Integrated GPS for Wireless Devices

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Lance Liu
Marketing Manager
Qualcomm
Agenda

1. Who is Qualcomm?
2. GPS Market Overview
3. Integrating GPS with Wireless Components
4. Integrated GPS Solutions in Action
5. Conclusion
1. Brief Qualcomm Overview

2. GPS Market Overview

3. Integrating GPS with Wireless Components

4. Integrated Solutions in Action

5. Conclusion
Who is Qualcomm?

Qualcomm is a leading developer and supplier of digital wireless communications products and services.

Quick Facts:
- Founded in 1985
- *FORTUNE* 500® Company
- NASDAQ Symbol: QCOM
- Approximately 3,000 patents and patent applications of CDMA and related technologies including WCDMA
- Member of the S&P 500 Index
- "100 Best Managed Companies" — *Industry Week*
- "100 Best Companies to Work for in America" — *FORTUNE*
- ISO 9001:2000 certified

Source: “About QUALCOMM”, at www.qualcomm.com
QUALCOMM Business Units

- QCT
- QTL
- QWI
- QIS
- QWBS
- QGOV
- QMT

Corporate/Reconciling Items

QUALCOMM Strategic Initiatives

Strategic Investments

MediaFLO USA
QCT: Complete, Proven, Modem and Application Solutions

- Integrated baseband & Computing Platform
- RFIC & Power Management with SW Drivers
- Proven Software Protocol Stack for multi-mode Modems
- Development Tools
- Launchpad™ Applications Suite
- Handset and Infrastructure Customers
- Application & Phone Design Support
Qualcomm GPS Products

Products

- gpsOne: 4-mode AGPS client HW&SW
- QPoint: Location Server
- WARN: Wide Area Reference Network
- Tools: Development & deployment
- Support: Deployment planning, support
- BREW: Application platform

Standards Compatible
- 1X, 1X/EvDO, UMTS, HSDPA, EDGE, GPRS, GSM

Control & User Plane

Intellectual Property

Pioneer of multi-mode Assisted GPS with over 250 location patents*

* issued, pending, or in process

Vision

Partnerships

Applications

Server

WARN

Client

Tools

System Architecture

Experience

Continuous Innovation

Qualcomm’s end-to-end system offering goes far beyond simply providing products, and is built on foundation of IP, experience, and innovation
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What is the GPS Market?

GPS Shipments by Application

GPS is a mass market opportunity and wireless communications is the largest segment.
How is the GPS Market Evolving?


Playstation 1st DSC 1st GPS HHs 1st MP3 1st MP3 Phone 1st CAM phone 1st gpsOne 1st video phone gaming phone(s)

Audio
- Recorded Music >100 years old
- MIDI >20 years old
- MP3 ~7 years old
- 1st MP3 phone in 1999

Video Games
- Video Games ~30 years old
- PC/Console >20 years old
- 1st game on phone in 1997

TV/Video Player
- Movies >100 years old
- TV >50 years old
- Video clips on PCs >15 years
- 1st video phone in 2003

Camera
- Photographs >170 years old
- Photos made accessible >120 years old
- 1st Digital Camera ~1995
- 1st Camera Phone 2000
How is the GPS Market Evolving?

Common themes for video, camera, audio and gaming:

• Established Markets

• Established Content
  – At most, a new format may be involved

• Value Proposition/Consumer Experience well understood
  – Based on prior experiences
How is the GPS Market Evolving?

- GPS system has been commercially available only ~10 years
- 1st gpsOne enabled phones in 2001
- GPS mass market applications just hitting stride today
- GPS Handheld market in ’04 was more than double that of ‘03
- Expect market to take off dramatically over 2006-2008 timeframe
### Why Should Wireless Operators Care about GPS?

**Answer:** Where deployed, they provide Operators with real LBS value

<table>
<thead>
<tr>
<th>Consumer per Month</th>
<th>Enterprise per Month</th>
<th>Operator’s view of other significant value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10-$15</td>
<td>$10-$59</td>
<td>Bringing in new subscribers, increasing ARPU from data services beyond GPS</td>
</tr>
<tr>
<td>$5</td>
<td>&gt;$25</td>
<td>Increased ARPU from enterprise by Cdn$25/mo</td>
</tr>
<tr>
<td>$3-$5</td>
<td>Planning</td>
<td>Extremely rapid service adoption, ARPU increase</td>
</tr>
<tr>
<td>$3-$10</td>
<td>Planning</td>
<td>Enabled KDDI to take subs from DoCoMo</td>
</tr>
<tr>
<td>+ €6</td>
<td>N/A</td>
<td>‘3’ Austria has seen €6 increase in monthly ARPU from users of its navigation service</td>
</tr>
<tr>
<td>Trial Planned</td>
<td>Trial Planned</td>
<td>GPS Navigation increased usage 8X over Cell-ID, 60% of chat usage tied to location.</td>
</tr>
</tbody>
</table>
Are Large Operators Using GPS?

Sprint launched AGPS in April of this year
- North America, 1X, Control Plane
- Concierge and security services

Verizon has announced their intention to launch AGPS later this year
- North America, 1X/EvDO, User Plane
- Service plans not yet disclosed

DoCoMo has publicly announced intention to launch AGPS later this year
- Japan, UMTS, Control Plane
- Service plans not yet disclosed
Why Should Consumers Care about GPS?

- Personal Navigation and security/peace-of-mind applications are currently the most popular applications
- Standalone GPS selling very well
  - →50% of all PDAs are sold with GPS
  - →200k GPS devices sold per month in Europe
- Many Operators already deployed PDA + GPS packages, and moving to solutions with everything in one device
- Enterprises looking for simple, effective, less expensive Mobile Resource Management (MRM) solutions

“We believe that location-based services will add a complementary and powerful dimension to the BlackBerry experience …”
Mark Guibert, VP, Corporate Marketing, RIM
What Apps and Services Will Come After Navigation?

• Real-world, location enabled games
  – Mogi
  – BotFighters
  – GeoCaching
  – Gizmondo

• Peer-to-peer
  – Push To Talk – “Push To Find”
  – Mobile Blogging
  – “Friend Finder” (resource management etc)

• Location Enhanced Services
  – Presence
  – Meeting services
  – Personal safety, roadside assistance
  – Billing
  – Customer Service
  – Pre-Pay top-ups
  – WiFi access
...And Why Should Your Business Care About GPS?

- If you build handsets, PDAs, terminals, etc.
  - It can differentiate your product

- If you are an applications provider
  - It opens up new markets of applications for you to develop

- If you are a content provider
  - It will create new uses for your data and content

- If you are a GPS provider,
  I hope you care already!!

In all cases, GPS can help your business grow!
1. Brief Qualcomm Overview

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4. Integrated GPS Solutions in Action

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What Is Meant By “Integrating GPS with Wireless”?

- Not just a GPS device connected electronically to a phone or PDA
- Not just putting a GPS Sleeve attachment onto a phone or PDA
- Not just putting GPS board along side a communications board in a consumer product
- Not just putting small GPS chips inside a phone or PDA

Pictures shown are for illustrative purposes only, and not meant to depict the exact implementation chosen by terminal manufacturers.
It Means Literally Putting GPS \textit{Inside} the Wireless Chip

That is, putting the GPS circuitry inside wireless chips that are necessary in the phone or PDA to perform core communication functions and drive the other core functionality of the device.

This includes putting the GPS digital baseband circuitry inside the modem device...

...and putting the GPS RF analog receiver circuitry inside the RF devices...
Why Would One Want to Integrate GPS into a Wireless Device?

Most of the large markets require a commercial wireless connection (CDMA, WCDMA, GSM, etc.), or are improved by a wireless connection.

So why not put it all in one spot to optimize for the Mass Market?!
What Are the Implications of this Approach?

Dense circuitry both inside the chip and inside the phone...but, this complexity turns into simplicity and efficiency for the PDA or handset manufacturer.

Multiple functions operating at once (processing, power management, RF, user interfaces, etc.)

Complex hardware and software interfaces

Dense circuitry both inside the chip and inside the phone...
Key Design Considerations when Combining GPS and Wireless For the Mass Market

Elements Necessary for Putting Any GPS Receiver into a Device

- GPS Antenna
- GPS RF Receiver
- GPS RF Filtering
- GPS Digital Baseband processing
- Frequency source
- Power
- Connection to the using function or user interface
- Connection to wireless (if Assisted GPS)

Key Design Considerations

- Time to market
- Development cost
- Product cost
- Size
- Power
- Memory requirements
- Sharing chips already in the Phone/PDA
- RF design and EMI
- Interaction with core wireless communication and multimedia hardware and software
- Technical support to help pull it all together at the system level
## How Design Considerations Compare Across Common Solutions

<table>
<thead>
<tr>
<th></th>
<th>GPS connected to Phone/PDA</th>
<th>Sleeve attached to Phone/PDA</th>
<th>GPS Chips in Phone/PDA</th>
<th>GPS integrated in Wireless Chip</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time to market</strong></td>
<td>Neutral</td>
<td>Neutral</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td><strong>Development cost</strong></td>
<td>Poor</td>
<td>Optimal</td>
<td>Neutral</td>
<td>Optimal</td>
</tr>
<tr>
<td><strong>Product cost</strong></td>
<td>Poor</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Shares chips in Phone/PDA</strong></td>
<td>Neutral</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Neutral</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>Uses Own Mry</td>
<td>Uses Own Mry</td>
<td>Neutral</td>
<td>Optimal</td>
</tr>
<tr>
<td><strong>Minimizes EMI Issues</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Interfaces to core Comm, MM SW</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>GPS Antenna</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Wireless, GPS from 1 vendor</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Presentation addresses these items.
Critical Design Consideration: Product Cost

- Separate solutions or sleeve solutions require the consumer purchase a GPS device usually well over US$100.

- These devices have a strong following, and meet many market needs, but are large, expense, support a small set of applications, and require that the user carry another device around that can’t easily be downloaded with new or updated apps over the air.

- This is a compelling argument for putting the GPS into a PDA or phone and recreating some of the “handheld” experience on the device that the consumer always carriers around, and doing it at a very low price to the consumer
Critical Design Consideration: Product Cost (continued)

Typical Non-Integrated Solution

A Highly Integrated Solution

- Video ASIC
- Audio Chip
- 3D Gaming ASIC
- Apps Processor
- Camera Module with DSP
- GPS Chips (2 typ)

- Mobile TV
- Music
- Gaming
- Camera
- Business
- GPS/LBS function & Apps
Critical Design Consideration: Product Cost (continued)

Typical Non-Integrated Solution

- $5-$7 Typically 2 GPS Chips
- $1-$2 Discrete parts
- $.50 GPS antenna

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$6.50 to $9.50 Total

A Highly Integrated Solution

- $0 No GPS chips!
- $1 Discrete parts
- $.50 GPS antenna

--------

$1.50 Total

Cost savings is $5 to $8 with integrated solution!
## Critical Design Consideration: Size and Power

<table>
<thead>
<tr>
<th></th>
<th>GPS Device Connected to PDA or Phone</th>
<th>GPS Sleeve assembly on PDA/Phone</th>
<th>Separate GPS chips inside a PDA or phone</th>
<th>Integrated GPS within modem for PDA or Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>Requires two devices</td>
<td>Makes phone larger and bulky</td>
<td>100% space savings over separate chips (~1 in²)</td>
<td></td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Uses own power source</td>
<td>Uses either own or PDA/phone power source</td>
<td>Power usage depends on GPS Co. design and system techniques</td>
<td>&lt;5% savings over separate chips</td>
</tr>
</tbody>
</table>
Critical Design Consideration: Sharing other Devices in the Phone

- Further cost reduction, space savings, and power optimization can be obtained by sharing other devices in the PDA or phone
- Requires knowledge of subsystem design
- One significant example:
  - It is possible to share the VCTCXO for GPS and eliminating the need for a dedicated GPS TCXO
- Other examples:
  - Utilize memory subsystem (in next slide)
  - Utilize user interface circuitry of the modem
  - Utilize interface circuitry of modem (eliminates need for UART to interact with GPS system)
  - Utilize Modem SW stacks for standard protocol interaction (common for control plane protocols)
  - Utilize power supply and power conditioning circuitry

Integrated Solutions enable sharing in 2 key ways:
1. System Design Knowledge. Because GPS design is tightly coupled with modem, power management, RF, and other processing elements, it can leverage across all parts of phone for more efficient sharing
2. Replication for mass market. Because overall system is always from the GPS/modem designer, can replicate across many manufacturers to neutralize uniqueness across wide variety of OEMs.
Critical Design Consideration: Memory Usage

- Separate GPS devices and GPS sleeves typically use their own memory. This is expensive, but does not affect the memory needs of a PDA/phone.
- Phone/PDA memory size is typically driven by functionality of the phone other than GPS, like camera, video, graphics, audio, and WinCE-type applications.
- Basic GPS code and data memory is typically in the range of .25MB to .5MB, commonly easily available within most PDA and wireless phones.
- But, when putting GPS into a PDA/phone, one must carefully consider these key questions:

  Can the GPS design use memory that is already in the PDA/Phone?
  If so, how much more complex is the design to accommodate this?

- Using separate GPS devices, the answer to these questions varies, depending on the vendor.
- Using GPS integrated with the modem device, the PDA/phone memory can certainly be used, and there is minimum complexity involved.
Critical Design Consideration: EMI

Examples of Common UMTS RF Spectrum Worldwide

**North America**
1. UMTS1900
2. UMTS1700/2100
3. UMTS850

**Europe**
1. UMTS2100
2. UMTS1800
3. UMTS900

**Korea**
1. UMTS2100
2. UMTS1800
3. UMTS850

**Japan**
1. UMTS2100
2. UMTS1700
3. UMTS800

**China**
1. UMTS2100
2. UMTS1800

**SE Asia**
1. UMTS2100
2. UMTS1800

GPS operates below noise level, is highly sensitive, and risks interference given the wide variety of RF bands in today’s wireless markets.

**UMTSxxxx** = Frequency in commercial use today
**UMTSxxxx** = Frequency under carrier consideration
Critical Design Consideration: EMI (continued)

- Some GPS chip vendors provide performance specs based on a dedicated GPS card. By the time the same technology is integrated in a small wireless handset or PDA form factor, the delivered performance can be far from what is originally claimed and the device vendor is left to figure out why.

  | GPS chips | GPS-Only Device | No wireless EMI issues |
  | GPS chips | Wireless PDA or Phone | Possibly serious wireless phone EMI Issues |
  | EMI usually affects sensitivity, stability |

- Superior GPS performance in close proximity of a wireless transmit path requires deep understanding of the GPS and wireless subsystem implementations and close coordination between the two.
Critical Design Consideration: EMI (continued)

- Integrated solution enables the integrated solution provider to design in mitigation schemes to handle signal interference between GPS and the wireless link as part of the overall design instead of leaving it to the device vendor to deal with.

**Integrated Solution…**

- Mitigates wireless phone EMI
- Minimizes EMI sensitivity, stability impact
Critical Design Consideration: Interfaces to Core Phone Functions (Communications and Multimedia Functionality)

- Applications
- Standard or Proprietary API
- GPS Driver
- Modem functionality and RF Hardware

Separate GPS chips

GPS Interface to phone or PDA SW stack on unintegrated modem chip is through API and is somewhat isolated from the other functions in the phone or PDA

Phone or PDA SW stack on unintegrated modem chip
Critical Design Consideration: Interfaces to Core Phone Functions (Communications and Multimedia Functionality) (continued)

Phone or PDA SW stack using integrated modem chip

Integrated GPS solution provides much closer coordination with basic phone/PDA functions than separate chips.
Critical Design Consideration: GPS Antenna

- The Antenna can have one of the largest impacts on GPS performance
- As GPS designs are placed into smaller and smaller PDAs and phones, the OEM will tend to reduce cost and size by compromising on the antenna.
- A poor GPS antenna, or poor antenna layout within a PDA/phone design, has a large impact on sensitivity. Assisted GPS can partially compensate, but for the optimum user experience, a good quality antenna is critical

<table>
<thead>
<tr>
<th>Antenna</th>
<th>GPS Device Connected to PDA or Phone</th>
<th>GPS Sleeve assembly on PDA or Phone</th>
<th>Separate GPS chips inside a PDA or phone</th>
<th>Integrated GPS within modem for PDA or Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Usually a fairly large antenna</td>
<td>Usually a fairly large antenna</td>
<td>Advise that the OEM use best possible solution</td>
<td>Advise that the OEM use best possible solution</td>
</tr>
</tbody>
</table>

The choice of antenna is equally important whether the design is based on separate GPS chips or an integrated GPS+wireless solution
Critical Design Consideration: Support to Pull it all Together

GPS is complicated, so systems support for implementing GPS with wireless is a critical factor to successful operation.

<table>
<thead>
<tr>
<th>Component</th>
<th>Integrated GPS Solution</th>
<th>Separate GPS chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS Baseband</td>
<td>Vendor A</td>
<td>Vendor 1</td>
</tr>
<tr>
<td>GPS RF</td>
<td>Vendor A</td>
<td>Vendor 1</td>
</tr>
<tr>
<td>Wireless modem RF</td>
<td>Vendor A</td>
<td>Vendor 2</td>
</tr>
<tr>
<td>Wireless modem baseband</td>
<td>Vendor A</td>
<td>Vendor 2 or 3</td>
</tr>
<tr>
<td>Power management</td>
<td>Vendor A</td>
<td>Vendor 2 or 4</td>
</tr>
<tr>
<td>Multimedia function or chips</td>
<td>Vendor A</td>
<td>Vendor 5</td>
</tr>
</tbody>
</table>

Using Integrated GPS, support for all system interactions comes from one vendor

Using separate GPS chips, support for all system interactions comes from up to 5 different vendors
Essential Steps Required Before Commercial Availability

System Architecture Definition
- Location Protocol(s) specifications
- Server and Handset Specifications
  - Handset Development
    - Server & Handset A-GPS SW Development
      - Server and Handset SW integration
        - Software Test and Integration
          - Validation and certification
            - Commercial Launch

These are functions related specifically to the PDA or handset, and system design

Remember to plan for these steps too!
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Is fully integrated GPS a Real and Viable Solution? 

Yes!

Today there are greater than:
- 150 different terminal models
- 100M Units

... and well over 30 PDA, handset manufacturers with commercial products

9 of Worldwide top 10 vendors¹ have delivered/announced GPS enabled commercial terminals - Nokia, Motorola, Samsung, Siemens, LG, Sony-Ericsson, Kyocera, <Sagem>, NEC, Panasonic

¹ Source: Strategy Analytics, Feb-05
Are there Performance Issues with Integrated AGPS? **No!**

**Bush Street, San Francisco**
- 100%, 52m typ, 7s

**San Jose Parking Garage**
- 84%, 50m typ, 14s

**San Jose Freeway**

**London, inside**
- 100%, 60m typ, 18s

**Rome, outside**
- 100%, 20m typ, 4s

**Countryside near Rome**
- 100%, 5m typ, 2s

Shown:
Yield, Accuracy, Fix Time (cold start)
Are there Application Limitations Using Integrated AGPS? No!

- Navigation / POI / Maps
- Peer-to-Peer / Social Networking
- Security / Tracking
- Peer-to-Peer / Social Networking
- Enterprise

Wireless integration enables enhanced AGPS performance and also the ability to support dynamic content to ensure maps, apps, and other content are current.
Are Integrated Solutions Limited to Certain Air Interfaces, Markets?

Intrado and TCS operate service bureaus serving an additional 25 operators.

Integrated AGPS solutions work well in 1X, 1XEVDO, UMTS, EDGE, HSPDA, GPRS, GSM, and PDC markets.

No! No!
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Summary and Conclusion

• The market for GPS is large and growing. The market for GPS integrated with wireless phones and PDAs is the largest part of this market.

• To address mass market needs, several critical design considerations are important that reach far beyond performance characteristics so often used to judge GPS solutions.

• When considering different implementations to address the mass market, a GPS solution that is integrated within the modem offers the most advantages in these critical areas.

• The Integration of both HW and SW minimizes the design and support burden for device manufacturers.

“GPS integrated with wireless” solutions are already proven in the mass market.
Thank You