Commercial and Civil Division

Indoor Positioning Technologies for Emergency Response: Overview of Emerging and COTS Solutions

Karen L. Jones

Agenda

- Introduction
- Cellular LBS
- TV Broadcast Signals
- Ultratight Coupling (UTC)
- Other Hybrid GPS Solutions - Example
- RFID Solutions
- Range Finders (back up slides)

Introduction

- **Emergency Responders need an indoor positioning technology.**
  - GPS is not adequate
    - signals are obscured in an indoor or urban environment
    - Signal acquisition time can be long
- **Several technology areas will be reviewed including:**
  - Cellular Position Location Services
  - UTC – Ultatight Coupling
  - RF (radio frequency) propagation positioning systems
  - TV Broadcast signals
  - Hybrid GPS Solutions
  - TV Broadcast
  - Range finders – back up slides

Introduction (cont…)

- **First Responders need:**
  - Sub-meter indoor localization accuracy and 3-D location
  - Position system free from dedicated fixed infrastructure requirements
  - Light wearable device
  - Rugged – high temperatures
  - Quick Response time
  - Other:
    - Status – health, pulse, other conditions…
    - adequate battery life

Executive Summary: No Magic Bullet

- **There is no magic bullet yet.**
- **Many new promising technologies…**
- **Two kinds of precision location systems are now available**
  - GPS
  - In place site calibrated infrastructure
- **Firefighters are currently using range finders – other technologies are still in R&D and technology demonstration phase.**

Cellular LBS

THE AEROSPACE CORPORATION

Cellular LBS Technology – Lacks Position Precision

Location Technology	Indoor	Urban	Suburban	Rural	*Attributes & Performance*
U-TDOA	●	●	●	◑	***Uplink – Time Difference of Arrival*** *– low cost, works with any phone, works well in obstructed environments.* ***(< 50 m)*** ***Cingular, T-Mobile***
A-GPS	○	◑	●	●	***Assisted GPS*** *– uses modified handsets that contain a GPS receiver and a special network server to assist in location determination. Works in rural and unobstructed environments.* ***(< 30 m)*** ***Sprint. Nextel***
Cell ID	◑	◑	○	○	***Cell ID*** *– works with any phone, enhanced Cell ID provides improved accuracy over in high cell site densities* ***(200 – 500 m – depends on cell density)*** ***All carriers – often as back-up loc. determination***
AOA	◑	○	◑	◑	***Angle of Arrival*** *– works with any phone, supports sparsely populated areas, utilizes two or more antennas to allow for calculations.* ***(100 - 500m)*** ***AT&T, Verizon and Cingular – as a back-up method***
Hybrid	●	●	●	●	***Hybrid*** *– any combination of the above technologies to achieve optimal performance.*

Key:

○ Low → ● High

● Highly Suitable ◑ Adequate ○ Not Suitable

Source: The Aerospace Corporation; K. Jones

Cellular Networks – No Precision Location System Yet

- **184 million wireless subscribers in the US (Jupiter Research), and over 30% of 911 calls in the US originate from mobile phones.**
  - Public safety and a range of other applications would benefit from precise indoor positioning of cellular devices. Potential applications include indoor navigation, shopping applications, concierge services, friend finder, etc…
  - Trimble, Garmin, SiRF and Magellan – total sales around 2 million units per year. Worldwide Sales of cell phones – over half a billion per year.
- **Systems currently discussed do not seem to fit the requirements of the emergency responder.**
  - E.g. MIT Cricket WayFinder – requires ceiling beacon grid, accuracy a few inches
- **Research and Technology Demonstrations by:**
  - Leading handset manufacturers – Motorola, Ericsson, Nokia, and SnapTrack Division, Qualcomm Company. Focus will be on low power consumption, TTFF, and cost (e.g. $10 parts cost threshold)
  - Univ. of Korea - Week Signal Acquisition; Stand-Alone Indoor Navigation System by Synchronized Pseudolite Constellation,
  - Nokia Mobile Phones (Finland) – reviewing how to improve location sensitivity w GSM and UMTS Networks.
  - University of Calgary Canada – involved in a few different areas - AGPS-Equipped Cellular Mobile Phones in the Laboratory,

TV Broadcast Signals

TV Broadcast Signals: Players

- **Rosum Corporation (Mountain View, CA)**
  - Uses digital and analog signals for 2D positioning. 3D tracking is in development – using mobile reference nodes which can be set up on site.
  - Investors: Charles River Associates, Allegis Capital, and Motorola Ventures.
- **Strengths**
  - Works well in severe urban and indoor environments.
  - Low power consumption.
  - Uses existing infrastructure – TV broadcast towers.
  - Signals penetrate buildings easily, lower frequency, less multi-path.
- **Weaknesses**
  - Accuracy is low – 20-25 meters
  - Need a big antenna for a long range

Ultratight Coupling (UTC)

Aerospace Contributors: Rama Gollakota, Walter Lillo, and Steve Saks

Hybrid GPS Solutions: Sensors for Navigation

- **Non-inertial Sensors**
  - Compasses / Magnetometers
  - Pressure Sensors / Altimeters
  - Pedometers
  - Odometers
  - Chip Scale Atomic Clocks (CSAC), DARPA Micro Electro Mechanical Systems (MEMS) development
- **Inertial Sensors**
  - Inertial Measurement Units (IMUs) comprised of 3 gyros and 3 accelerometers
- **Navigation Techniques and Systems**
  - Radio (Non-GPS) Navigation
  - Dead Reckoning
  - Waypoint Navigation
  - Map Matching

Ultra Tight Coupling (UTC) : Strengths and Weaknesses

- **Overview**
  - Ultra Tight Coupling (UTC) emerged in the mid to late 90s – orginally intended as an anti-jam technology.
  - UTC is an effective way of integrating raw GPS measurements with raw IMU measurements.
  - GPS can also be “Ultra Tightly Coupled” with other positioning devices such as a clock, altimeter or pedometer.
- **Strengths**
  - UTC architecture using IMU, clock and data from all satellites (vs. just single satellite) results in improved GPS availability in an urban environment
  - Microelectromechanical Inertial Mechanics (MEMS) IMUs and clocks provide cost, size, and performance improvements.
  - Aerospace designed an asynchronous IMU interface that allows for a simple integration of IMUs from any supplier
- **Weaknesses**
  - MEMS IMU are inaccurate- drift quickly
    - Drift could be mitigated with periodic, zero-velocity updates for alignment and calibration
  - Urban environment causes GPS multi-path problem due to signal reflections

Ultratight Coupling (UTC) : Market Maturity

- **Market Maturity**
  - November 2001 – the first official government sponsored test of an UTC coupling formulaton at Eglin AFB.
  - UTC is currently in “technology demonstration” phase with the Air Force.
  - The Army is also experimenting with UTC and coupling GPS with a pedometer.
  - When will GPS UTC be in the hands of the consumer and public safety?
    - Strong motive for commercial interests to integrate inertial measurement units – for general consumer navigation, cellular location based services, and public safety.
    - GPS JPO Advanced Technology branch is working to bring UTC to the warfighter and will thereby make the technology available to the civilian community as well.
  - The combination of GPS Receivers, IMUs and adaptive processing algorithms and antennas will be the DoD GPS blueprint for the next several decades.

Ultratight Coupling: Players

- **Who are the leading researchers and competitors in this area??**
  - Air Force
    - Air Force Research Lab (AFRL)
    - Air Force Institute of Technology (AFIT)
  - Army
    - CERDEC
  - Navy
    - Naval Surface Warfare Center
    - SPAWAR Systems Center (SSC)
  - DARPA
  - The Aerospace Corporation
    - Spearheading UTC efforts on behalf of the Air Force GPS Joint Program Office (JPO)
    - Patent No. 396105 filed on September 14, 1999 and issued on Feb. 4, 2003.
    - Several other patents filed since then and a few more applications are in process

Ultratight Coupling: Players (continued)

- **Who are the leading researchers and competitors in this area??**
  - Draper Labs
    - Deep Integration (DI, Draper's version of UTC named DI)
  - L3/IEC
  - Raytheon
  - Boeing
  - Rockwell-Collins
  - Honeywell
  - Duncan B. Cox (DBC) Communications

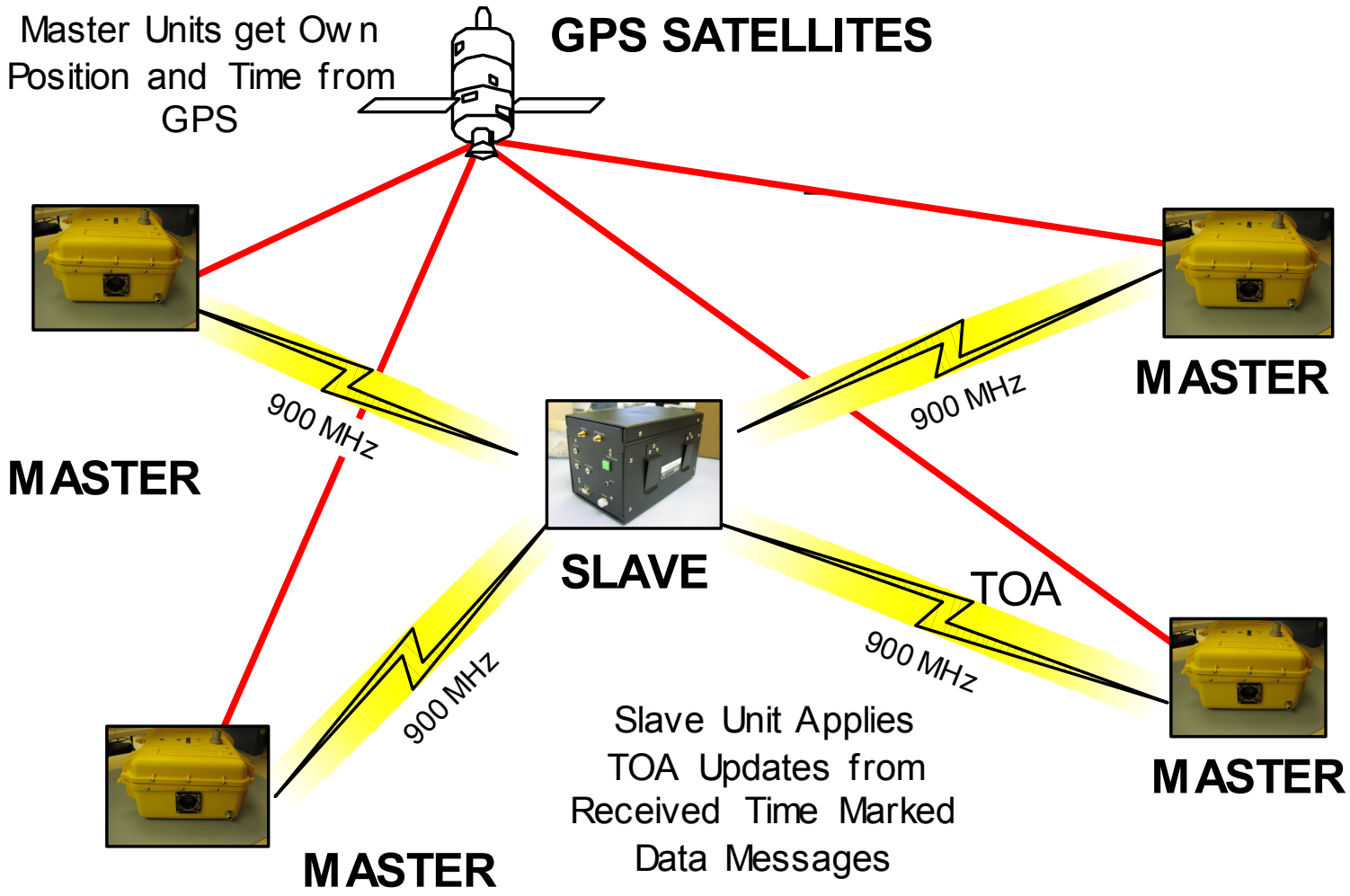
Hybrid GPS Solutions

Software Defined Radio + GPS

- **Navsys (Colorado Springs, CO)**
- **Developed POSSCOMM units to provide urban navigation solution for positioning inside buildings where the GPS signals cannot be recieved.**
- **Applies Software Defined Radio (SDR)* architecture - allows for both GPS receivers and 900 MHz transceivers to operate.**
- **For indoor positioning 4 reference nodes or "master units" operating on 900 MHz transmit TOA message to the "slave unit" which is the mobile unit which can be carried by the emergency responder. Slave units will default to GPS tracking if satellites are in view.**

** The SDR context is loosely defined since this SDR works on only two frequencies – GPS and 900 MHz.*

Software Defined Radio + GPS



Source: www.navsys.com

RFID Solutions

NIST: RFID Assisted Localization for First Responders

- **NIST "philosophy" of the RFID-assisted system involves reducing the dependence on RF links to external data sources by exploiting the capability of RFID tags to store critical building information for retrieval when it is needed, where it is needed.**
- **RFID assisted location coupled with ad-hoc wireless communication network**
- **RFID tags are fixed inside a building and the RFID reader is mobile. (Typical RFID applications are the flipside – e.g. mobile tags and fixed readers)**
- **Still in R&D phase. NIST needs to:**
  - Determine the amount and type of tags for inside buildings
  - Develop a ruggedized reader
  - Integrate reader with wireless communication
  - **http://www.antd.nist.gov/wctg/RFID/RFIDassist.htm**

Galileo and Glonass

Galileo and Glonass – plans for indoor positioning?

Galileo - Europe's own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be inter-operable with GPS and GLONASS, the two other global satellite navigation systems.

Although GNSS is capable of providing accurate location in areas where the satellite signals are available, this is unlikely to be the case inside buildings, hence, if exploited, indoor navigation is not only a promising market but also seen as an essential local area augmentation for GPS, EGNOS*, and Galileo.
(source: European Space Agency – Navigation)

11 July 2006 - The Galileo Joint Undertaking, set up by the European Commission and ESA, has issued a call for ideas relating to global navigation satellite systems research and development activities.

**** European Geostationary Navigation Overlay Service - Terrestrial Regional Augmentation Networks)***

END

- **Questions?**

- ***NOTE:*** *All trademarks, service marks, and trade names are the property of their respective owners*

BACK UP SLIDES

Note – range finders were discussed in detail during previous presentations – as a result did not cover review during this presentation.

Range Finders

Range Finder

- **RF Ranging uses time of flight information , advanced algorithm can generate a relative location of firemen. For instance, for a group of firemen in a building. If there are several members of the group that have absolute position (e.g. GPS) then absolute positions can be obtained.**
- **Weaknesses: difficult to overcome wall penetration attenuation and multi-path reflections.**
- **DARPA – Networking in the Extreme Environment (NetEx) –**
  - will create a wireless networking technology for the military user that enables robust connectivity in harsh environments and integrate into emerging sensor and communication systems.
  - will develop an improved physical layer for networked communications by adapting the unique properties of a family of new ultra wideband (UWB) devices: the ability to communicate in harsh environments, to very accurately resolve range, and to act as a radar-based sensor.
  - will adapt new and emerging ad-hoc routing protocols and multiple access schemes to take advantage of the unique properties of UWB, enabling reliable and efficient operations in harsh environments.

Range Finders – Current COTS Products

- **Survivair (Santa Ana, CA) – Established COTS solution for firefighters**
  - 16.7 Mill per year, founded in 1961, 220 employees
  - Company focuses on respiration systems
  - Pulse ultrasound technology, including omni-directional transmitter (the beacon) and narrowly focused device (transmitter).
- **Other COTS Rangefinders**
  - Exit Technologies (Boulder, CO) – used mainly after an avalanche to find victims under snow; transmits and receives using the 457 kHz signal.
  - UWB Range Finders (next slide…)

Ultrawide Band (UWB) – Strengths and Weaknesses

- **UWB system includes a transmitter that emits a sequence of impulses that are detected by a corresponding receiver.**
- **Advantages:**
  - UWB signaling is less susceptible to multi-path fading and better able to penetrate building materials
  - Low Power
  - Security – appears as noise, difficult to detect and jam or intercept signals
- **Disadvantages**
  - Raises the overall noise level
  - Still prone to multi-path

UWB Range Finders (cont…)

- **Multispectral (Germantown, MD)**
  - Currently developed a Rangefinder product for the Army – **not FCC Part 15 compliant.** MSSI is now working on a Part 15 compliant product.
  - Works from a single pulse
  - Received a “go” decision from DARPA Netex Program
- **Aetherwire (Sunnyvale, CA)**
  - Works from a multi-pulse, has a range/movement trade-off. E.g. if the firefighter is moving, range decreases.
  - Received a “no go” decision from DARPA Netex Program
- **Time Domain (Huntsville, AL)**