Geographic Data Servers for Wireless Clients

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ABSTRACT:

Natural and man-made disasters in the coastal environment require the rapid mobilization of many people with a broad range of talents. Often they are needed in many locations or are required to move during their work to areas they are unfamiliar with. Providing a responsive information infrastructure that is easy to use presents unique technical problems. One such problem is providing continuous and up-to-date geographic information. For field personnel with the capacity to carry only a handheld computer there are very few options to acquire map-based data. This project investigated a new integration of existing network and data management tools to give field personnel access to geographic information. The core technologies used included a handheld computer with wireless Internet access, an integrated Global Positioning System (GPS) receiver and a geographic information system (GIS) enabled website.

DESIGN ASSUMPTIONS:

- Map graphic data volumes are large and should therefore not be over a wireless IP connection.
- Down-loading positions and feature definitions over wireless IP should be fast.
- Portable GPS devices are extremely well engineered for durability, interface design and field-based map graphics.
- User interaction with the handheld computer should be minimized, using a stylus while moving in the field is awkward.
- Wireless IP service is intermittent so map-graphics should be provided / conducted by the GPS device to ensure higher rate of availability.
- Users should be able to access a variety of NOAA related spatial databases on demand.
- User data volume and currency needs outstrip the storage capability and functionality of handheld devices.
- Actual data needs of the field user are usually simple but variable, such as what is the location and definition of an object within X distance of my location, or what is the name of the habitat/zone/area that I am standing in?
- The cost of a field unit should be practical to distribute in large volumes. If possible avoid licensed software.

- The Palm Operating System has the majority of the handheld computer market for operating systems. Therefore the largest audience of potential users can be reached with PalmOS enabled devices and the richest set of application software and development tools are also written for the PalmOS enable devices.
- Industry standards like National Marine Electronic Association (NMEA) and XML should be employed.

SUMMARY OF FINDINGS:

General

Access to a multiple sources of NOAA spatial data can be provided to field personnel for a minimal cost using non-proprietary software and a combination of a handheld computer, wireless modem, and a handheld GPS. The transfer of the spatial data between various web-based data sources and the GPS unit is provided by a proxy server and a small PalmOS applet that reads and writes data between the GPS and the Palm micro-browser. Field personnel can interrogate a data source through a web application and search by geographic layer, database field and distance from their location. After querying data from a remote source it is moved to the GPS via the applet. By using the advanced mapping and interface functions of the GPS, field personnel can easy navigate to a location without having to repeatability interact with a handheld computer that requires a stylus and two hands. Development and field tests were conducted using NOAA Environmental Sensitivity Index Map data, FEMA HAZUS99 data and several remote public data sources. Common code and communication standards like NMEA and XML were used to ensure extensibility. The development code and design concept from this project is not closely tied to any specific technology that will be out of date in the near future, and would be a practical starting point for a NOAA office seeking to support field personnel with live geographic data.

The overall configuration worked as originally conceived with limited modifications. The goal was to provide location-based NOAA information to field personnel equipped with a GPS, handheld computer and wireless modem. By interrogating a web server via wireless in the field, personnel are able to get live geographic data from extremely large and or changing databases for only the immediate area of interest. During development we found that a significantly larger amount of time then had been expected was required to program the handheld to pull and push coordinates between the web server and the GPS without user interaction. A lesser amount of time then expected was required to build the web service/map service. Additional unplanned functionality was easily added that allowed a user to select data sources from many map servers and not just one. Additional functionality was also easily added that allowed a user to query their geographic relationship to polygon features as well as point locations.

The final design that was developed to interrogate and move data from the server to the GPS is extremely extensible, performs well, is easy to use, stable, easy to implement and requires no commercial software on the handheld device. The code is still considered development grade and would need considerable engineering before it should be relied on in a true disaster response environment where property or life maybe dependent on it

Handheld Computer – Palm Prism (Figure 1)

The Palm Prism worked very well overall during the project. When it was unpacked both units had to be hard-rebooted while in the cradle, which was un-documented in order to force the unit to begin charging. The screen resolution was adequate however the color capabilities added little functionality. The unit held charge extremely well, not once over a year did it loose complete charge and its contents. Setup with the desktop was very straight forward and adding programs or data to the unit from the desktop is quite easy. The PalmOS interface is clean and easy to follow.

The Compaq PocketPC is nicely designed and has a very useful dual expansion pack that allows both a modem and GPS to be installed and run simultaneously in one physical device. The screen interface is crisp and impressive. The OS user interface is awkward in comparison to the Palm. Setting the unit up with a desktop was poorly designed. By following the default instructions the unit failed to make a connection to the desktop. It was only after investigating submenus and screens was I able to force the unit to connect with the desktop. Loading programs and data was easy and logical. Battery life is extremely poor and leads to frequent complete loss of all resident data and installed programs.

Handheld GPS – Garmin 12CX (Figure 4)

Both units came from the factory with such a low charge on the battery that neither could be charged at all. Both units were replaced at no cost. Satellite acquisition time was amazingly fast, and the user interface/ergonomics were excellent. The unit can easily be used with only one hand. Setup for receiving data from the handheld was simple, as well as setting all other ordinary parameters. Battery life was reasonable and screen resolution and contrast were adequate. The stored database of place names was surprising large, and the unit received well while in flight in an airliner, in cars, inside houses and on foot. The location of the output connection to the handheld computer is terrible and makes if difficult to package as a combined unit with the handheld computer.

Commercial Handheld Software

DeLorme for the Palm: very nice interface, however no apparent mechanism to programmatically enter a waypoint. Requires a DeLorme base map for the area of interest to be most useful.

Teletype GPS for the PocketPC: This was a free mapping package provided with the PCMCIA-based GPS receiver. It has an attractive interface especially well designed for navigation while moving. The mechanism for moving data from the CD-ROM or Desktop to the handheld is cumbersome and non intuitive.

ArcPad: This is designed as a toolbox application and is typically used for displaying maps. It would take a considerable amount of customizing to merge the mapping capabilities with web interface requirements for efficient remote data access.

ThinkDB: Probably one the most useful and well engineered database products available for a handheld device. Very powerful and intuitive. Migrating data from the desktop is well documented. ThinkDB would be an excellent complimentary tool for this project if only records queried from the web could be synchronized to the ThinkDB database on the handheld. This might allow a user to run map graphics on the GPS interface while access attribute graphics on the handheld computer.

Integration of Handheld Devices

A special $50.00 cable was required to connect the Palm and Garmin GPS. These are not easy to find, but they work perfectly. The PalmOS has distinct problem seeing two peripheral devices connect at the same time. For example when a unit is connected to the expansion port (Modem) and another unit (GPS) is connected to the synchronization port.

Wireless IP Service – OmniSky and Verizon

Wireless coverage is intermittent. Most major populated areas across the county have some reception. Current IP service is mostly CDPD and is only available in the U.S. Non U.S. IP services are based on GSM. GSM service is now available from at least AT&T for large areas of the U.S. The baud rate for the IP service was more then adequate for shipping the requests and responses needed by our design. An attempt was made to us ArcPad over the Wireless IP which performed so poorly that it was unuseable. This poor performance was probably due to the fact that ArcPad was downloading actual graphics (gif files) across the network from an ArcIMS server.

Sample Data Sources

FEMA HAZUS 99' data for South Carolina was used for development. Both polygon and point based data was extracted, cleaned and published as a local map service. The original data was structured poorly and inconsistently populated.

NOAA Environmental Sensitivity Index map data was also used during development and testing. No cleaning or restructuring was necessary prior to map publishing. Some of the field codes are non intuitive and could be enhanced with human readable codes.

ESRI city location data was extracted from shape files and transformed to an access database. Code was developed and tested for connecting and reading this as a data source directly from the server-side ASP code, and not through the ArcIMS connection. No significant data modification was necessary.

Field Trials and Usability (Figure 2 and Figure 3)

All field trial activity was conducted by the developers typically in a geographic area restricted to eastern Massachusetts. Frequent wireless testing was done standing outside the development lab on a parking lot near Scituate Harbor MA in full daylight. The packaging of the handheld computer and GPS unit into a portable pouch worked adequately. During moving exercises it was very convenient to remove the 2 separate units from the pouch. During communication and querying the database only the handheld computer was needed and during navigation only the GPS was necessary.

This approach allowed the user to store either the handheld computer or the GPS in their pocket most of the time which greatly enhanced navigation.

Handheld computer interface: If the user had selected the “fast” interface then only 2 screen interactions were necessary which could either be done with a stylus or the tip of a finger. Users that access the more advanced query functions could easy have 10 to 15 screen interactions. The browser and handheld computer design allows a user to power down the system, and power the system backup without loosing their in process memory, for example, minutes or hours of time can pass between server queries and the user is still not required to manually revisit the mapserver website. Once the user browses to another web server they are required to type in a URL or trigger it from a pull-down menu or the back button.

GPS interface: All interactions could be completed with one hand primarily using the thumb digit while holding the unit with the palm of your hand. This functionality is critical when considering that the GPS navigation component consumes the largest amount of system interaction time when in the field.

Server Architecture

The map server is composed of a multiprocessor Windows2000 intel cpu running Microsoft IIS and ESRI ArcIMS. The server is located behind a firewall and the local data sources were stored on local disk as shape files.

This configuration worked well for a development environment with a limited number of connections. The placement of the ArcIMS box behind the firewall required only a small modification of namespaces within the code, and the creation of an output directory on the public web server. Very large local data sources would probably perform poorly as local shape files and are best moved off to a separate database server with a spatial wrapper like ESRI/SDE or Oracle/Spatial.

Server-side Code Development and Design

All server-side code was written in VBScript and used Active Server Pages. The map service was written from scratch with object calls to the ESRI provided ASP objects or with calls directly to ArcIMS via XML. Using the Microsoft XML parser saved a lot of time by eliminating the need to parse and build strings with VB. Because most of the computations needed by the end user occur on the web/map server we were able to keep the Palm application code very focused and independent of database or user requirements. The core functionality that the web/map server prove include:

- Point Queries (list all NOAA tide gauges within 5 km)
- Polygon Queries: (what flood zone am I standing in?)
- Remote ArcIMS sources: (queries are forwarded to others)
- Remote Database: (queries occur against listed database)
- Remote Web pages: (planned but not implemented)
- Remote Web services: (not planned, but same as #3 above)

Handheld Computer Code Development and Design

All code was written in MetroWerks C. Development testing was conducted using a handheld emulator. Most available libraries for the Palm were restrictive by comparison to desktop development environment. Other unusual design considerations included programming for limited memory and processor resources, and different event-based mechanisms. No browser libraries were available. To avoid “hard-wiring” the Palm application to either a specific web/map server or a specific GPS, the Palm application code was designed to only move data between the browser and the GPS via the NMEA protocol. This should facilitate the modification of either the web/map server or switching of GPS devices in the future. The design of the Palm code will make distribution and implementation significantly easier then other more sophisticated handheld-based mapping applications.

RECOMMENDATIONS FOR FUTURE DEVELOPMENT:

Continue with PalmOS and a browser based application. The commercial and non-commercial public code base is primarily designed for the PalmOS. There are no apparent technical limitations to the PalmOS for the simple communication of geographic locations between a map server and handheld GPS. Palm, Handspring and other vendors are beginning to move to the RISC based chips which should enhance cross platform development. Palm and Handspring are also now supporting the SDIO expansion option and vendors will begin distributing GPS for this connection type.

Continue with map graphics provided by the GPS device. GPS units typically have a very well developed graphics/mapping interface by comparison to most handheld computer applications. This approach also allows field users to only need to handle one physical unit during typical operations.

Do not attempt to download map data as graphics across the wireless network. Moving map graphic data across a wireless network is extremely slow to the point of unusable. Increases in bandwidth may help, although performance will still be substandard for live field operations.

Use a PalmOS based device with an integrated modem and attached GPS. Using an integrated modem, such as on a TREO will eliminate additional bulk and reduce the chance of communication errors with multiple attached devices.

Add a user defined, map server address selection. With only a small amount of code, it should be possible to allow a field user to enter any map server http address, in addition to using those in the pull-down menu.

Add error control. Most web/map server ASP code has little or non error control and should be enhanced for a production grade system. Additional user feedback can also be provided when results such as “no available layers” occur.

Log queries to study patterns of use for optimization. By logging user queries on the server an analysis of use patterns could be extracted and used to modify the design to eliminate cumbersome or un-necessary steps.

Query only the 10 closest features. An additional checkbox type trigger could be added to the browser interface to force a spatial query to limit its results to the ten closest records. This would simplify user interaction.

Query for the entire feature record for a limited set of objects. Once a user is on-site, it would be helpful to extract the entire spatial and non spatial record for a single specific feature. Current non-spatial attributes include a single user selectable field.

Add data while in the field. Posting data to the web/map server from a field unit could allow other remote users to share data.

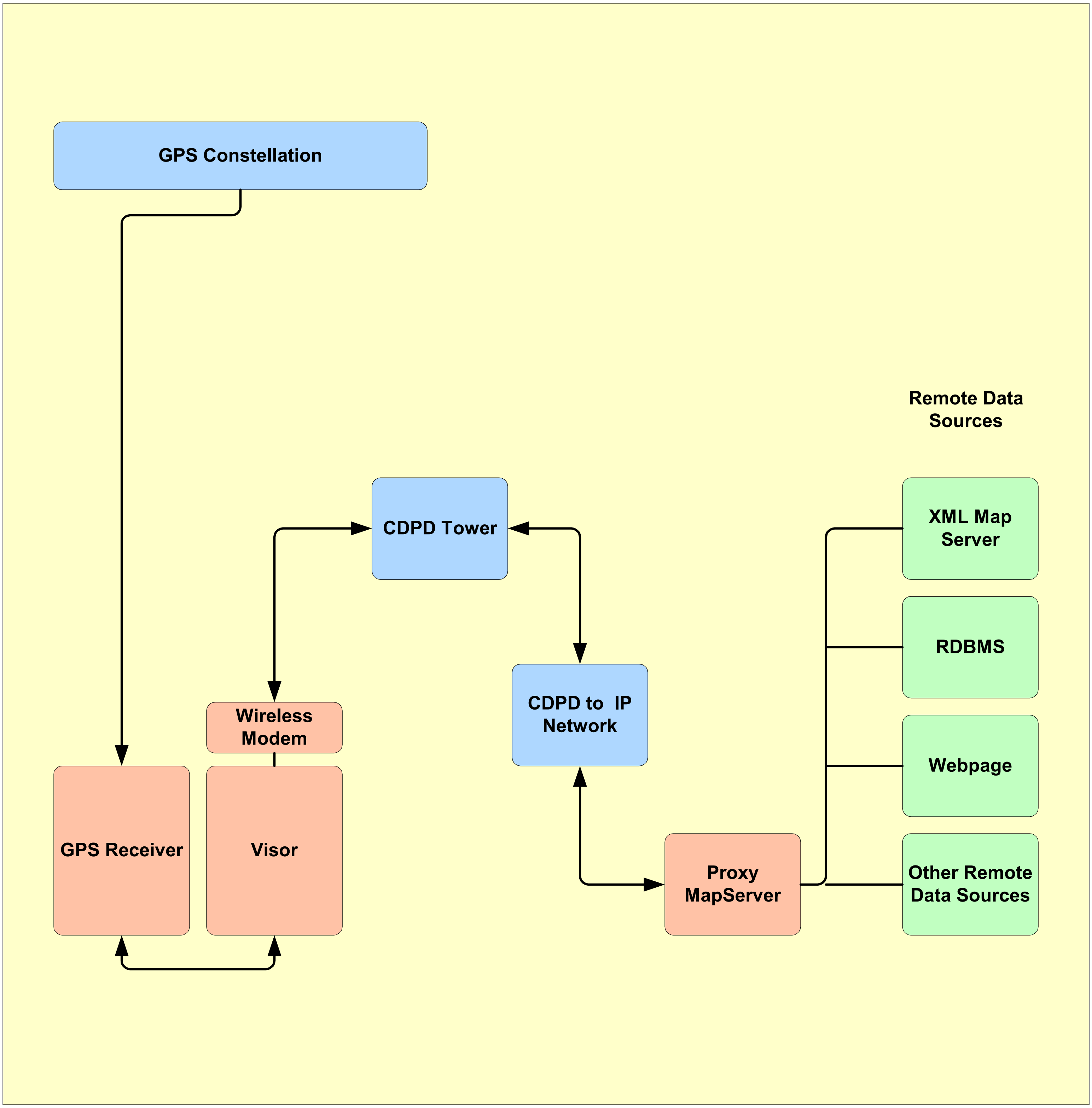
Filter candidate data sources from only those that support decimal degree. All data sources are considered decimal degree at this point. An error check to eliminate non-decimal degree data would be useful.

Ability to output projected stateplane coordinates from a decimal degree source. A browser based trigger could be added to output data in a projected coordinate system. This would require significant code modifications on both the server and handheld side, and may cause confusion among some users. Power users may find it helpful when they are navigating to projected coordinates.

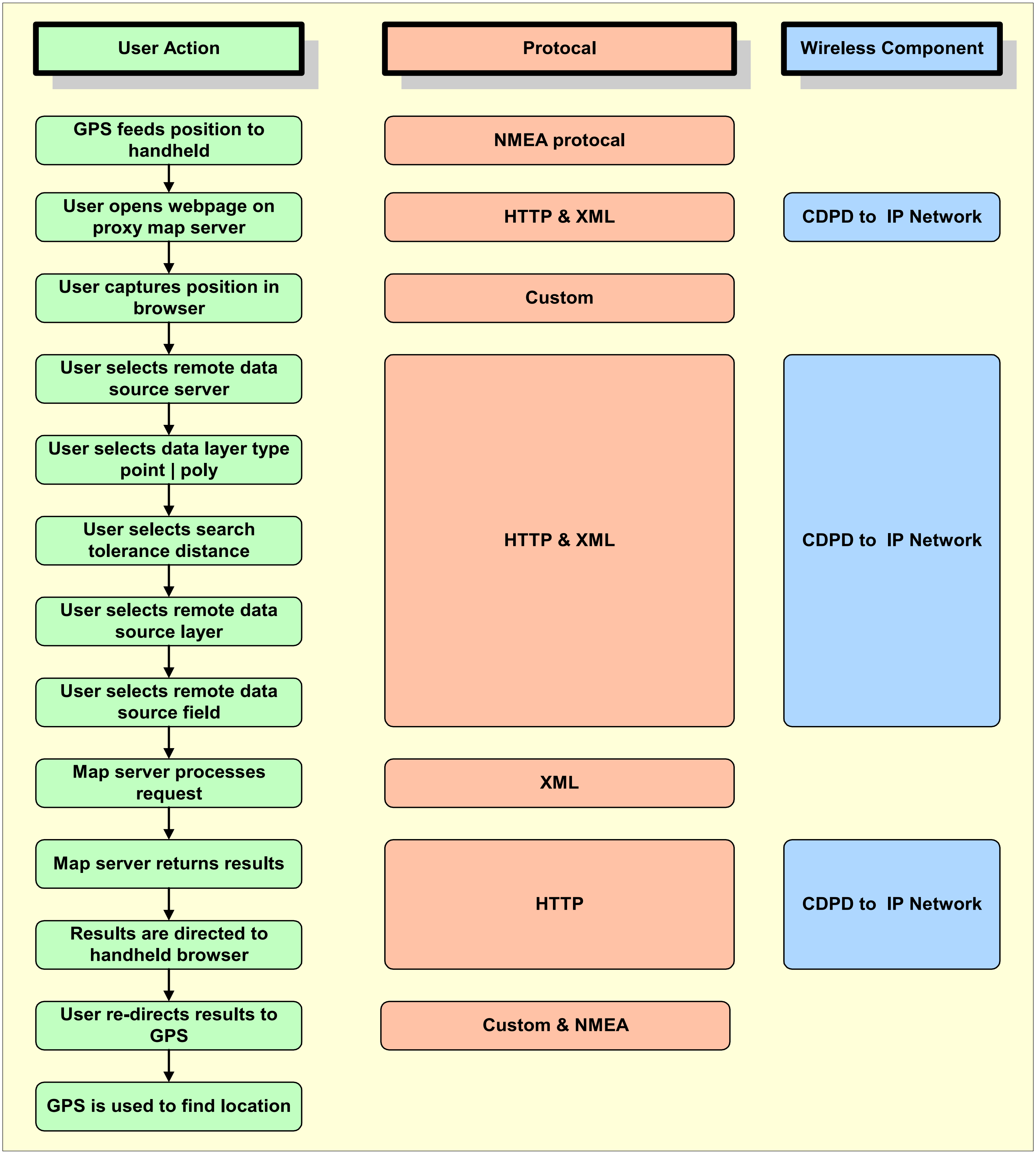
Enhance the browser to GPS and GPS to browser functionality. Additional error checking and cross system testing would make the code base more robust.

Extend functionality to WindowsCE devices. Rewrite the GPS to Handheld Applet under VBScript.

Physical Design Model



Logical Design Model



Hybrid Physical/Logical Design

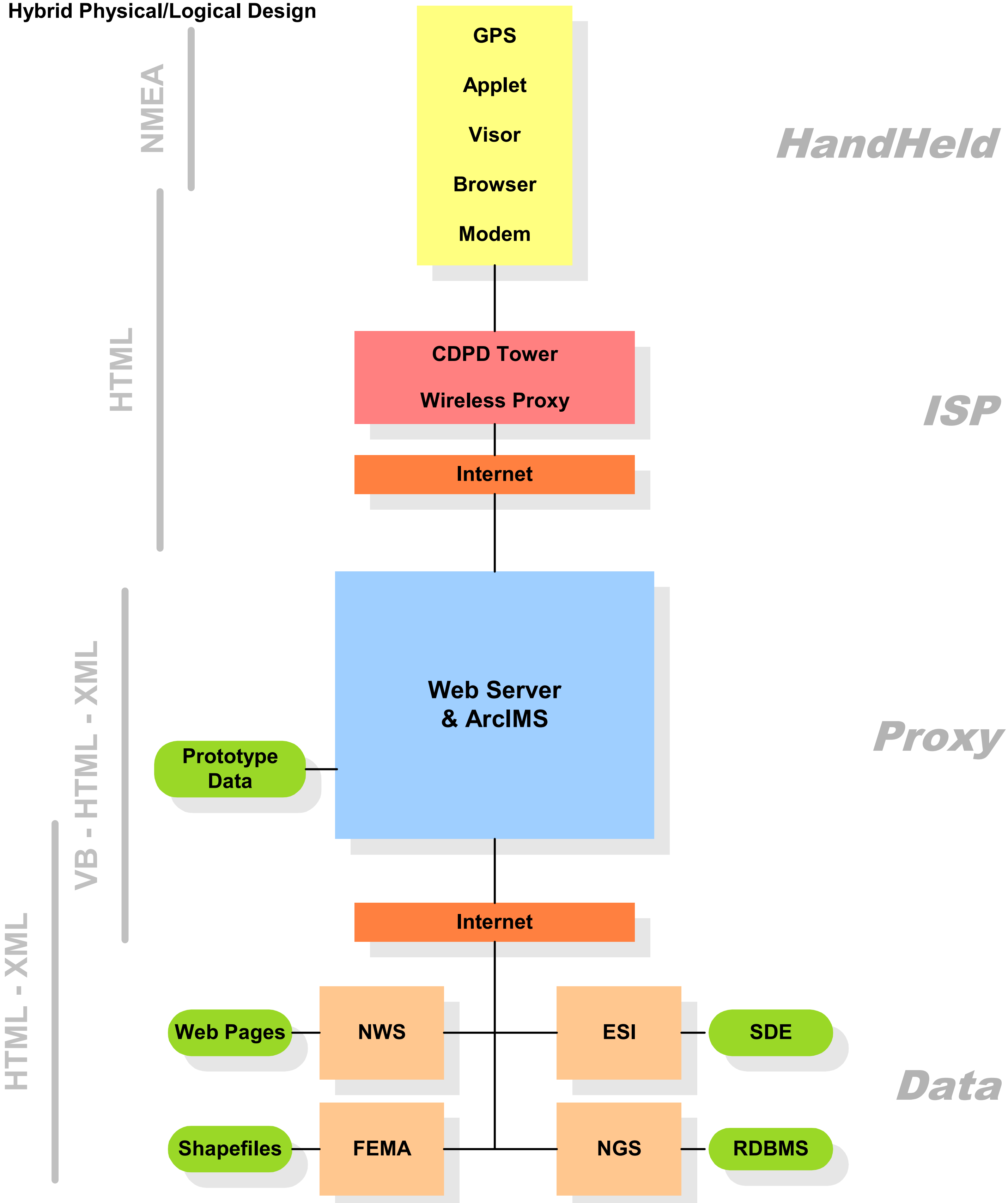


Figure 1. Visor with Modem

Figure 2. Fast Search Interface

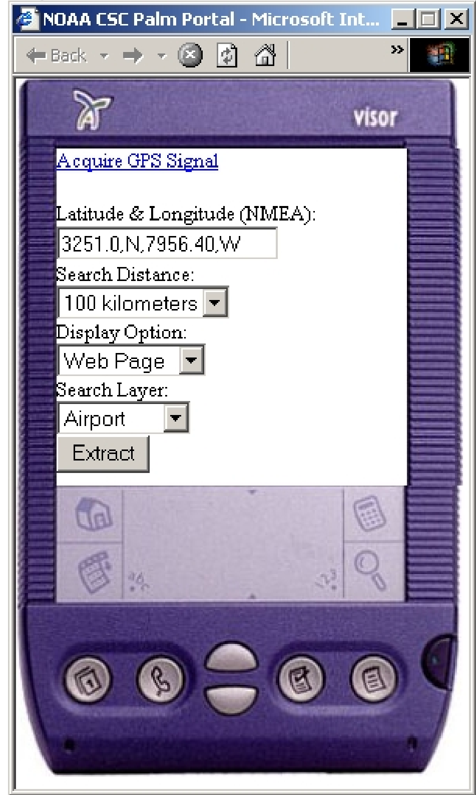


Figure 3. Point Query Output

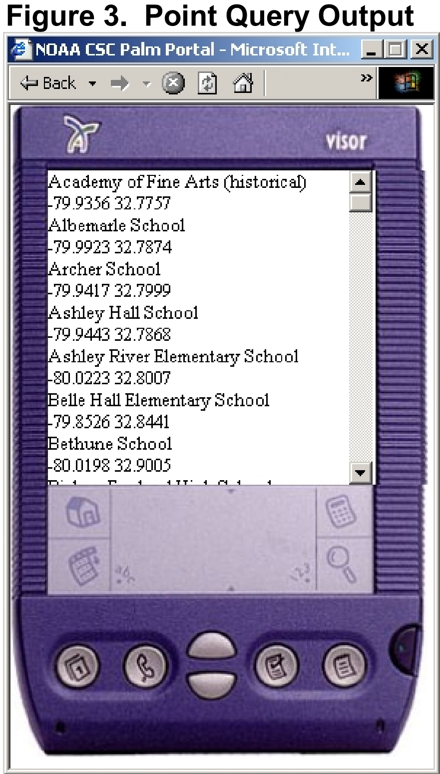


Figure 4. Navigation with the GPS