

Location Awareness is Where It's At

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**“Good company in a journey makes
the way to seem the shorter”***

- Motivation
- Technology of location awareness
- Geospatial Addressing
- Geospatial Namespaces

*Izaak Walton (1593-1683), *The Complete Angler*

Motivation

- **“Situating” information**
 - **Who**
 - **What**
 - **When**
 - *Where*
 - **How**
- **“Continuous” information**
 - **Always available and appropriate to the situation**
- **“Registered” information**
 - **Overlay the virtual atop the physical**

Technology of Location Awareness

- **Global Positioning System (GPS)**
- **Inertial Measurement Unit (IMU)**
- **Infrared beacons**
- **Radio Frequency Identifier (RFID)**
- **Localizers**

Global Positioning System

- **“Plain” civilian GPS**
 - Horizontal accuracy of ± 100 m
 - Vertical accuracy of ± 150 m
- **Differential GPS**
 - Horizontal accuracy of ± 2 m
 - Vertical accuracy of ± 3 m
 - Requires a differential base station within 100 km
- **Real Time Kinematic GPS**
 - Horizontal accuracy of ± 2 cm
 - Vertical accuracy of ± 3 cm
 - Requires a differential base station within 10-20 km

Global Positioning System

- **The size and price of GPS receivers is shrinking**



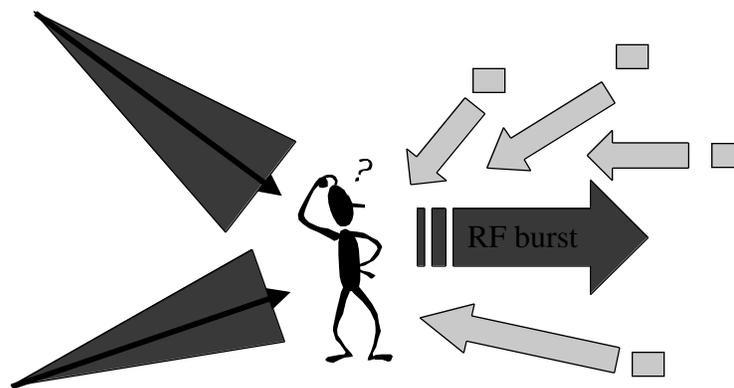
World's smallest commercial GPS receiver (www.u-blox.ch)

- **Differential GPS receivers are inexpensive (\$100-250)**
- **Differential GPS available in all coastal areas**
- **Real Time Kinematic GPS receivers are expensive**
- **GPS will not work indoors**

Inertial Measurement Unit

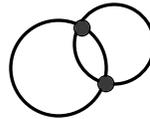
- **Magnetic compass + MEMS-based electronic pedometer + barometric altimeter + DSP**
- **Designed to work in combination with differential GPS**
 - Takes over location determination when GPS fails
 - Resynchronizes when GPS is reacquired
- **Position error of 2-5% of total distance traveled**
- **Point Research Dead Reckoning Module**
 - World's most expensive pedometer (\$2,200)
 - Compact (half-inch thick credit card)
 - Lightweight (1.5 oz = 43 g)
 - Works indoors
 - www.pointresearch.com

IR Beacons and RFID



Localizers

- Long term goal is coin-sized devices
 - Relative position with centimeter accuracy over kilometer distances
 - Low bandwidth (1-10 kbs) data communications for free
- Relies on sub-nanosecond synchronization of time signals among localizers



- Prototypes focusing on single chip implementation
 - Currently two custom chips
 - Pager-sized experimental units
 - Centimeter accuracy over 30 m
 - www.aetherwire.com

Summarizing Location Awareness

- 1 cm resolution available outdoors (differential GPS)
 - Prices dropping rapidly
- 2–3 m resolution available indoors (various means)
- Federal mandate for geolocating cellular E911 calls
- Localizers promise sub-centimeter resolution
 - VLSI implementation suitable for widespread use
 - Works well indoors
 - Easy to integrate with GPS

Centimeter resolution location awareness will be cheap and universal

The technology is there. They will come.

Geospatial Addressing

- How big an address space do we need?
 - Earth's radius is 6378 km
 - Earth's diameter is 40,075 km = 4.0075×10^9 cm
 - $2^{32} = 4,294,967,296$
- 32 bits gives a resolution of .93 cm
- <latitude, longitude, height> in an Earth-centered frame of reference
 - 96 bits is enough
 - From the center of the earth to well beyond geosynchronous orbit
 - Easily fits into an IPv6 address (128 bits)

Geospatial Addresses

- Any cubic centimeter in, on, or around the planet can be directly addressed as a triple $\langle x, y, z \rangle$
- Higher-order geospatial addresses
 - Sphere $\langle x, y, z \rangle, r$
 - 3D polygon
 - Closed polygon $\langle x_0, y_0, z_0 \rangle, \langle x_1, y_1, z_1 \rangle, \dots, \langle x_{n-1}, y_{n-1}, z_{n-1} \rangle$
 - $\langle x_0, y_0 \rangle, \langle x_1, y_1 \rangle, \dots, \langle x_{n-1}, y_{n-1} \rangle$ is a general 2D polygon
 - $z_0 = z_1 = \dots = z_{n-1}$
 - Height h
 - Set $\{g_0, g_1, \dots, g_{k-1}\}$
 - Each g_i is itself a geospatial address
 - Union of the volumes represented by g_0, g_1, \dots, g_{k-1}
 - g_i 's not necessarily contiguous

Geospatial Domain Names

- Introduce a new top-level domain “.geo”
- Subdomains represent higher-level geospatial addresses
 - $d_{k-1} \dots d_1 d_0$.geo where d_{i+1} is a subvolume of d_i
 - uci.irvine.orangecounty.ca.us.geo
- However, there are *many* ways to organize geospace
 - Street address
 - ZIP code
 - Long distance area codes
 - Thomas Guide page number and grid (732, J2)
 - Relative addressing
 - 50 yards southeast of the intersection of Main and Elm

Slicing Geospace

- Subdividing *interior* space is even worse
 - Floors and suites of office buildings
 - Dilbert cubicles
 - Equipment closets
 - “Joan’s office”
 - Relative descriptions
 - “Just down the hall from the water fountain”
 - “Above and to the right of the bookshelf”
- We employ an extremely rich vocabulary for describing interior space
- Many different kinds of maps
 - They exist for a reason
- Any single geospatial namespace is inadequate

Deconstructing Domain Name Services

- $[x]y$ means “interpret x in the context of domain y ”
 - Contact domain y
 - Ask y to interpret x
 - y returns a higher-order geospatial address
 - [J2.732]geo.thomas.com
 - [2223c.A3.el_segundo]geo.aero.org
- $[x_{k-1}]...[x_2][x_1]x_0$ means “interpret x_i $i > 0$ in the context of domain $[x_{i-1}]...[x_1][x_0]y$ ”
 - [‘north bookcase’][2223c.A3.el_segundo]geo.aero.org
- Should domain names be restricted functional programs?
 - Change the paradigm from lookup to execution

Summary

- Universal, centimeter-resolution, location-awareness is inevitable
- Location awareness makes possible entirely new computing and information services
- Geospatial addressing is an immediate and natural consequence
- Geospatial name services introduce unprecedented diversity and complexity
- Fundamental shift in name services is required
- It gets much worse
 - Think about introducing timespans