sampling, meteorological and oceanographic research, municipal and utility maintenance operations, and location marketing.

As tradeshows and product marketing evolve from a technology focus to a marketing focus, and as location-aware devices become ubiquitous, the term *Location Based Services* is being overshadowed by more consumer-focused terms like *Social-Local-Mobile*.

1.2 The need for common standards

Communication means *“transmitting or exchanging through a common system of symbols, signs or behavior."* Standardization means *“agreeing on a common system.”*

[4] Pew Internet, http://www.pewinternet.org/Reports/2012/Location-based-services.aspx

Standards enable communication of spatial data between software systems. Such communication takes place in the application layer and is built on lower level protocols. When your smartphone responds to your request for a street address, or when a disaster-response center sends a warning to phones and television sets in the path of a tornado, a stack of standards defined by a variety of standards organizations comes into play.

The spatial standards community is concerned with the consistent encoding of location data and the use of well-defined, consistent service interfaces for finding, accessing and invoking LBS and associated data. Invocation of the standards service stack takes place, for example, when a web browser accepts your waypoints to create a map showing the route you have taken, or when it overlays that map on an Earth image or a 3D contour map.

1.3 Spatial communication and processing is complex!

Processing digital geo-information is a great deal more complicated than simple verbal geo-communication (e.g. *"Meet me at my house"*).

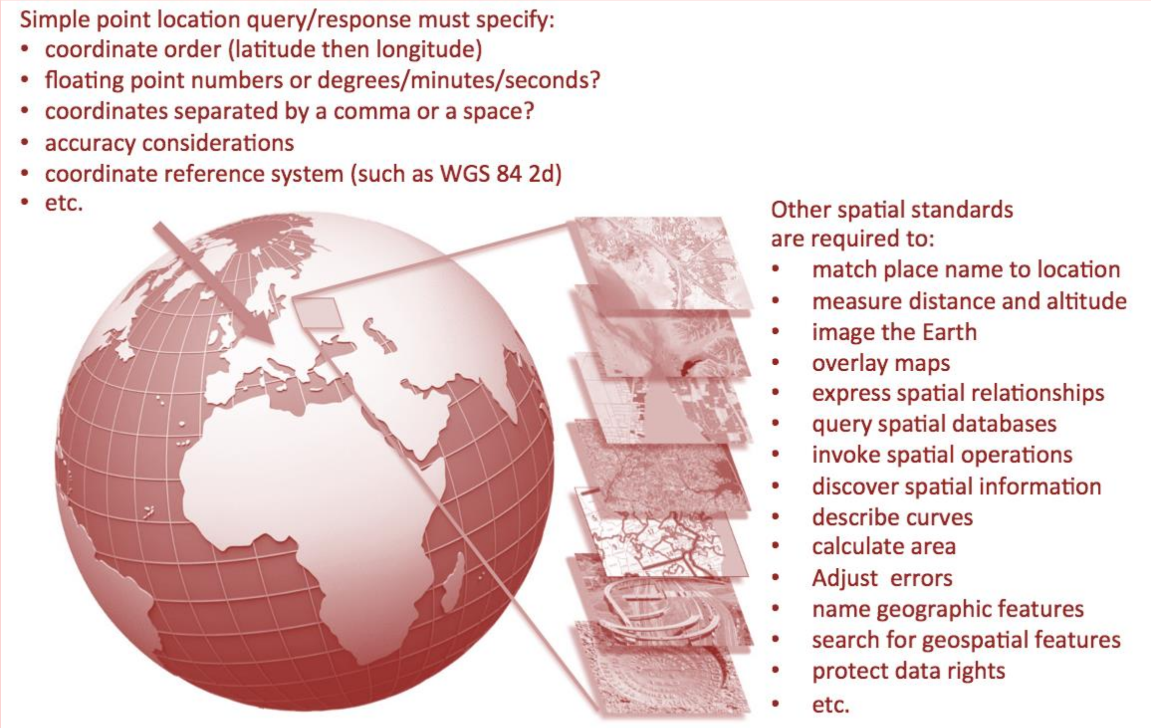
Communicating simple latitude-longitude coordinates is not complex, but computers expect consistency. To ensure interoperability in the service stack, a standard is required. The point profile of the Geography Markup Language (GML) or the coordinate parameter of Open GeoSMS, a standard that has been submitted to ITU for adoption as an ITU-T Recommendation (see Section 5.1), define rules, such as coordinate order (latitude then longitude); whether these numbers are to be expressed as floating-point numbers or degrees, minutes and seconds; whether coordinates are separated by a comma or a space; accuracy considerations, and so forth.

It may come as a surprise that there are many Earth coordinate reference systems (CRS) in use today. Specification of the CRS is critical (e.g. the World Geodetic System (WGS) in its latest revision, WGS 84 2d). Improper expression and use of a CRS can introduce significant positional error in the coordinate – potentially a hundred meters or more![5]

GML is a joint OGC/ISO standard that defines an XML grammar for encoding and transporting geospatial content. GML is vendor and technology neutral and is designed so that any kind of geospatial information can be encoded. Open interfaces that read and write GML are the interfaces that enable, for example, a geographic information system (GIS) containing elevation data to query another GIS containing road data to return the slope of a road at a given location. GML is part of the interoperability platform that enables a single software program to control and access data from multiple Earth-imaging devices on satellites or aerial platforms. The standard enables cities and countries to provide vendor-neutral public access to data about elevation, water bodies, transportation infrastructure, population density, land cover, vegetation, geology and other *data layers* that comprise *spatial data infrastructure*. GML is embedded in international encoding standards for domains such as weather, aviation, hydrology, geology, Augmented Reality, and emergency response.

[5] See ISO 6709, Wikipedia, http://en.wikipedia.org/wiki/ISO_6709

Figure 2: Spatial standards are necessarily complex because digital geographic data and processing are complex



Geospatial standards must meet many interoperability requirements beyond defining a standard way to express a lat-long coordinate. Standards define and provide consistent ways to exchange and process Earth-referenced data that may be encoded using grid cells, vectors, polygons or other methods of representing Earth features and phenomena. Information products, such as maps provided by map browsers or turn-by-turn directions provided by navigation devices, are the result of complex operations involving diverse spatial databases, analytical engines and display functions. Interoperability is essential because in today's web-services environment these operations are more commonly performed on distributed systems than in a GIS running on a single computer. These distributed systems must interoperate to support complex geospatial value chains.

It is important to keep in mind that a large body of geospatial standards pre-date location-aware smartphones. Smartphone apps and Earth browsers build on a foundation of standards driven by earlier needs for communication among GIS, Earth-imaging systems, sensor webs and databases containing location information.

1.4 Standardization gaps

While GML and related standards give smartphone app developers access to extraordinary geospatial resources, critical gaps remain.

One glaring gap is between indoor and outdoor location systems. Users accustomed to easy and accurate outdoor navigation expect a seamless transition when moving indoors, but as yet there are only limited environments in which this is possible.

In contrast to outdoor spatial information, there is currently no single technology that provides for uniform coverage of positioning information indoors. However, such technologies are advancing rapidly, and forward-thinking institutional technology providers and users with a stake in the convergence of indoor and outdoor location technology owe it to their stakeholders to support coordination among SDOs previously involved with only indoor location or only outdoor location.

Things in the Internet of Things all have location, and usually their locations matter. Where a sensing device is located in a building is highly relevant to applications that use data from that sensor. Access to accurate building information – not just floor plans – is becoming increasingly important. Building Information (BIM)-based standards are needed to provide building information, such as the location of devices, throughout a building's lifecycle. Many or even a majority of the devices in the emerging Smart Grid will be user-owned devices inside and on top of buildings, rather than utility-owned devices in outdoor electric power transmission and distribution networks.

Other standards gaps need to be addressed to clear the way for progress in LBS markets. BIM standards and other built environment standards will not succeed in the marketplace until there are also open standards for communicating information about spatial data provenance and rights of ownership and access. Data provenance involves tracking not only rights and the lineage of data through many operations, but also information about uncertainty and quality. Location privacy concerns are expected to help drive standards work in this area.

Capabilities like the communication of data provenance are cross-domain requirements, as useful for the advancement of science as they are for location marketing and BIM. Diverse industries can share the cost of developing such standards and reap extraordinary returns on their investments.

2. Overview of LBS technology

LBS require three basic kinds of technology and standards: network communication, position determination, and spatial analysis and portrayal.

For most LBS applications, network communication is provided by the wireless communication infrastructure that supports cell phones. This infrastructure is rapidly transitioning from technology that supports only voice and data (text messaging and photos) to technology that supports Internet Protocol (IP).

Internet connectivity enables LBS to take advantage of everything available through the World Wide Web: search, video and video conferencing, music, social networking, file sharing, shopping, advertising and more. Phones designed for IP (*smartphones*) have opened the door to applications (*apps*) that leverage both Internet-resident resources *(the cloud)* and the phones' extraordinary processing power, sensors and graphical user interfaces to provide unprecedented capabilities, many of them location-based.

Although position determination is increasingly being accomplished by means of GPS, many older and less expensive phones rely on a *trilateration* service from the carrier's *Location Server* that determines cell phone location from measurements of the time it takes signals to travel between the cell phone and the nearest three cellular transmission points. Cell phone GPS is usually less precise than a dedicated GPS, but it is usually within 7 meters.[6] However, GPS seldom works indoors. Trilateration is usually only accurate to about 8-25 meters outdoors and is even worse indoors. The major problem that distinguishes indoor from outdoor location and mapping is that there is no indoor equivalent of GPS.

Spatial analysis and map portrayal are, in most cases, provided as services delivered from data centers that perform spatial processing and build images from geospatial data to portray transportation features such as roads and bridges.

Network communication, position determination, and spatial analysis and portrayal are all widely available today through a combination of open standards and proprietary encodings and interfaces. Carriers and platform providers have compelling business reasons for keeping users in providers' *walled gardens* by means of proprietary approaches. The market is however very dynamic and the trend, as in other technology domains, is in the direction of open standards that open up the market. Just as TCP/IP, HTTP and free use of the GPS satellite network have created a huge LBS market space, free access to other kinds of infrastructure will further expand the LBS market.

Sooner or later, depending on the pace of inter- and intra-industry collaboration and efficient SDO cooperation, this opening up of LBS-dependent markets will become a reality.

2.1 Seamless indoor/outdoor LBS

We do not yet have an open standards infrastructure comprehensive enough to support seamless LBS delivery as the user leaves the street or sidewalk and enters a building and moves about inside. As with outdoor LBS, three elements are needed for indoor LBS: network communication, position determination, and spatial representation.

[6] U.S. National Coordination Office for Space-Based Positioning, Navigation, and Timing, http://www.gps.gov/systems/gps/performance/accuracy/

Wireless communication between devices in both the indoor and the outdoor worlds can be provided by the cell phone infrastructure, but this is not practical for all applications. Other physical networking technologies such as RFID, IR, WLAN and Bluetooth are better suited to communication between a building's sensors and mechanical systems. More importantly for LBS, these networking technologies can also be used for wirelessly determining physical location of mobile devices indoors. Indoor location cannot be determined by GPS because GPS signals are blocked by building materials. *Trilateration,* the other main method of cell phone location determination, lacks sufficient precision.

Fortunately many SDOs are engaged in an increasingly collaborative effort to establish the indoor network-communication and position-determination standards infrastructure. The SDOs include, among others, IEEE, IEC and ITU-T. This standardization work is complicated by the fact that the technologies are advancing rapidly and market uptake of standards depends on potential users' assessment of many often uncertain factors such as accuracy, coverage, the frequency of location updates, and the cost of installation and maintenance.

Indoor/outdoor LBS also requires a way of representing both the indoor and outdoor worlds. The small-scale street maps that appear on our GPS units and smartphones take us to a building, and they may even provide street views or 3D renderings of building exteriors at a large enough scale to show us the entrance to the building. However, once inside the building, navigation requires 2D floor plans or 3D renderings of interiors.

Systems for design (BIM, Computer Aided Design (CAD) and Civil Engineering software) and systems for observation and management (sensors, imaging and geospatial processing) were created by different professional communities to solve different kinds of problems. Despite these differences, progress toward interoperation is accelerating as SDO cooperation improves and visions of the Smart City BIM become more compelling for both government and business.

3. Market, content, applications and trends

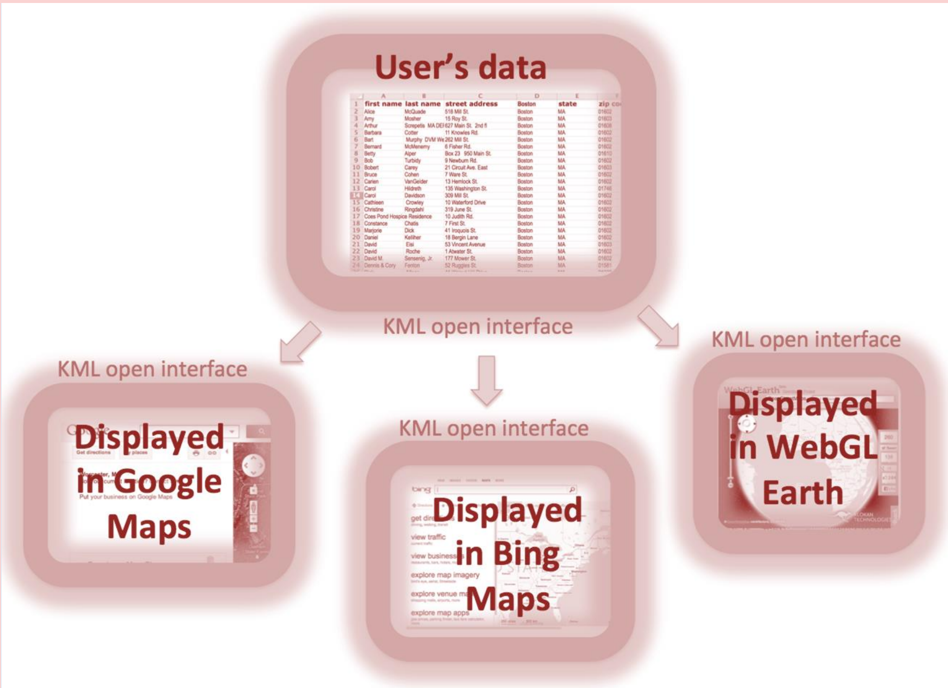
LBS markets are enabled by technologies and technical standards, but they are driven by the needs of individuals and institutions and by businesses' forecasts of the scale of those needs and the revenue to be earned in meeting them.

Network effects[7] are an important part of location-service market value as perceived by private-sector players. Network effects can be roughly quantified by Metcalf's Law, which states that the value of a network (and a node on the network) is proportional to the square (or some other exponent) of the number of connected users in the system.[8]

Consider how LBS market value comes not only from the number of devices that are connected, but also from the number of spatial datasets that can be quickly discovered, accessed and used. The global implementation and use of existing geospatial standards makes a huge amount of spatial data available to applications.

The value of an Earth browser such as Google Earth, Bing Maps or WebGL Earth is enhanced significantly if the browser is capable of processing KML data. KML (formerly Keyhole Markup Language) is an encoding standard that enables a user's unique spatial data to be displayed on top of the map provided by an Earth browser.

Figure 3: A location database can provide location data for multiple Earth browsers via its open standard KML interface



In addition, the value of spatial communication standards comes not only from the number of devices and number of datasets in the network, but also from the number of diverse types of systems that can be connected. When indoor/outdoor LBS standards become available and widely deployed, it will lead to significant value-add for smartphones and their LBS apps as well as for Augmented Reality and Location Marketing developers and customers.

[7] Wikipedia, http://en.wikipedia.org/wiki/Network_effect

[8] Wikipedia, http://en.wikipedia.org/wiki/Metcalfe's_law

Network effects also apply to the number of entrepreneurs attracted to the mobile app space. Larger networks equate to greater market potential; leading to more app developers and apps, and thus further increases in the value of the market.

The expanding market potential also drives investment in new and improved technologies designed to converge with and build on existing technologies. Consider, for example, how the volume of indoor and outdoor location data would explode if every smartphone had a miniature LiDAR[9] device that could determine location by matching a LiDAR image against other users' prior contributions of LiDAR data to a cloud-resident 3D model.

Figure 4: Awila Augmented Reality browser transfers geospatial data from a Web service to the mobile client and overlays the real world with useful digital information (Figure from Augmented Technologies)

Spatial standards enable people to communicate efficiently via mobile devices about features and phenomena that have a particular location on the Earth. Investments in developing, implementing and deploying open spatial standards yield extraordinary socio-economic value, and evidence of this can be found in several application domains.

3.1 Emergency and disaster management and response

Wireless networks are incredibly valuable in emergencies and disasters, not only because cellular networks are more disaster-resistant than wired networks, but also because timing data collected at the transmitter sites can be used to calculate and report cell phone location, even if peoples' phones do not have GPS. In recent years, crowdsourcing and Volunteered Geographic Information (VGI) have emerged as major factors in disaster management. As was widely reported by news media, the first photo of US Airways Flight 1549's emergency landing[10] in the Hudson River was posted on Twitter from an iPhone.

Humanitarian aid requires meticulous coordination of tasks, aid workers, equipment, resources, etc. Much of this aid is accomplished through ad hoc inter-agency cooperation, making it critical that their diverse systems are able to communicate through open standards. Humanitarian-aid workers are often racing

[9] Light Detection And Ranging (LiDAR): an optical remote sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light

[10] Wikipedia, http://en.wikipedia.org/wiki/US_1549

against time and successful inter-agency cooperation thus requires seamless information sharing and interoperability.

Viewed from a disaster-management and humanitarian-aid perspective, it is unfortunate that platform and social-networking companies avoid exposing interfaces that implement open geospatial standards. These companies have compelling business reasons to keep users within their service *ecosystems* and so find ways to prevent users from easily navigating to other websites. In the interests of providing more widely accessible disaster-relief location information, a number of volunteer organizations have developed open-source social media, crowdsourcing and user-generated content applications. Organizations such as Ushahidi, InRelief, Sahana and Haiti SDI VGI implement open standards in their software to broaden participation by developers and users.

Figure 5: Mark Kempton, Senior Pilot from EMQ Helicopter Rescue in Australia told in the Google Search Stories[11] that during the Queensland Floods his team could not tell locations based on addresses, but cell phones providing longitude and latitude enabled them to find and rescue people in need.

The Sahana platform for disaster management was created in response to the 2004 Sri Lanka Tsunami. The Ushahidi map visualization application for crowdsourcing the collection of crisis information was developed to map reports of post-election violence in 2007/2008. Sinsai.info[12] is a crisis-mapping site that used the Ushahidi platform in response to the Great East Japan Earthquake. It was launched four hours after the earthquake occurred.

Entities responsible for disaster management – major coastal cities, international relief organizations, national emergency-management and military agencies, etc. – are disadvantaged by mobile platform providers that do not implement and publicize open location encoding and interface standards. It is important that these entities make use of disaster-management tools based on open-source platforms or open standards (described above), but it is more important that they indicate their preference for specific open standards in their requests for quotations when procuring systems and solutions. It is also essential for these entities to ensure that their interoperability requirements are addressed by SDOs.

[11] Google, https://plus.google.com/105705606437451864842/posts

[12] Sinsai means earthquake disaster in Japanese; http://www.sinsai.info

3.2 Smart Infrastructure – Topologies, geographies and mobility

Transportation; urban planning; public works; and electricity, natural gas, water and sewage utilities are under pressure to employ new technologies to become more efficient and to address issues such as fossil fuel depletion, water shortages, greenhouse gas (GHG) emissions and the sanitation needs of growing cities. These industries are important sources of requirements in technology policy studies on NGNs (Next Generation Networks) and the future Internet.

Electricity utilities and their customers will in the future depend increasingly on distributed energy production (such as solar panels and heat/power co-generation units) and distributed energy storage (including intermittent and mobile storage in batteries of hybrid and electric cars). All of these things have locations, and their locations often matter.

Smart Grid standards efforts have been led primarily by electrical engineers thinking in terms of network topologies rather than mappings of devices to real-world spaces. In other words what matters in most of their applications is which device is connected to which device, not where the devices are located in a city or a building. Nevertheless, location of these devices often matters, and this is evidenced by the fact that GIS has become essential in managing a utility's assets and operations. However, utility GIS alone cannot address the need for a smooth flow of spatial information within a utility's enterprise and between a utility and other entities such as contractors, public agencies, and yet-to-emerge players in the Smart Grid ecosystem. In the development of this ecosystem, it is crucial that Smart Grid information architectures specify open spatial standards to support use cases in which spatial information is needed.

IEC (IEC TC57 on power systems) has thus set a goal of harmonizing its Common Information Model (CIM) with GML. CIM enables software applications to exchange information about the configuration and status of an electrical network. Through the development of open standards and interoperability guidelines, this move supports IEC's overall goals of fostering enhanced functionality, lowering integration costs and increasing the rate at which the market adopts Advanced Metering networks and Demand Response solutions.

Meters are all sensors, and sensor webs have interoperability requirements that are not addressed by GML. Ad hoc communication of sensor location information with diverse contractors, data providers and first responders will require the use of both open geospatial standards and open sensor-web standards.[13] Cities' and utilities' energy, environmental, real-estate, facilities-management and public-safety responsibilities are all tied to location.

Surveying/civil/geospatial interoperability problems are part of the longstanding set of challenges that includes BIM interoperability and 3D modeling interoperability. The OGC CityGML Encoding Standard for 3D modeling provides a foundational part of the solution. The Netherlands – a flat country in which small elevation differences are very important – has made CityGML-encoded 3D data a key part of their National Spatial Data Infrastructure. Members of the Web3D Consortium[14] worked to help identify key technological issues and develop common integration strategies with web approaches for non-geospatial 3D modeling.

A great deal more remains to be done. One major BIM standards effort is the conversion of building SMART International's Industry Foundation Classes[15] to service interfaces and encodings that are consistent with CityGML and with service-oriented computing in general.

SDOs working on smart cities and smart infrastructure need to consider open standards that enable the integration of vertical and horizontal LiDAR with existing surveying/civil/geospatial technologies. These

[13] OGC Sensor Web Enablement, http://www.opengeospatial.org/domain/swe

[14] Web3D Consortium, http://www.web3d.org/

[15] buildingSMART IFC, http://www.buildingsmart.org/standards/ifc

SDOs must also consider the spatial integration of imagery collected not only from cell phones but also from unmanned aerial vehicles (UAVs).

An OGC Standards Working Group (SWG) on IndoorGML aims to provide a common schema framework for interoperability between indoor navigation applications covering a wide spectrum of application areas including indoor LBS, web map services, emergency control, guiding services for visually handicapped persons, and robotics. Several commercial services for indoor spatial information have been launched recently, such as Google Maps and Bing Indoor Maps. There are also strong demands for organizations including ISO/TC204 (intelligent transportation systems) and the IEEE Robotics and Automation Society to extend existing standards in a way that will seamlessly cover indoor as well as outdoor space.

Public- and private-sector planners and policy makers considering the lifecycle costs of the world's real estate, buildings and capital projects (such as airports, roads and bridges) need to be aware of the value they would derive from a technically unconstrained (but policy-controlled) flow of spatial information. This is particularly true in a time of rapid urban build-out; urgent requirements for new and replacement infrastructure; and financial, energy and natural-resource constraints.

Smart cities and smart infrastructure will depend, *inter alia*, on numerous Web-resident data and processing resources that can be used together in an ad hoc fashion, in diverse scenarios.[16] These scenarios are the source of the spatial interoperability requirements that stakeholders must communicate to SDOs.

3.3 Water

A previous Technology Watch Report gave an overview of how ICT can be a strategic enabler for smart water management policies, and surveyed related standardization activities.[17] Following the outcome of a recent workshop on the topic, the ITU membership established an ITU-T Focus Group on Smart Water Management[18] to further study and raise awareness of the benefits associated with using ICT for smart water management in agriculture, domestic and industrial water use sectors, as well as the wider aspects of socio-economic development. Water-related mobile applications, sensor webs and control applications will become critical assets as populations urbanize, as climate change drives more frequent extreme weather events, and as water technologies of all kinds assemble themselves into *"water spatial data infrastructures."*

The OGC has been working with the World Meteorological Organization (WMO) since mid-2009 to improve water management by enhancing the discoverability, accessibility and usability of water information.

Part of this effort is WaterML 2.0 Part 1: *Time series, a standard for encoding water observation time series*, represents a breakthrough advancement for linking local, regional, national and global water information sources into connected water information networks.[19] It enables any online collections of water data to become part of a water information network. Hydrological data models and collection standards are notoriously heterogeneous, and this often reflects important differences in application requirements. The intention of WaterML2.0 is not to impose a single standard for data models and collection practices, but rather to provide a means through which diverse systems can encode their particular data in a standard way so as to ease communication with other systems and to improve the aggregation of data from diverse sources.

Major cities' water and sewage systems make use of SCADA (supervisory control and data acquisition) systems to gauge and control flows. In many cities these systems are being integrated into Web-based architectures that provide many kinds of improved flexibility. Once on the Web, a SCADA system can be read

[16] ITU-T, http://www.itu.int/en/ITU-T/techwatch/Pages/smart-city-Seoul.aspx

[17] ITU-T, http://www.itu.int/en/ITU-T/techwatch/Pages/smartwatermanagement.aspx

[18] ITU-T, http://www.itu.int/ITU-T/newslog/TSAG+Delivers+New+Focus+Group+On+Smart+Water+Management.aspx

[19] OGC, http://www.opengeospatial.org/standards/waterml

from mobile devices and can provide inputs to cloud-resident monitoring and analysis tools. Similar systems can be employed to optimize networks of storm drains during flood conditions. Sensors in storm drains can help environmental managers look for 'point' and 'non-point' sources of phosphates and nitrates. Such knowledge can help in sizing pollution abatement facilities, meeting regulatory limits, and designing policies that encourage reduced pollution by local citizens and businesses. Sensors can also be used to monitor salinity and pH in the soil around buried pipes and concrete. This is critical information in coastal cities like New York City, where record tidal surges have shortened the expected useful lifetimes of buried infrastructure.

3.4 Transportation

Transportation is undoubtedly the domain where industry and consumers make the most of use of LBS. GPS has revolutionized way-finding for drivers worldwide and created a new market niche for transportation data and service providers. Corporations and governments use LBS to realize significant improvements in logistical efficiencies, maintenance and the tracking of their fleets of vehicles.

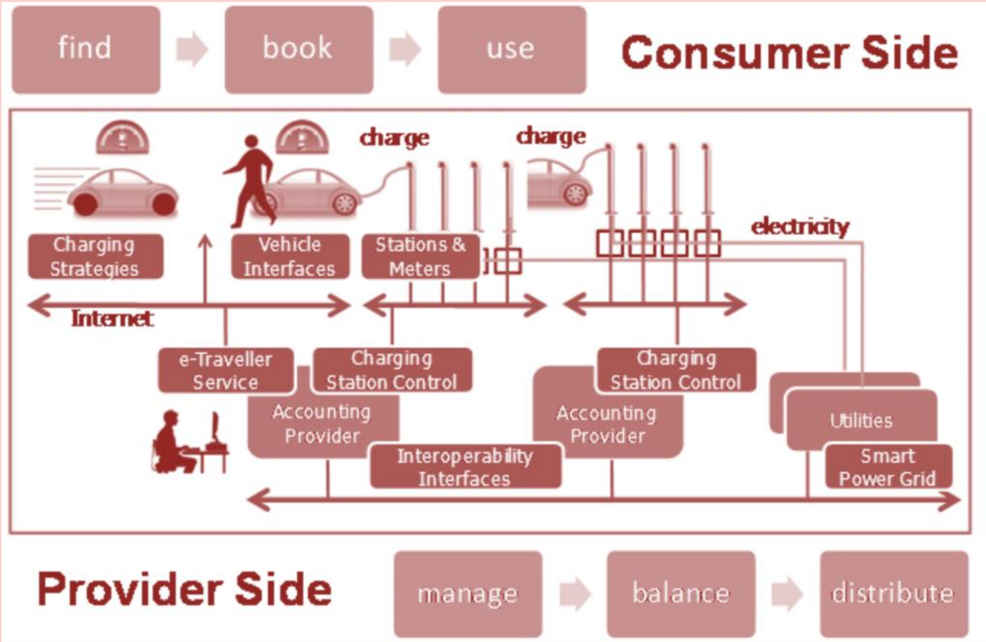
The field of Intelligent Transportation Systems (ITS) goes beyond the reach of today's GPS services to encompass a range of new capabilities related to traffic safety, reductions in congestion and GHG emissions, and auto-pilot capabilities for vehicles.

In transportation, as in other domains, the seamless exchange of geospatial information between platforms and applications requires a coherent framework of geospatial standards.

New transportation applications provide opportunities to build on open geospatial standards that address transportation location requirements. The e-mobility initiative, BALLADE (named in German, *"Benutzerfreundliche allgegenwärtige Ladestellen für Elektrofahrzeuge"*), is a European experiment in managing networks of intelligent geo-located charging stations for plug-in electric vehicles (PEVs). In this trial, drivers typically discover charging stations through navigation services delivered by the Internet-connected navigation devices in their vehicles.

To maximize opportunities for commercial players and others to build on the results of BALLADE, the charging stations have been made discoverable and queriable through existing international standards for open interfaces and encodings.

Figure 6: The BALLADE ecosystem of electromobility uses OGC standards. (Figure from EOX)



Transportation standards activities often focus not on geospatial data and processing, but on topologies related to transportation routes or on surveying/Civil Engineering software and data. Neither of these discipline-specific technologies is able to manage coordinate systems, datums, 3D data or spatial data accuracy in the same way as GIS and LBS. GIS and Architectural, Engineering and Construction (AEC) Computer Aided Design (CAD) vendors provide means of integrating these technologies within their proprietary platforms. However, vendors and users have not yet adequately solved the vendor-vendor interoperability issues related to transportation.

Organized by the ITU, the intent of the Collaboration on ITS Communication Standards[20] is to provide a globally recognized forum for the creation of an internationally accepted, globally harmonized set of ITS communication standards to enable the rapid deployment of fully interoperable ITS communication-related products and services in the global marketplace.

3.5 Trends in LBS

Forecasting the likely evolution of the LBS landscape is today much more difficult than it was a decade ago, as innovation continues to accelerate. The coupling of progress in digital communication technologies with progress in domains such as nanotechnology is sure to result in exciting developments that few can even imagine today.

Trends the OGC sees as important:

Pervasiveness: The number of people using cell phones continues to rise, as does the percentage of cell phones with Internet access and location awareness. The cost of Internet access is decreasing and the percentage of the electromagnetic spectrum allotted to wireless Internet is increasing. Improvements in electronics are expanding the options for efficient use of spectrum through such means as dynamic spectrum access technologies. The relatively new WiMAX-Advanced and LTE-Advanced standards have led to new opportunities in broadband wireless access, building on different widely adopted technologies. The Russian GLONASS Global Navigation Satellite System is in operation, and the European Galileo satellite navigation system is expected to become operational by 2019. All of these trends will support continuing growth of LBS for the foreseeable future.

Interactivity: In popular terms, *broadband* refers to bits per second, and the average number of bits per second available to mobile applications continues its upward trend. Broadband also refers to the number of channels that a connection can support simultaneously, and possibilities for interactivity thus increase in line with the number of channels. Interactivity in a complex LBS application might involve frequent updates of location data and direction-of-view data, while also providing two remote users with live two-way video and audio. It might also, with the movement of a cursor and click of a button, provide a label on selected buildings in the video stream. The LBS market has begun a healthy trend by attracting developers that create highly interactive apps for games, learning environments, environmental models, way-finding, shopping, and entertainment.

Consumer engagement: In response to consumer demand, fifty-four percent of developers working on apps for mobile devices are fitting their apps with location-based and mapping services, according to a survey of more than 400 mobile app developers by Evans Data, an IT industry market research firm.[21] Although some LBS users (such as soldiers) are not consumers, and although mobile devices provide many free services, the LBS market is driven largely by consumers. The rapid growth of giant Internet companies like Google, Apple, Amazon and Facebook reflects these companies' ability to capture and hold the attention of consumers,

[20] ITU, http://itu.int/go/ITScomms

[21] Evans Data Corporation, http://www.evansdata.com/press/viewRelease.php?pressID=183

and much of their revenue potential is ultimately based on their ability to sell retailers the aggregated attention of consumers. The sudden diversion of people's attention away from the real world toward a commercial virtual world raises many interesting questions, including questions about the ways in which LBS may redirect people's informed attention back toward the real world.

Machine-to-machine communication: The falling cost of an Internet connection and the falling size, cost and energy requirements of sensors and actuators mean that we can expect to see many new LBS applications in which people can remotely adjust settings on a device. One example would be setting a thermostat and then letting the device function autonomously by communicating with another system, in this case a heating and cooling system.

This is the *Internet of Things* or *Pervasive Computing*. Planetary Skin, Smarter Planet and CeNSE are prominent projects in this field. The Internet is beginning to be augmented with mobile machine-to-machine (M2M) communications and ad hoc local network technologies. At the network nodes, information about objects will come from barcodes, RFIDs, and sensors. The location of very many objects will be known and the objects will interact extensively with fixed and mobile clients. Soon trillions of everyday objects will be part of our digital information environment.

A mobile phone can be thought of as a sensor. A smartphones typically includes a gyroscope, accelerometers, GPS, Wi-Fi, Bluetooth, cell, sound, light, time, near-field communications (NFC), compass, and camera. This list will soon include thermometer and gravimeter. Applications using combinations of these sensors are already providing capabilities for navigation, with indoor positioning soon to follow. A real-world example is the smartphone application that detects and transmits the location of potholes in the street, information uncovered by a phone's accelerometer. These tiny, inexpensive, geo-located, network-connected sensors are rapidly making their way into vehicles, buildings, pipes, ducts, bridges, stores, and factories.

Web-resident sensors (such as webcams) and *everyone-as-a-sensor* are not new concepts, but today's availability of open sensor communication standards greatly enhances the significance of such ideas. Network effects come into play to increase the value of sensors and the data they produce, thereby opening up countless commercially feasible possibilities for new applications.

Hundreds of billions of dollars are at stake when you add up the savings and new business that could be realized from an *Internet of Things and Places* based on a foundation of consensus-derived open location standards.

4. LBS standards landscape

The OGC today collaborates with over twenty different SDOs. These partnerships strengthen OGC standards by providing requirements and use cases. Standards developed in other SDOs benefit from OGC expertise in LBS, GIS, geospatial services, and sensor systems. In addition, many standards developed in other SDOs include elements of OGC standards, particularly the GML encoding standard.

The OGC began working on GIS-related interoperability issues in 1994 and has since tackled Earth imaging, Web Mapping, and GML. Work on Location-based standards began in 1999. This early work resulted in the development and approval of the now widely implemented Open Location Service (OLS) Core Interface standard. The first OGC LBS standards activity was titled 'OpenLS', and it resulted in an OpenLS reference architecture, information model, and core interface specifications.

No standard exists in isolation. Harmonization of how location content is modeled and encoded through the LBS standards stack is critical to ensuring interoperability, ease of implementation, and network effects.

The Location Interoperability Forum (LIF)[22] was established by mobile phone manufacturers in 1999. The goal of LIF was to offer LBS providers a standard set of interfaces that hide the different implementations of the Location Server. LIF approached location interoperability from the viewpoint of the wireless network, which at that time had no shortage of unresolved issues. The result of LIF's effort was the Mobile Location Protocol (MLP), first approved in 2002. From the text of the standard: *"The Mobile Location Protocol (MLP) is an application-level protocol for getting the position of mobile stations (mobile phones, wireless personal digital assistants, etc.) independent of the underlying network technology, i.e., independent of location derivation technology and bearer. The MLP serves as the interface between a Location Server and a LBS (LCS) Client. This specification defines the core set of operations that a Location Server should be able to perform."*

Recognizing the existence of a LBS standards stack and that the OpenLS initiative could not exist in isolation, the OGC began to participate actively in the definition of the MLP API. The primary goals for participation were: (1) to ensure that OpenLS services operated within the standards stack and specifically with the MLP; and (2) to ensure that the modeling and encoding of the location elements in the MLP were consistent with existing OGC and ISO standards.

The OGC has since enhanced the OLS standard as well as defined a range of other standards that can and have been used in LS applications. These include Open GeoSMS, Geography Markup Language, OGC sensor standards, and most recently, standards work on augmented reality applications.

In addition to the use of GML by OMA for the MLP, the following are examples of the use of GML by other standards organizations:

4.1 Internet Engineering Task Force (IETF)

From the IETF GEOPRIV Working Group Charter: *"The GEOPRIV working group is chartered to continue to develop and refine representations of location in Internet protocols, and to analyze the authorization, integrity, and privacy requirements that must be met when these representations of location are created, stored, and used."*[23]

As a result of OGC's input into GEOPRIV, a GML application schema was developed for expressing a limited set of geometry types in IETF Requests for Comments (RFCs). The IETF developed a concept known as *"location object"* with two types: civic and geodetic. The geodetic location object type is encoded using the

[22] LIF is now part of the Open Mobile Alliance (OMA)

[23] IETF GEOPRIV, https://datatracker.ietf.org/wg/geopriv/charter/

GML application schema[24] and has been incorporated in a number of Internet standards including *HTTP Enabled Location Delivery (HELD)* (RFC 5985); *LoST - A Location-to-Service Translation Protocol* (RFC 5222); and *Filtering Location Notifications in the Session Initiation Protocol (SIP)* (RFC 6447). There is now also a location extension for *Dynamic Host Configuration Protocol (DHCP) Option for Coordinate-based Location Configuration Information* (RFC 3825) that uses the same information model as GML.

4.2 US National Emergency Number Association (NENA): Next Generation 911

"NENA serves the public safety community as the only professional organization solely focused on 9-1-1 policy, technology, operations, and education issues."[25] Next Generation 9-1-1 (NG 911) is a system comprised of Databases, Data Management processes, Emergency Services IP networks, and IP-based Software Services and Applications that are interconnected with Public Safety Answering Point (PSAP) premise equipment. The system provides location-based routing to the appropriate emergency entity and uses additional data elements and business policies to augment the routing. The system delivers geodetic and/or civic location information and the call-back number.

Work by the IETF related to location-enabled standards that support a range of applications, including emergency services, has led the US NENA NG 911 to determine that GML is a preferred mechanism for sharing GIS data between PSAPs and countries.

4.3 Organization for the Advancement of Structured Information Standards (OASIS)

The OASIS Emergency Management Technical Committee approved a profile of GML (version 3.2.1) for use in OASIS EM standards such as the Emergency Data Exchange Language (EDXL[26]) and EDXL-HAVE (the Hospital AVailability Exchange), a standard which allows for the communication of a hospital's status, services and resources (including bed capacity, emergency department status, and available service coverage). A future version of CAP (Common Alerting Protocol; CAP Version 1.1 is adopted as Recommendation ITU-T X.1303[27]) is expected to use the OASIS GML Simple Features (gsf) profile.

4.4 W3C Point of Interest (PoI) Collaboration

The mission of the Points of Interest Working Group is *"to develop technical specifications for the representation of "Points of Interest" information on the Web."*

The current public draft utilizes the OGC/ISO geometry model and states that GML is the preferred encoding language for PoI location elements.[28] Based on the W3C work, the OGC has formed a new Point of Interest standards initiative which first convened in January 2013.

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[24] OGC, http://portal.opengeospatial.org/files/?artifact_id=21630 and http://tools.ietf.org/html/rfc4119

[25] U.S. NENA, http://www.nena.org/

[26] OASIS, http://www.oasis-open.org/apps/org/workgroup/emergency-gis/download.php/42737/edxl-gsf-v1.0-wd07.odt

[27] ITU-T, http://itu.int/ITU-T/X.1303

[28] W3C, http://www.w3.org/2010/POI/documents/Core/core-20111216.html

4.5 ITU Telecommunication Standardization Sector (ITU-T)

The OGC is collaborating with ITU-T Study Group 11 (Signalling requirements, protocols and test specifications) toward formalizing Open GeoSMS as an international standard (ITU-T Recommendation). Under the working name, Q.ProGeoSMS[29] (Protocol for Open GeoSMS), Study Group 11 is progressing Open GeoSMS through ITU-T's consensus-based approval process, with development efforts on course to achieving the goal of approval as an ITU-T Recommendation before the close of 2013. Open GeoSMS (described in detail in Section 5.1) is a standard that uses Short Message Service (SMS) to exchange location-based information; it is valuable in providing relief to individuals affected by natural disasters.

Location is particularly relevant to ITU-T standardization work on the Internet of Things (IoT), Web of Things, and Ubiquitous Sensor Network (USN). Location is also of integral importance to Machine to Machine (M2M) communications which is being tackled by the ITU-T Focus Group on M2M Service Layer (FG M2M). FG M2M is studying M2M APIs and protocols to support M2M services and applications, and the final product of the group's research will form the basis of future ITU-T standardization work in this arena.

The ITU-T Joint Coordination Activity on Internet of Things (JCA-IoT) is a key forum for standards organizations on topics related to the Internet of Things (IoT). The OGC, alongside many other relevant forums, SDOs and international bodies, has contributed to the JCA-IoT Roadmap[30] and is coordinating its IoT work with that of ITU-T through the OGC *"Sensor Web for IoT"* SWG.[31] The OGC is a member of ITU-T and works with the various ITU-T Study Groups responsible for developing IoT-related standards. In addition, OGC is considering participation in the Internet of Things Global Standards Initiative (IoT-GSI[32]).

IoT work in ITU-T is led by ITU-T Study Groups 11 (Signalling requirements, protocols and test specifications) and 16 (multimedia coding, systems and applications), with central roles also being played by ITU-T Study Groups 2 (Operational aspects of service provision and telecommunications management), 3 (Economic and policy issues), 9 (Broadband cable and TV), 13 (Future networks including mobile and NGN), and 17 (Security).

[29] ITU-T, http://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=9659

[30] ITU-T, http://www.itu.int/en/ITU-T/jca/iot/

[31] OGC, http://www.opengeospatial.org/projects/groups/sweiotswg

[32] ITU-T, http://www.itu.int/en/ITU-T/gsi/iot/

5. Current OGC activities related to LBS

The OGC has a long history of developing standards that enable interoperable access to geospatial services, the sharing of location-enabled content, and the integration of geospatial and LBS content into enterprise architectures. Many other ICT standards organizations encounter requirements to provide location encodings or interfaces. The OGC works with these organizations to help them avoid *reinventing the wheel* and to avert the risks associated with disjointed standardization efforts.

5.1 Open GeoSMS

OpenLS provides a standard set of service interfaces that are typically implemented as part of the back-end servers used to implement a LBS framework. As such, the end user need never see nor even be aware of the standards being used. Furthermore, the OpenLS interfaces, while not complex, are not necessarily lightweight. The OGC thus began considering much more lightweight, consumer-facing location service standards in 2009.

The Industrial Technology Research Institute (ITRI)[33] contributed its Open GeoSMS specification to the OGC in 2009. Open GeoSMS facilitates the communication of location content in Short Message Service (SMS) transmissions. SMS is a feature in every mobile phone; all mobile phones therefore have the potential to communicate location information in a standard way.

The lightweight and easy-to-implement standard facilitates location interoperability between mobile applications and the rapidly expanding world of geospatial applications and services that implement OGC standard interfaces, encodings and best practices.

GeoSMS-enabled software is available for Android and used by Sahana and Ushahidi. It provides for communication between victims and rescue teams and sends location updates to Sahana for relief and rescue coordination. Another application, developed by GeoThings[34], enables users to share their location (e.g., during/after a disaster) on Facebook or Twitter with an SMS in Open GeoSMS format.

5.2 Augmented Reality (AR)

AR allows the user to see the real world with virtual objects superimposed upon or composited with the real world. The many potential application domains for AR include medical, manufacturing, visualization, path planning, entertainment, and military.[35]

AR applications have recently emerged in mobile devices equipped with sensors for orientation and location (iPhones, Android devices, etc.). *"In fact, location based services (LBS) — used with smartphones and other types of mobile technology — are a major driving force behind AR's entering the mainstream."*[36]

The AR industry's growth will clearly depend on the availability of standards and standards profiles tailored to AR. While extending existing standards will be highly beneficial to achieving the ultimate objectives of the AR community, there must also be room for the inclusion of new ideas and evolving technologies.

In 2010 the OGC became an active participant in an International Augmented Reality Standards Coordination group.[37] The goal of this group is to avoid duplication of standards efforts as well as to enable

[33] ITRI, http://www.itri.org.tw/eng/

[34] GeoThings, http://geothings.tw/post/35189456432/find-me-maybe

[35] Ronald T. Azuma: "A Survey of Augmented Reality," Hughes Research Laboratories, Presence: Teleoperators and Virtual Environments 6, 4 (August 1997), 355-385. http://www.cs.unc.edu/~azuma/ARpresence.pdf

[36] Steven J. Vaughan-Nichols: "Augmented Reality: No Longer a Novelty?", IEEE Computer, December 2009. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5353455

[37] AR Standards Coordination Group, http://www.perey.com/ARStandards/

dialogue among and between the various SDOs addressing standards requirements for different portions of the AR standards track. These standards coordination meetings allow all players to discuss requirements and use cases and to establish focused working groups that address specific AR standards issues. This approach harnesses specialized expertise but also ensures a unified approach to standards development in the broader AR community.

The OGC has a focused AR standards development activity known as *"ARML, Augmented Reality Markup Language."* ARML 2.0 provides an interchange format for AR applications to describe and interact with objects in an AR scene, focusing on mobile, vision-based AR. The candidate standard describes the virtual objects placed into an AR scene as well as the registration of the virtual objects in the real world, allowing interaction with and dynamic modification of the AR scene using ECMAScript[38] bindings. ARML 2.0 is on track to be approved by mid-2013.

5.3 IndoorGML[39]

Indoor LBS is a very hot topic. Beyond the issue of locating a mobile device in an indoor environment, the indoor environment is host to a complex set of standardization challenges, such as how navigation directions are supplied (take the elevator to the 3rd floor and turn right); semantics (my first floor is not your first floor); special zones (heating, security, Wi-Fi, etc.); and the lack of a standard for modeling and encoding floor plans. In addition, outdoor navigation tends to be 2D whereas indoor navigation must necessarily be 3D.

The OGC work on indoor LBS started with the discussion paper, *"Requirements and Space-Event Modeling for Indoor Navigation."*[40] The objective for IndoorGML is to represent and exchange the geo-information required to build and operate indoor navigation systems. IndoorGML will provide the essential model and data for applications such as building evacuation, disaster management, personal indoor navigation, indoor robot navigation, indoor spatial awareness, indoor location-based services, and support for the tracking of people and goods. IndoorGML also provides a framework for the flexible integration of different localization technologies, allowing the ad hoc selection of the appropriate navigation data according to the capabilities of the mobile device and the offered localization technologies of a building.

5.4 Sensor Interface for Internet of Things

Recognizing the growing importance of the IoT, the OGC hosted a special meeting on OGC Sensor Web Enablement (SWE)[41] and IoT standardization in order to discuss requirements for geospatial and location-based standards for the IoT.[42]

In 2001 the OGC took on the task of standardizing sensor communication because every sensor has a location, whether in situ (such as a rain gauge) or remote (such as an Earth imaging device), and the location of a sensor is highly significant for many applications. The resulting suite of SWE standards – now being implemented worldwide – enables developers to make all types of networked sensors, transducers and sensor-data repositories discoverable, accessible and useable via the Web or other networks.

These meetings and discussions resulted in an SWG for a *"Sensor Interface for IoT/WoT".* The scope of work for this SWG is to develop a candidate standard for access to sensors in an IoT/WoT environment.

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[38] Wikipedia, http://en.wikipedia.org/wiki/ECMAScript

[39] OGC, https://portal.opengeospatial.org/files/?artifact_id=47562

[40] OGC, http://portal.opengeospatial.org/files/?artifact_id=41727

[41] OGC, http://www.opengeospatial.org/domain/swe

[42] OGC, http://www.ogcnetwork.net/IoT

6. Overcoming the obstacles to LBS standardization

Hundreds of social location apps connect people and places in scores of unique ways, but the *where* information generated by different apps and platforms seldom connect. Location interoperability faces a number of challenges:

The Consumer: Consumers want technologies to deliver all advertised benefits and they value offerings that expand their connectivity options. Users of consumer technologies need not have any knowledge of open standards in order to understand the appeal of a location app that works with any other location app and so prevents them from being locked into a wireless carrier, social-networking service provider, or cell phone or tablet provider. The situation is similar for enterprise customers with CIOs facing constraints imposed by rigid proprietary legacy enterprise information systems.

If they knew it was possible, consumers would demand an *Internet of Things and Places* that works as smoothly as the Internet and Web, which are based on open standards such as TCP/IP, HTTP, HTML and XML. Consumers vote with their dollars, but interoperability is a feature that no single vendor can sell them.

Location app developers: Location app developers would welcome open standards that make it easy to write an app for any user on the open Web. Currently, open standards exist for getting location coordinates and transferring location data to maps and Earth images: Google Maps Javascript API for Android, Apple's iOS SDK API for the iPhone, and similar (usually *"open but proprietary"*) APIs available for social networking sites. Ideally, non-proprietary open standards could let you write code once, for all devices.

Digital marketers: Advertisers see terrific potential in connecting people and places with point-of-sale information, but hyper-competition among their partners providing the locations and delivering the ads to customers creates frustrating obstacles to location advertisers' operations and growth.

Others, too, would benefit from a better LBS standards framework:

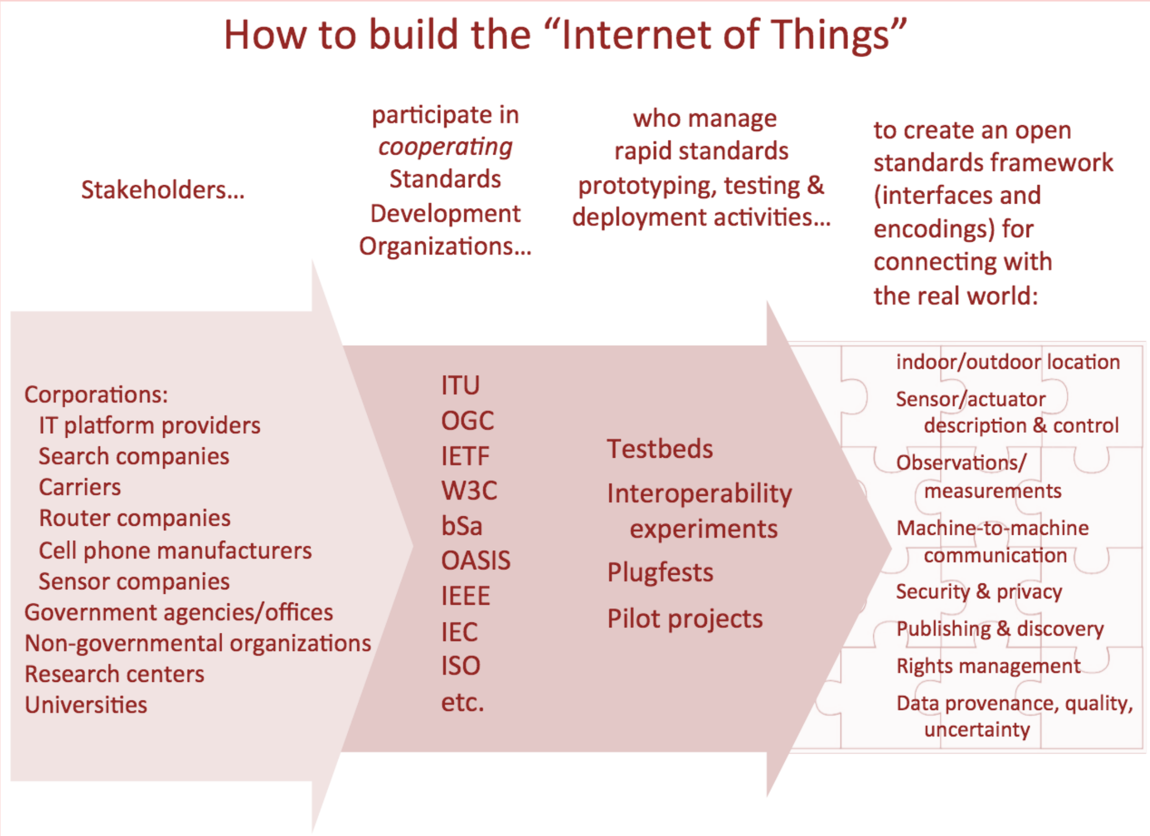
- Firefighters want to have floor plans and knowledge of hazardous materials before they enter a burning building.
- Disaster managers want all possible location information when disasters strike.
- Smart Grid actors – human, digital and mechanical (think e-vehicles) – need to be able to communicate regarding the indoor and outdoor locations of electrical equipment and phenomena that affect the power grid.

Standardization: Concerted SDO participation is the only means through which to overcome such obstacles. Governments across the world impose mandatory compliance with certain standards and they sometimes fund standards' development, but it is very unusual for governments to fund the SDO coordination efforts that are becoming so urgent for spatial communication. SDOs may sign agreements to cooperate but this in itself is not sufficient as most SDOs are membership organizations that do not have business models permitting them to pay the experts that develop and harmonize their standards. The participation of standardization experts in the working groups of SDOs is therefore funded by these experts' industry, academic or government employers.

Key stakeholders would reap great benefits by agreeing to share the costs of building the necessary standards infrastructure, including the costs associated with cross-representation in the expert groups of a variety of SDOs.

SDO coordination is becoming crucial as domains such as LBS, Smart Grid, Internet of Things and Augmented Reality grow beyond the original narrow bounds of research projects and proprietary solutions. The Internet is a global network, and ICT commerce is becoming an ever-more global market. Global ICT markets stimulate investment and innovation when appropriate international standards are in place as interoperable new products or services quickly find large numbers of buyers. An efficient LBS standards framework will usher in tremendous social, economic and environmental benefits and in the next phase of standards development the emphasis will remain on enhancing cooperation between SDOs as well as with governments, industry and academia.

Figure 7: Roadmap for building the LBS standards framework (Figure from OGC's article in the April 2011 issue of LBx Journal)



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