Geospatially Enabled, In-Vehicle Information Services Architecture: Visual Data Radio

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ABSTRACT

A GPS-augmented radio with minimal processing and display capabilities combined with XML technology and wireless communications can provide a simple yet robust method of delivering spatially enabled data to drivers at low cost with a minimal data-processing burden. This paper explores the benefits of this proposed architecture. In this architecture, the information displayed to the driver is obtained via wireless communication, such as satellite radio broadcasts or wireless internet devices, commonly referred to as WiFi. The data is filtered specifically for the vehicle’s location (geospatially enabled). The traveler views only information on requested services such as restaurants, lodging, fuel, or travel advisories. The revenue format is similar to advertising in telephone directories or via radio. Service providers are charged to be included in the spatially enabled database, much in the same way they pay to appear in the yellow pages or industry trade journals. Additional subscriber fees could be charged for value-added information, much in the same way that cable charges for enhanced broadcasting. Information is displayed in a simplified map format, hence the name the visual data radio.

Key words: GIS—GPS—visual data radio
INTRODUCTION

The information revolution is quickly changing traditional paradigms of data access. Resources available via the internet have become the primary source of reference information for the majority of the U.S. population in a little less than a decade. Quickly maturing mobile data communication technologies and standards combined with the inexpensive and effective location referencing provided through GPS will, within the next few years, enable a completely new paradigm for accessing traveler information and resources while navigating U.S. roads and highways. Products and services currently on the market provide evidence of this rapidly developing area. This paper reviews several existing commercial products and services that exhibit the supporting technologies that will form the basis of the next generation of in-vehicle information services, here called the visual data radio (VDR). The architecture upon which this concept is based comes from the culmination of several maturing technologies combined with an established business model that generates revenue by providing access to and distributing information.

The VDR architecture is diagramed in Figure 1. The VDR is not a product, but rather a conceptual method for delivering location-sensitive data in an efficient and supportable manner. All of the elements in Figure 1 are commercial products or standards. The significance of the architecture is that combining all these existing technologies enables a new method of delivering content to the mobile user. Every block in Figure 1 is a critical path or critical technology. In short, the VDR appears to the user as a display screen within the vehicle. Unlike traditional computer products, the VDR has no keyboard or confusing buttons over-laden with functionality by navigating on-screen menus. The radio is tuned to various services. For instance, the tuner may have selections for restaurants, gas stations, hotels, historic sites, recreation, etc. The display resembles a map and the vehicle itself is marked on the map. Another knob is used to control the extent of the map. The extent may be only a city block or an entire state. Information on the location of available traveler resources (restaurants, hotels, etc.) is communicated to the traveler through a data connectivity infrastructure providing ubiquitous communications. Physical communication is accomplished either through high-speed, terrestrial communications technologies, such as the popular IEEE 802.11 standard and its associated family of products, commonly referred to as WiFi, or through centralized satellite broadcasts. Using either medium, the data exchange is handled via common data structures and formats such as XML. This allows for the decentralization of the supporting application architecture and thus cost efficient management of the whole system. Push technologies made popular on the internet for filtering the broad spectrum of available news and information is embedded in the VDR to access only the requested data and display it appropriately. The GPS equipment automatically provides the vehicle with location coordinates, which in turn enable location-specific display and filtering of data. The revenue model of the whole system is analogous to existing directory advertisements for phone service as well as radio advertising. Businesses pay to have information about their establishment listed in the directory or perhaps even actively marketed through the system. The advertisement revenue funds the infrastructure elements and provides the majority of profits. Travelers pay only for the onboard electronics, which include the display, GPS, and associated communications equipment.
Figure 1. Supporting architecture of the visual data radio

The architectural elements of the VDR are discussed in detail in the remainder of the paper. Each element is briefly explained, and then its role in the VDR architecture is characterized. The goal of this paper is to explore the new realm of information accessibility that will result from the confluence of several quickly maturing technologies. The prognostications are based solely on the authors’ observations and experience and do not reflect any vested business interest. It is the hope of the authors that the evidence presented will begin a discussion that will hasten the movement toward such systems, thus hastening the benefits.

ARCHITECTURAL ELEMENTS

The key technologies and concepts that enable the VDR are briefly explained. Specific technology examples are given as appropriate.

Communications Technologies

A robust mechanism is needed for transmitting information to a vehicle. Two such mechanisms are described below. A satellite broadcast provides the benefit of a single point of administration and global coverage. However, a true broadcast does not allow for two-way communications. The technologies associated with the IEEE 802.11 family of standards provide license-free, short-range, line-of-sight, two-way data communications. These technologies, commonly known as Wi-Fi, are quickly spreading. This technology benefits from rapid, inexpensive, standards-based, license-free deployment. The two-way communications enables capabilities and efficiencies over a pure broadcast-type mechanism. However, the power restrictions and line-of-sight nature of the medium limit the area of any single installation, requiring a network of antennas to provide region-wide connectivity.

Note that cellular coverage is not addressed in this discussion. Its properties are similar in some ways to the 802.11 technologies, but are dedicated to point-to-point voice circuits. The author does not preclude the use of cellular infrastructure, but doubts its ability to adapt quickly to the growth market, as the VDR.
802.11 Technologies

The 802.11 family of technologies has enabled a new generation of portable computing. Since 2002, the number of laptop computers sold yearly has eclipsed the sales of traditional desktop computers. This trend has been fueled in part by the Wi-Fi technology that provides high-speed connectivity, typically at 2 MBits per second or better, to computers without any physical connection. An explanation of the Wi-Fi technology or supporting standards is beyond the scope of the paper. Some important characteristics to understand is that Wi-Fi is full two-way communications, is license-free, line-of-sight and highly directional, and relatively inexpensive, costing roughly $100 for the basic equipment.

In March of 2005, a British company announced a plan to roll out a wireless network to support location-based services based on Wi-Fi technology. The company plans to use lampposts throughout a municipality to mount transmitters. As further evidence of its proliferation, in 2004 and 2005 both Texas and Iowa initiated programs to provide Wi-Fi connectivity at rest stops. The programs are intended to distribute traveler information (such as weather advisory or road closure information) to the traveling public via a wireless internet connection. Travelers with a Wi-Fi-enabled laptop or similar computing device can view a web site with pertinent traveler information. The traveler can also visit other web sites or check email (this may require a small fee, depending on the program). Both the Iowa and Texas WiFi programs cost the respective departments of transportation nothing. The vendor in each circumstance recoups cost (and obtains profit) through a combination of advertising and/or charging for general-purpose internet access.

In the near future, major travel corridors may be blanketed with Wi-Fi access, either for general-purpose internet access or for application-specific connectivity (such as the DVR). Already, 802.11 standards are used for communication-based train control along rail corridors. The Wi-Fi technology has advantages over broadcast in bandwidth and configurability. The drawbacks include limited coverage for a single antenna and the management burden of distributed assets. Low-volume rural roads may never possess significant revenue potential to draw investors to implement the Wi-Fi infrastructure.

Digital Radio Broadcasts

Traditional audio radio is being overhauled for the digital age. In 2005, the National Radio Systems Committee (NRSC) approved a digital broadcast standard. This will pave the way to offer not only improved audio quality for traditional programming of music, sports, and talk, but also data. The data is initially intended to carry such items as song titles and artist information. This would allow the user to program the radio to watch for a specific song or artist on the airwaves and then switch automatically to the appropriate station when available. Once in a digital format, the data capabilities of the radio are completely generic and could be used for a variety of purposes. In relation to the VDR concept, the data capacity of digital data radio could include information on traveler services and updates of local maps. This data is not audio or spoken information, but rather a machine-readable data structure, as discussed in the XML explanation later in the paper.

Satellite-based radio is quickly becoming popular. Currently for a subscription-based service, the audio broadcasts are digitally encoded and transmitted from satellites. The digital nature of the transmission provides for flexibility of content other than audio (music and talk), as described above.
GLOBAL POSITIONING SYSTEM

Initiated as a military application and later popularized through industry, the GPS provides accurate positioning information at a relatively low cost. The OEM circuitry that enables a GPS receiver has fallen below $40 and is being incorporated into many consumer goods, such as cell phones and watches in addition to dedicated navigation devices. The basic GPS receiver provides a three-dimensional position fix in terms of longitude, latitude, and altitude that is accurate to within 15 feet worldwide. GPS is one of the primary drivers enabling many geo-spatial information systems, such as the DVR.

With the DVR architecture, GPS provides location fixes for the traveler in an automobile. The data is encoded in standard formats and used as a filter for querying traveler services databases and cross-referencing the location of the vehicle on available road maps. GPS also enables easy construction and maintenance of traveler service databases. Although address matching is frequently used in mapping software, a direct longitude/latitude attribute for services greatly simplifies application complexity. It can also ease the burden for businesses subscribing to the advertising service. Terrestrial coordinates can be measured by the business owner and input directly. This places the burden for accuracy on the entity that will directly benefit from advertising.

Garmin, a navigation electronics corporation based in Kansas, leads the market in GPS devices in several markets. Their Street Pilot series of products provides a clue as to what DVR can provide. These products by Garmin package a GPS receiver with a mobile computer that contains mapping software and a travel service database. The instrument allows the user to view the location of the vehicle in reference to a route map and surrounding attractions. The primary difference between the DVR and the Street Pilot device is that the information in the Garmin products is static. Although its database can be updated periodically if docked with a desktop computer, these devices can only access data if it already exists in its own database. The DVR is a dynamic system that can retrieve and store data interactively through a mobile communication system. Some data items change very rarely, such as the coordinates that describe roads and highways. However, some information is very dynamic, such as road closures due to weather or amber alerts. The latter cannot be managed in a static database arrangement. It is this time-sensitive data that is most critical to traveler safety.

XML Data Structures and Information Feeds

The extensible markup language (XML) is a natural choice for delivering information that may be sensitive to one or any combination of time, location, and context. In its simplest form, XML presents data and metadata in a strictly structured yet intuitive form. Consider this possible example of a data stream that might be sent to the VDR device:

```xml
<DATA>
  <LATITUDE>390651N</LATITUDE>
  <LONGITUDE>0943738W</LONGITUDE>
  <RADIUS>125</RADIUS>
  <CATEGORY>ATTRACTION</CATEGORY>
    <SUBCATEGORY>MUSEUMS</SUBCATEGORY>
    <SUBCATEGORY>FREE</SUBCATEGORY>
  <CATEGORY>CHILDREN</CATEGORY>
  <CATEGORY>ADULTS</CATEGORY>
  <MESSAGE>Come see the world famous Metropolis Museum of Natural History. Guided tours every 90 minutes. Open 11–9 Mon.–Sat., 11–4 Sun.</MESSAGE>
</DATA>
```
From a business model perspective, the simplicity, flexibility, and intuitiveness of XML lends itself well to direct content management by the advertising customer and furthermore could place the customer in the position of optimizing their advertising dollars based on an *a la carte* product list. Consider the following simple menu of options that could be in a level-of-service contract:

**RADIUS**
- 25 Included
- 50 add $2.50/mo.
- 100 add $3.00/mo.
- 125 add $3.50/mo.
- MORE please contact us…

**MAJOR CATEGORY**
- 2 Included
- 3 – 5 Add $1.00/mo. per each.

**SUBCATEGORY**
- 2 per MAJOR CATEGORY Included

**MESSAGE**
- 125 Characters Included
- 126 – 150 Characters Add $.15/mo. per each character.

The XML structure is necessary to allow electronic parsing and filtering of content appropriate to the user. The XML tags form an agreed-upon lexicon between the traveling public, the electronics that support the VDR, and service providers. It is this type of structured data format and standards that has fueled the information explosion through the internet and will propel geospatially enabled delivery of data into mobile platforms.

Categorization of information and advertising offers the traveling customer control over the messages they wish to receive. The success of this kind of service will be strongly tied to the accuracy and reliability of that categorization. If people looking to purchase a used car happen upon a newspaper, they will likely navigate straight to the classified advertisements, then onto the automobile section. Likewise, if travelers only want to know about lane closures within 10 miles, zoos within 100 miles, and Mexican restaurants within 5 miles, they should have the ability to filter the information they receive to include only those categories. The internet search engine market teaches us that, unless information can be obtained intuitively and the results of filtering the information by category are relevant, the service will not be used.

**Driver Display**

The driver display concept is given in Figure 2. The primary point of Figure 2 is the simplicity of control. The layout reflects the control concept of existing appliances and radios, rather than some type of data entry device. The information is displayed in a map format. The controls are knobs and push-buttons, not keypad entries or complicated multi-function, reprogrammable buttons. This does not preclude the use of touch screens, heads-up displays, or more complicated controls. It simply emphasizes that the interface of basic electronics must have a low-level entry point in order to be accepted across the broad spectrum of society. The form factor for the basic car radio has survived the digital revolution without replacement of the primary controls of a tuning mechanism, volume control, and preset stations. Although rotary dials have, in some models, been replaced by up and down buttons, the basic minimal control philosophy has survived and appeals to a broad spectrum of users.
Internet Backbone and Internet-Based Applications

Similar to GPS, the internet and internet-based applications that have proliferated in the past ten years provide the template for a distributed, maintainable backend data support structure for the VDR. The business model to support the VDR will require extensive input from geographically diverse clientele. Although it is conceivable that all the data pertaining to traveler services could reside in a single, highly fail-proof data center, experience with internet applications indicates that a distributed application architecture is dependable and much more scaleable and expandable. For instance, time-sensitive traveler alerts may emanate from a number of different sources, such as weather services, law enforcement agencies, road departments, or the homeland security department. The time-sensitive data is, in most instances, location-dependent as well. The distributed application infrastructure can more easily distribute load and provide fail-over support in the event of network outages.

The database necessary to drive the VDR and make it useful to travelers is immense. It can be pictured as a compilation of all the phone directories of all municipalities interconnected and searchable. The internet-based application used to input traveler services provides for a highly parallel architecture for data input. The burden of the inputting the data and maintaining its accuracy can be transferred to the business owners seeking recognition as traveler services. Fee collection can be completely automated, eliminating accounts receivable.
Access to data by the traveler, particularly in the 802.11 data communication mode, is streamlined. All updates to servers are conveyed over public infrastructure. Data encryption ensures security and accuracy of information.

**Business Model**

Although the business model is discussed last, it is probably the most critical link in deploying a VDR concept. Methods to generate revenue to recover the cost of deployment and maintainence of a consumer information system vary. Telephone circuitry is billed by the connection. Radio is essentially free to the consumer, except for the investment of the receiver. Satellite radio (with traditional programming) requires a monthly access fee, much in the same way cable TV and dish TV networks operate. However, apart from the telephone system, the majority of consumer data systems derive the revenue from advertising rather than user fees. This is true even for internet access, as described in the Wi-Fi initiatives for Texas and Iowa. Businesses will pay a premium for exposure to customers.

The primary revenue source envisioned for a VDR is advertising. Similar to the phone directory, the system will provide highly directed marketing to customers. The information will not only be location-specific, but also highly time-sensitive. The data is delivered to potential customers as they pass through the service area. In many instances, customers may have no prior knowledge of the services available, so the opportunity to provide relevant, targeted marketing service is immense. The VDR architecture does not preclude the use of other revenue sources; however, evidence from other markets indicates that advertising will be the primary driver.

**CONCLUSION**

The architecture presented for the visual data radio is simply an educated guess of the direction that in-vehicle information systems will evolve in the coming years. The confluence of GPS technology and wireless networking will usher in a completely new paradigm of information access for a mobile society. These two technologies, combined with the robust, distributed internet architecture and the electronic data standards, such as XML, made popular through the internet, will form the backbone of spatially enabled information services, not only for roads and highways, but also for any form of mobility. The proliferation of wireless communications offers the ability to distribute information with a minimal investment in physical infrastructure. Similar to broadcast television, wireless data communication offers the promise to reduce the infrastructure cost to a point that advertising revenue could sustain the system. The information device within a vehicle is the only cost born by the user. The robust and scalable nature of digital data provides a path to upgrade service and content (and possibly even functionality) in the future. It will be exciting to see this application develop in the coming months.

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