Indoor Location-Based Services

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The development of location-based services (LBS) initially focused on outdoor use. However, it is estimated that North Americans spend 90% of their time indoors (Figure 1). That fact implies the additional task of developing LBS for indoor coverage. Since LBS targets the users of modern wireless devices, such as smartphones with Global Positioning System (GPS), the main difference between outdoor and indoor use is the lack of a feasible GPS satellite signal. Since some applications require high precision, the Assisted GPS (A-GPS) alternative could also be too inaccurate (and too costly) for such purposes, when in a densely populated area with numerous points of interest (POI). From the perspective of usage, it is also possible to include some outdoor topologies (such as the so-called "urban jungle" – narrow streets between high skyscrapers) to be considered as indoor, and therefore supported by Wireless Local Area Network (WLAN), rather than A-GPS.

The particular attractiveness of indoor LBS usage is related to frequently visited public locations (transportation nodes, exhibition galleries, shopping centers, medical institutions, sports facilities etc.), where people could benefit from utilizing the contents and services on their devices, and

related to the specific floor plan (provided within the application) of such an "intelligent building." The technology used to achieve this goal could be based on IEEE 802.11 WLAN, optionally combined with Radio-Frequency Identification (RFID) or Near Field Communication (NFC). Since the latest generation of various smartphones will soon be (or is intended to be) equipped with RFID- or NFC-compatible devices and usually also contains a WLAN adapter, it is feasible to extend the use of smartphones to the various indoor scenarios.

Although this article is oriented toward smartphones (with mobile users) as WLAN-enabled resources, other targets (objects with RFID, NFC, or Bluetooth enabled) could participate in this location-aware infrastructure, providing information about their location and sending it to the network, which might be of interest to mobile users who search for these objects.

FIGURE 1: Indoor LBS in practice – displaying places of interest related to the user's current location (SOURCE: THE NEW YORK TIMES)

Applications of Indoor Location-Based Services

Indoor LBS is currently in an emerging phase with promising perspectives. Numerous indoor LBS-based applications could create intelligent environments (Figure 2).

With regard to the different revenue generators, some of the applications are identical extensions of outdoor use for unreachable indoor areas – particularly gaming, leisure and management functionalities. In these cases, integration between outdoor and indoor location recognition is required, where both methods would report the user's position to the same LBS server within the Service Provider's (SP) network. The same gaming services would be provided based on the user's current location, whether at home, in a waiting room, at a transportation facility etc. – but also in a park or at the seaside. It is possible to create alerts similar to those used to report the proximity of another recognized user, identified as a friend. For management purposes, another protection option in addition to the password would be to limit access to the network or a particular service based on location under a particular access point (AP). Further, the indoor LBS could be integrated with the Customer Relationship Management (CRM) system, offering improved corporate applications with additional information.

A communication benefit of indoor LBS can be noted in the Cisco location-based Call Admission Control (CAC) for an enterprise voice solution. In the Session Initiation Protocol (SIP) and H.323 protocols is a proprietary Information Element (IE) containing the location information, transmitted through the Intercluster Trunk (ICT) between different locations that have the voice design with Cisco Unified Communications Manager (CUCM). The location-based CAC will prevent the use of the ICT if destination and source are under the same location, and will hairpin the call back from the ICT to the same location, preserving the bandwidth.

FIGURE 2: Possible indoor LBS applications

Another application of indoor LBS is in the **retail** industry. When the user enters a shopping center covered with a mesh of WLAN access points (AP), he might need to use an application showing his location on the floor plan (Figure 3), and any available stores (especially those where the user is participating in a loyalty program), or only the targeted (searched) shop. The indoor positioning could be done by several methods: Cisco Radio Frequency (RF) fingerprinting, AP triangulation or Received Signal Strength (RSS) lateration.

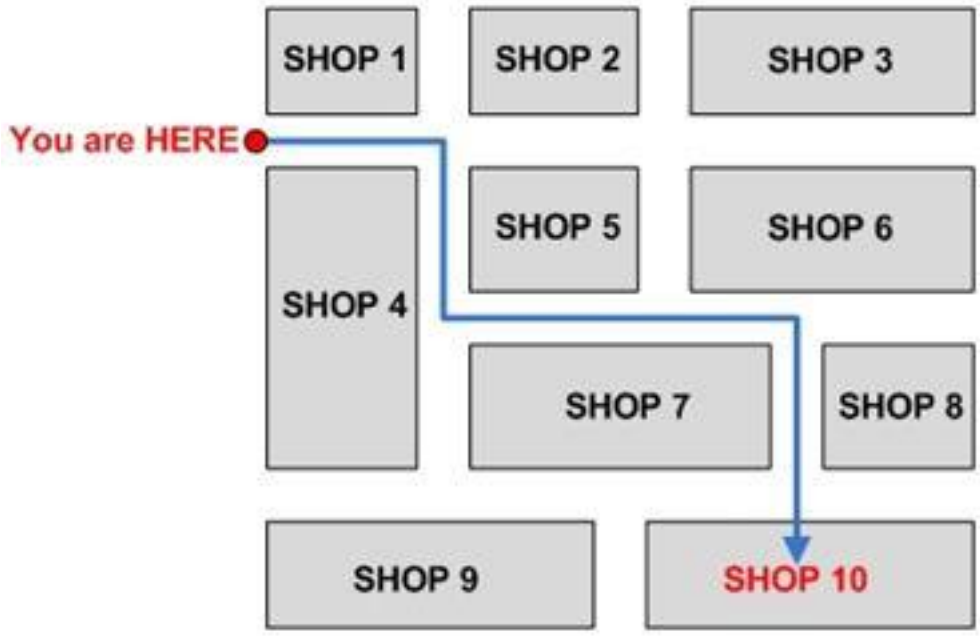

FIGURE 3: Retail application – floor plan used to find the searched shop and determine the route from the user's location

Once the user finds a desired store, another application can be implemented by using a cheap miniature passive RFID tag. When RFID is integrated – for example, into Cisco Unified Wireless Network (UWN) architecture – it is possible to find RFID-tagged products on a specific shelf within a store. Product descriptions, price reductions, and product availability could also be displayed with the location of the product within the store. In the future, such an application might even be extended into the "intelligent home," with purchased RFID-tagged products being remotely counted within the home refrigerator or pantry, and the smartphone displaying an alert indicating the absence of any favorite products.

In **education** services, indoor LBS finds its place in classroom-related multimedia content that might be displayed on the application screen of the user's WLAN device, depending on his location (biology classroom, math, geography and so on).

Advertising is probably the most profitable application for the near future of LBS generally (outdoor or indoor). Imagine this possible use: the potential customer steps through the entrance of a shopping mall, and promptly his smartphone receives welcome promotion offers with available

discounts. Walking by some of the shops, the customer receives alerts describing particular opportunities at those locations.

For **emergency** calling, the benefit introduced by this technology is the indoor localizing of the caller with high precision. Consequently the nearest resources might be engaged and quick appropriate action taken.

When using indoor **navigation**, a user (Figure 4) could drive into a large parking structure and check the availability of free space with the routing hint on his phone application. A traveler at an airport (or any other traffic node) could find indoor directions together with the supplied information (Figure 5).

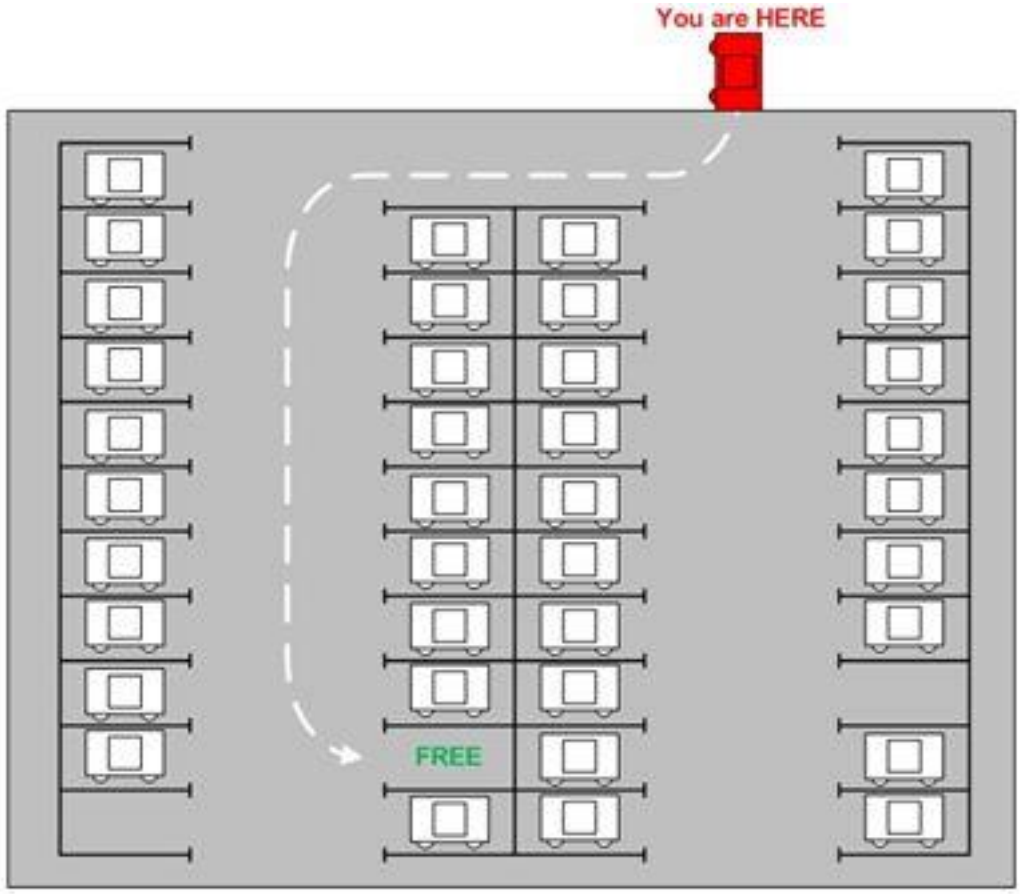

FIGURE 4: Indoor LBS routing a driver to free space in the parking structure

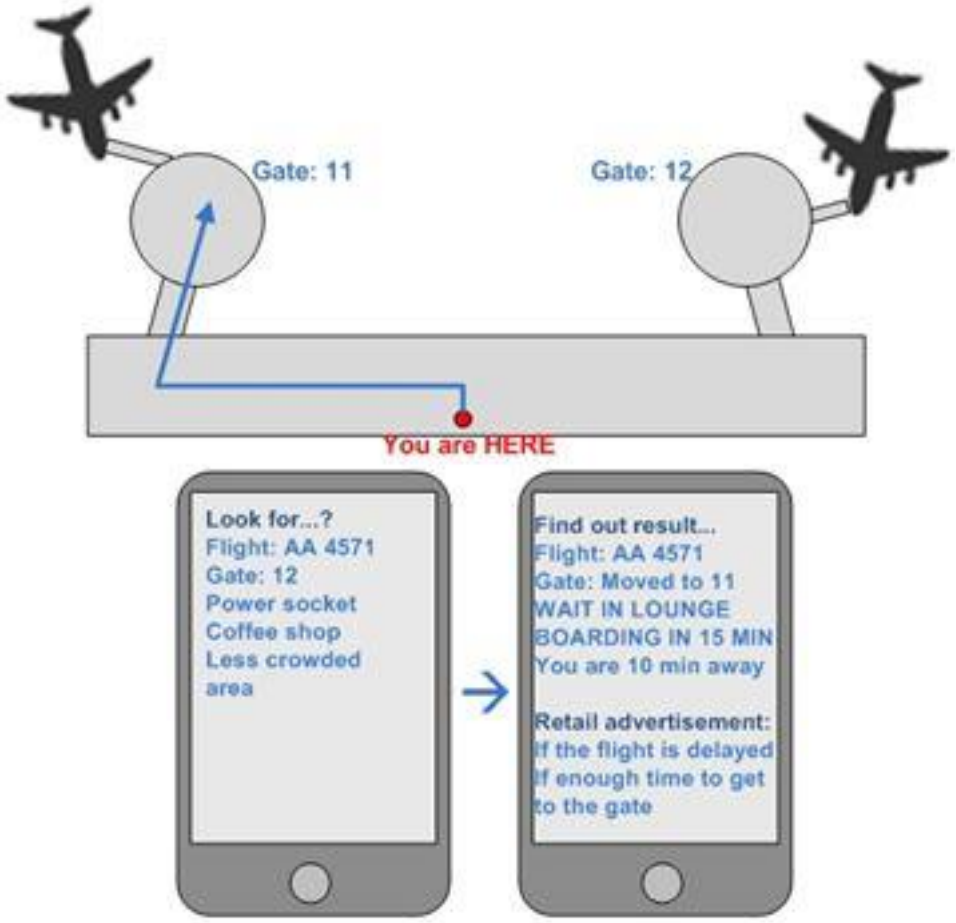

FIGURE 5: Example of indoor LBS routing a user to the airport gate

The information application provides for a wide set of different useful guides to frequently visited public places. It is possible to determine the user's location and give additional information related to nearby facilities based on that location. In medical institutions, relevant information might describe the hospital departments. In government buildings, descriptions of the available services, working hours, documents needed/issued etc. could be presented. Museums and galleries have the opportunity to present their collections with location-based multimedia content describing their exhibits. In addition to the search option previously mentioned for retail applications, it's possible to offer a guide related to the shopping center. Sports or leisure facilities might use the same concept, offering informational guides to the user.

In addition to locating objects, indoor tracking can be used for people (friends, children, mentally handicapped individuals, and so forth). For example, hospitals might track a patient, integrating his location with his

medical record. This usage is especially interesting when targeted persons enter a larger group of people.

For application to objects, a better option would be using RFID tags. Commercial systems are currently available that combine active RFID real-time location systems (RTLS) with GPS, presenting a complete solution for indoor or outdoor tracking of objects such as containers on cargo vessels.

Indoor Location-Based Services Architecture

This article focuses on localization methods based on the 802.11 standard and RFIDs. Widely deployed enterprise and SP-owned WLAN networks already exist for determining the location of user equipment. By integrating location tracking, these deployed WLANs gain additional corporate value.

Location tracking and positioning systems can be categorized based on the different techniques used for measurement and estimation of the mobile device's location (localization). There are several WLAN-positioning software products. The following list describes the Cisco techniques that could be implemented:

- **Cell of origin** (Figure 6) – the simplest way to determine the originating position (in 802.11, the *associated access point*), but this method could be inaccurate if the mobile device is not associated to the nearest AP. For greater accuracy, this system could be combined with the Received Signal Strength Indicator (RSSI).
- **Distance** or lateration (Figure 7) uses two measurements:
  - Time of Arrival (ToA) – with the emitting mobile device synchronized, ToA indicates the measured signal's traveling time, which determines the distance to the target (velocity multiplied by time); three neighboring APs create a triangulation to determine the location.
  - Time Difference of Arrival (TDoA) – if the emitting mobile device is not synchronized, relative time is measured between several receiving devices that are synchronized with each other and detect the same signal in different locations. Three neighboring APs create a hyperbolic tri-lateration.

- **Angle** or angulation (Figure 8) – Angle of Arrival (AoA) is a technique that determines the angle of incidence of the received signal from the mobile station. When two APs that send signals are compared, it is possible to determine the originating location.
- **Location patterning** or pattern recognition – this software-implemented technique samples and records radio signal pattern; each potential device location has a unique RF signature (mostly based on RSSI):
    - Calibration phase – data collection of the multiple AP sensors by moving around the targeted mobile device across an area represented as a grid.
    - Operation phase – a group of receiving AP sensors provide signal-strength measurements related to the targeted mobile device.

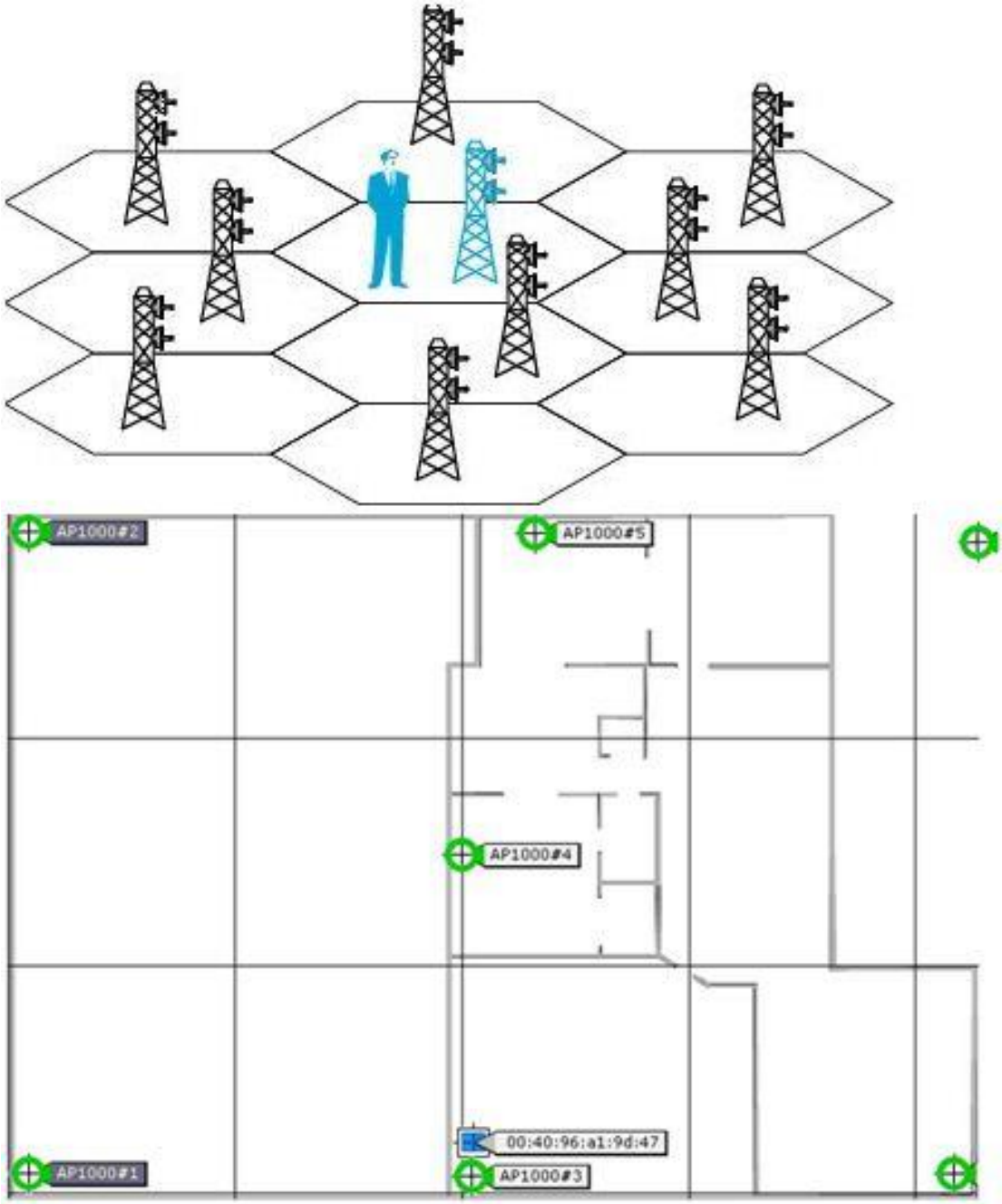

FIGURE 6 : Cell of origin and Received Signal Strength Indicators (RSSI) (SOURCE: CISCO)

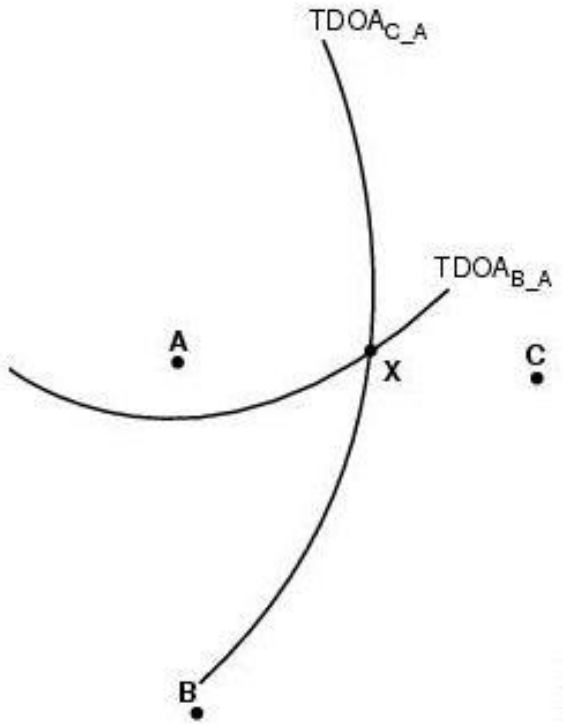

FIGURE 7 : Time Difference of Arrival (TDoA) – relative time of arrival of the emitted signal between the neighboring access points (SOURCE: CISCO)

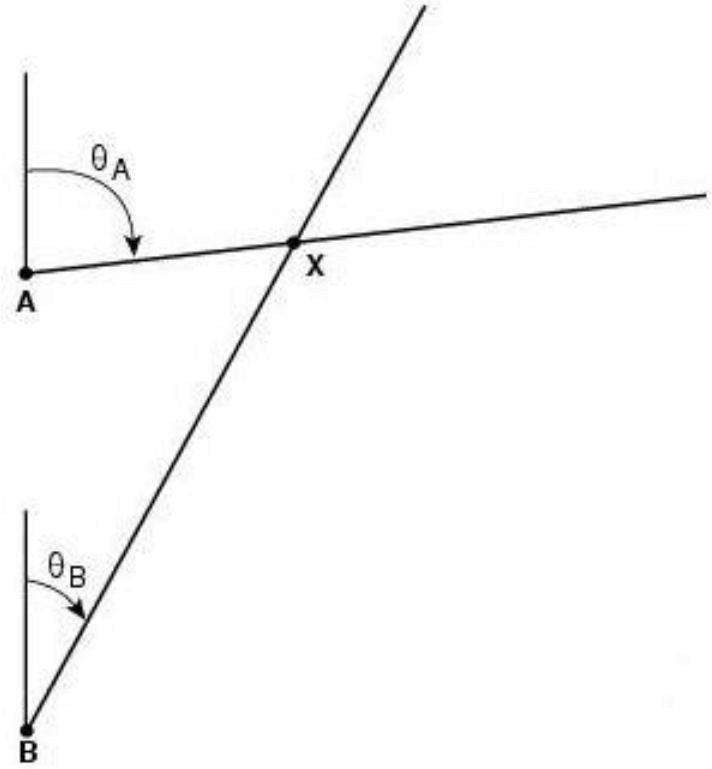

FIGURE 8 : Angle of Arrival (AoA) (SOURCE: CISCO)

Indoor LBS Based on Radio-Frequency Identification (RFID)

Indoor LBS could be optimally combined with another International Organization for Standardization (ISO) standardized invention – RFID technology. The information location obtained from RFID, combined with the previously described location-tracking information, opens new technological scenarios. One possible scenario for indoor location-based applications is in retail and tracking services. RFID could be used to describe, track and identify products, objects (car, computer, cell phone) and people (instead of using security badges). RFID is more efficient than barcodes, as there's no need for optical visibility – just sufficient range. Compared to Bluetooth, it's simpler, and it works on the reader-antenna principle, what makes it wider applicable.

There are active and passive RFID tags, with most of the currently produced RFID tags being passive (Figure 9 shows a comparison). These tags are cheap (starting around $0.05 up to $5) miniature microcircuits with antenna. They're called *passive* because they have no power source; they get induced voltage from the interrogator. (Figure 10 shows a passive RFID tag and a tag reader.)

Active RFID tags contain a battery. This type of tag has a longer life, holds more information and is “always-on.” However, the size and the price (starting around $50 up to $100) are much higher than the passive tags.

	Active RFID	Passive RFID
Tag Power Source	Internal to tag	Energy transferred from the reader via RF
Tag Battery	Yes	No
Availability of Tag Power	Continuous	Only within field of reader
Required Signal Strength from Reader to Tag	Very Low	Very High (must power the tag)
Available Signal Strength from Tag to Reader	High	Very Low

	Active RFID	Passive RFID
Communication Range	Long range (100m or more)	Short or very short range (3m or less)
Sensor Capability	Ability to continuously monitor and record sensor input; date/time stamp for sensor events	Ability to read and transfer sensor values only when tag is powered by reader; no date/time stamp
Data Storage	Large read/write data storage (128KB) with sophisticated data search and access capabilities available	Small read/write data storage (e.g. 128 bytes)

FIGURE 9: Comparison of active and passive RFID tags (SOURCE: CISCO)

FIGURE 10: RFID readers and passive RFID tags (SOURCE: CISCO)

Figure 11 shows how the location-aware Cisco Unified Wireless Network integrates the chokepoint triggers. APs transmit the information about the received signal of any WLAN client (WLAN phone, RFID tag etc.) toward the WLAN controller, and further to the Cisco Wireless Location Appliance. This application has a database that is checked against the user's reported

real-time location so that the location can be shown on the browser-based console on the map of the floor plan.

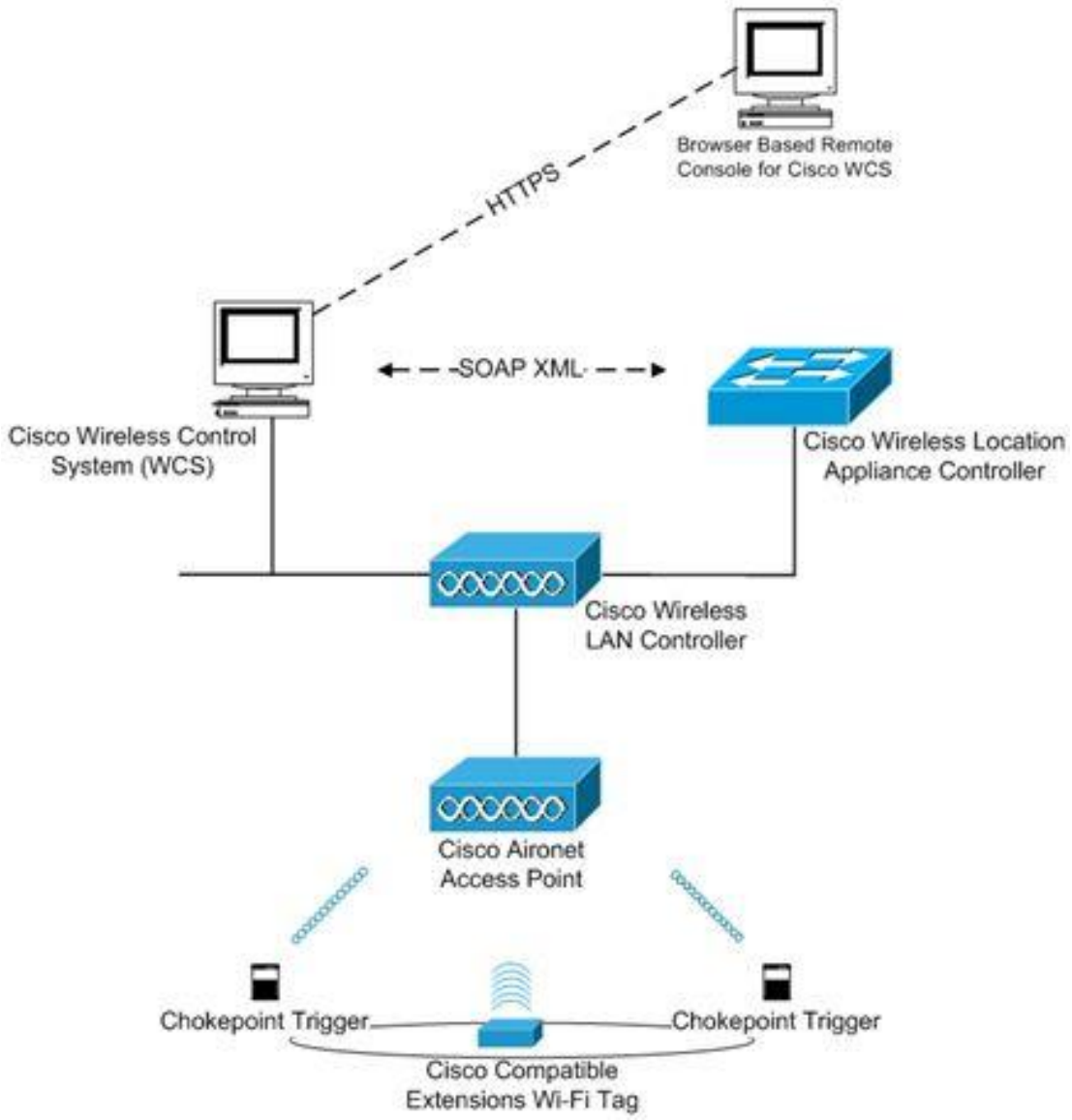

FIGURE 11: Location-aware Cisco UWN architecture (SOURCE: CISCO)

Conclusion

Indoor location-based services are ready to expand rapidly within the next two years. Figure 12 shows the current distribution of all outdoor and indoor LBS on Android phones. The revenue generator is the aggregation of the indoor user's location with the advertised content and location of the points of interest within public or commercial locations covered with the WLAN signal. Advertisers will get the opportunity to know if someone is

looking for their product/service inside a mall and will be able to attempt to influence the user's decisions on shopping sites. Therefore, a growing number of companies offer maps of malls, airports, walkways and other public places. Indoor navigation has been improved significantly and is ready to be implemented commercially. Further improvements are foreseen in the introduction of advanced technologies such as Near Field Communication (NFC), which is based on RFID. Indoor LBS might benefit from NFC to correlate directly to mobile commerce services, which promises some high-commerce exploitation. The success of the indoor LBS (and LBS generally) is an additional benefit for Service Providers (traffic, subscribers database), smartphone vendors (sold devices), users (satisfaction) and all the merchants involved (sold goods, advertised trademark).

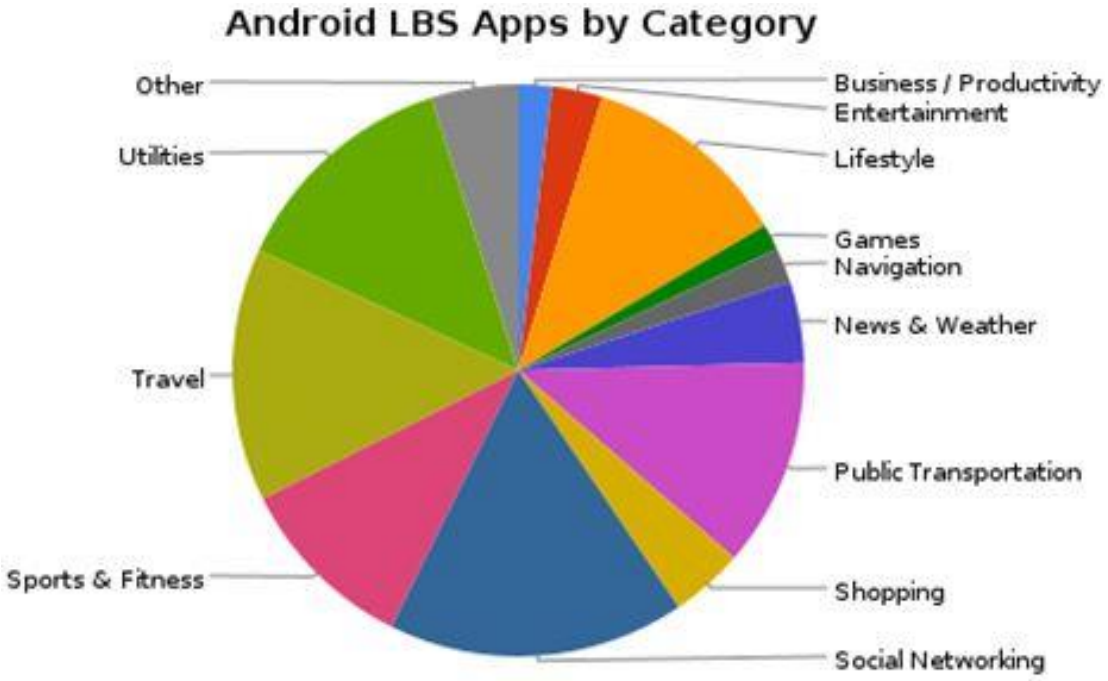

FIGURE 12: Percentage of LBS applications, for Android phones (SOURCE: SKYHOOK)

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