Evolution of Navigation Platform in Smartphones

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Qualcomm is the leader in Location Technologies

60% GNSS market share*
3B+ devices with IZat technology
>100 mobile OEMs
>80 carrier deployments

“While others are playing catch-up, Qualcomm continues to innovate, with all new Snapdragon processors supporting its new IZat location platform.”

Patrick Connolly, ABI Research

* Source: ABI Research, Sept 2013
Delivery of Seamless and Ubiquitous Location “Anywhere”

Most Precise Indoor (<5m)

Partnering to build the ecosystem for indoor location-based services

Over 1Billion Devices Shipped

Integrated & Standalone Chipsets

Indoor Location Solutions

Satellite-Based GNSS Solutions

Augmentation Technologies (Cellular, Wi-Fi, Sensors, Servers)

Industry's Broadest Portfolio

Always Available, Always-On

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Requirements for the “Best Indoor Location Experience”

Delivering a great location service is challenging

**Ubiquitous**
Works everywhere – indoors and out

**Accurate**
Best positioning performance

**Intuitive**
Works without user intervention

**Private**
Overcomes concerns about consumer privacy & security

**Optimized Power**
Long lasting battery

**Universal**
Meets global industry standards and operator requirements

**Scalable**
Supported by major devices, OSes, and applications
Why indoor LBS have been slow to reach mass market

- Lack of **universal, cross-platform** solution
- Use cases and **monetization models** are still being defined
- **No standards** exist for storing, managing and viewing indoor data
- Venues perpetually searching for a **silver bullet** that serves all customers and all use cases
- **Confusion** caused by small(er) companies pitching one-off platforms and technologies to venues
- Lack of solutions that tie to **backend systems** at venues
- **Privacy and data ownership** issues are still a major concern for venues, operators, developers, etc.
Applications

Device Orientation
E-compass

Navigation
Retail Analytics

Ambient Intelligence
Personal Analytics
Fitness
Elderly Monitoring

Store hours?

How do I get there?

How long do people linger here?

Have my friends arrived?

What’s on sale?
Indoor Location Technologies

- Wi-Fi
- Bluetooth
- BLE
- iBeacon
- Hybrid
- Active
- Magnetic-field
- NFC
- LED
- UWB
- RFID
- Passive
- Handset-based
- Infrastructure-based
- Audio
Technical Evolutions

Technologies

- Outdoors
  - More GNSS constellations
- Indoors
  - WiFi (2.4 and 5GHz)
  - iBeacon support
  - Pedestrian Dead Reckoning
  - Mag field
  - VLC
- Emerging
  - Collaborative Positioning
    - LTE direct (or LTE ProSe)
    - DSRC based Vehicle-Pedestrian Collision Avoidance
  - Visual Perception
  - Probabilistic Positioning Algorithms

Challenges Across Technologies

- Map procurement
  - Emergence of Unreferenced Crowdsourcing for RF radiomap
- Power Consumption, Always ON
- Sensor Fusion
Comparison of Indoor Location Technologies

Location Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Indoor Accuracy</th>
<th>Ambient Intelligence</th>
</tr>
</thead>
<tbody>
<tr>
<td>• GNSS (concurrent) • BLE/iBeacon • Wi-Fi (RTT)</td>
<td>• Sub 5m • limited coverage</td>
<td>• First indoor maps • Google launches project Tango</td>
</tr>
<tr>
<td>• Sensor Fusion • Always-on location • Magnetic-Field • LTE</td>
<td>• Sub-3m • Filling in the gaps</td>
<td>New proprietary ambient intelligence services emerge • Augmented Reality re-emerges • Mobile Payments</td>
</tr>
<tr>
<td>• BLE 2.0 • Wi-Fi 2.0 • Smallcells</td>
<td>• Sub Meter • Next generation of technology</td>
<td>• Significant ramp in indoor maps and services • Wearables more predominant. • Location networking</td>
</tr>
<tr>
<td>• LED • Audio • LTE-Direct • Indoor GPS • Data-fusion</td>
<td>• Sub-meter everywhere</td>
<td>• IoE begins to take effect • AmI APIs as standard • Proximity based information exchange</td>
</tr>
</tbody>
</table>

Source: ABI

2014 2015 2016 2017
Handset-Based Vs Infrastructure-Based

Handset-Based

- Pro
  - Low-cost
  - Hybrid technology
  - Large number of providers
- Con
  - iOS Wi-Fi APIs blocked
  - Regular Updates

Handset-Based

- Pro
  - Leverage existing infra and relationship
  - Control rests with retailer
  - Large number of providers
- Con
  - Privacy
  - High Cost

Source: ABI
Wi-Fi – Pros and Cons

- **Strengths**
  - Large retail penetration
  - High level of competition
  - High smartphone penetration
  - Has potential to support advertising, push notification, where no cellular coverage.

- **Weaknesses**
  - Apple Wi-Fi APIs remained closed.
  - Google potentially owns handset-based market
  - Accuracy/cost specs and reality vary
  - Not standardised. May be difficult to work across different implementations and infrastructure

- **Threats**
  - AP providers slow to support low-cost solutions
  - BLE has stolen the headlines

- **Verdict**
  - Still a fundamental anchor technology
  - Wi-Fi evolutions coming
Bluetooth – Pros and Cons

**Strengths**
- High handset penetration
- Fully passive implementation for analytics
- Standardization - scalability and price
- High accuracy
- Huge potential for vertical-specific application

**Weaknesses**
- Full infrastructure installation required.
- Only proximity, not location-based (No in-store navigation)
- Device must be “Active” - limits penetration to 25-30%.
- Unsuitable for advertising today
- Short-term kinks in iBeacon standard

**BLE/iBeacons:**
- Qualcomm Retail
- ilinside (previously WirelessWERX)
- BestFit
- Estimote
- Zebra Technology (Zatar IoE platform)
- Data Display Inc. (integrated into digital pricing labels)
- shopkick (American Apparel rollout)
- GPSHopper
- StickNFind
Visible Light Communications Technology

VLC enables a number of indoor positioning Use cases

- **Product Level Navigation**
  - Retailers forego 20% of revenue from shoppers not finding products
  - Higher-efficacy nav for search, shopping lists, promotions

- **Product Level Location Triggered Promotions**
  - 70% of sales are made at aisle
  - 84% of smartphone users use devices to help shop in store
  - CPG companies consider product level advertising 2.5x more valuable than store level

- **Product Level Analytics**
  - More accurate location & navigation heat maps
  - Orientation data opens new dimension of analytics

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a 20% of total US retail market = $4.7b; 20% of Luminiscat target market = $1.7b
b Source: Aisle411
c Source: POPAI Consumer Buying Habits Study
VLC – Pros and Cons

**Pros**
- Zero Cost for Infrastructure (LED revolution underway)
- Ubiquitous sub-meter accuracy
- Tight integration with iBeacons, Sensors Fusion, etc.
- Huge potential for vertical-specific application

**Cons**
- Accurate location of LED lights
- Modulation techniques
- Provisioning and Deployment
- Smartphone camera orientation
Beacon Location or RF fingerprinting

Knowledge of and access to accurate beacon information is critical

- **A-priori knowledge**
  - From Venue Owners
  - Very diffused or information not available
  - Not always accurate
  - Operator mistakes

- **War driving/War walking**
  - Tendency to have all APs aligned on the road
  - Too inaccurate
  - Limited hearability for indoor beacons

- **Systematic survey**
  - High cost
  - Ground reference
  - Turn-around time

- **Crowd-Sourcing**
  - Coverage as large as the user wanderings
  - Very fast update and very fast growth
  - Legal Aspects
  - Ground reference
  - Access to mobile measurement engine
  - Needs centralization point
RF Radiomap Collection

- Collected data
  - RF signature only or RF+Sensor
- Bootstrap
  - From another location technology
  - Building Topography
- A priori information
  - None
  - Topographic map and walkable area
- Georeferencing
- Accuracy
- Initial Collection or Maintenance

Similar situation for other fingerprinting methods (e.g. magnetic field)
Device to Device Location (D2D)

**Stand-alone and Self-organizing**
- WLAN D2D
  - (E.g. WiFi Direct, Bluetooth, NFC)

**Network Assisted or Network Controlled**
- WAN + WLAN D2D
  - (E.g. LTE + WiFi Direct)

**Network Integrated and Heterogeneous Network**
- WAN D2D
  - (E.g. 3GPP LTE D2D)

Source: Intel
Sensor Fusion

Always ON Intelligent Hub

**Sensor fusion is becoming a key differentiator:**

- E-compass: Accelerometer+Magnetometer
- Tilt Application: Accel+Gyro+Magneto
- PDR: Compass+Gyro+Accel
  - Double integral vs. biometrics bounding errors
- Geofencing
  - GNSS+WiFi+Accel
- Hybrid Location
  - WiFi+Mag field+PDR (+Cellular)

**Brings Benefits and Limitations**

- Fills gaps
- Crowd-sourced RF mapping
- 18 to 25 MIPS dedicated processing hub

More the play of large companies such as Broadcom and Qualcomm
Startup companies have algorithms, but no access to API
Thank you