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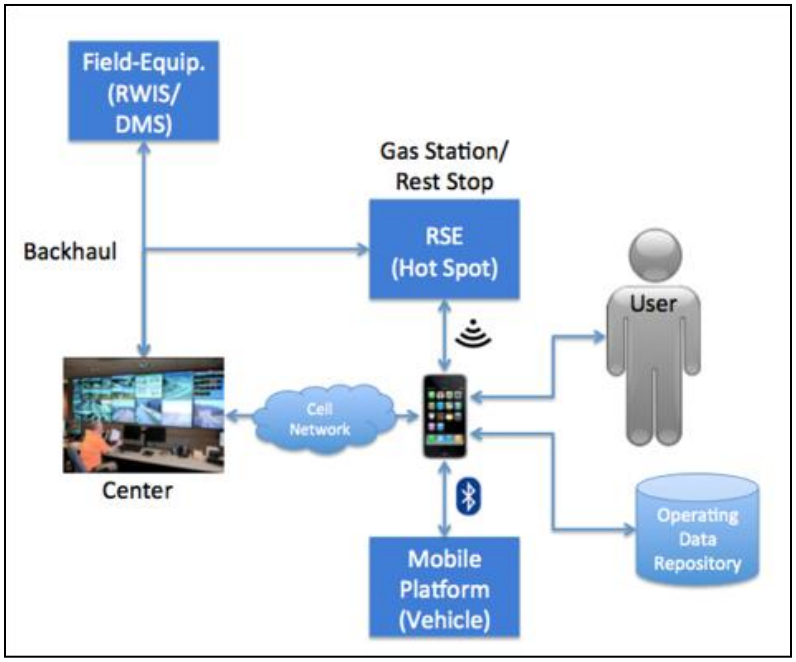

Deployment Strategy for Rural Connected Vehicle Systems

FINAL REPORT

Prepared by

COGENIA Partners LLC

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16. Abstract This document describes the deployment options and the recommended strategy of the deployment of a Rural Connected Vehicle system. The intent of this effort was to identify the needs of rural users and the constraints imposed by the rural environment, and to conceptualize a variant of the connected vehicle system that is uniquely adapted to meet those needs given those constraints.			
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Project Champion

Bob Koeberlein, Idaho Transportation Department, was the ENTERPRISE Project Champion for this effort. The Project Champion serves as the overall lead for the project.

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Revision History

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0.3	8/22/2014	Initial Release
1.0	9/23/2014	Revisions for publication

Deployment Strategy For Rural Connected Vehicle Applications

Introduction

This document describes the deployment options and the recommended strategy of the deployment of a Rural Connected Vehicle system. The intent of this effort has been to identify the needs of rural users and the constraints imposed by the rural environment, and to conceptualize a variant of the connected vehicle system that is uniquely adapted to meet those needs given those constraints.

Earlier documentation developed as part of this project summarized the assessment of the rural user needs, and provided a description of the different rural environments identified by various rural stakeholders (primarily ITS practitioners in rural states). A system design description document provided a high level technical description of the system. This is summarized below in this document.

This document outlines ways that the system could be deployed, specifically the technical approach to deployment, and the strategy for executing that technical approach. It also outlines what could be achieved at which rough timeframes, and outlines the key challenges and open questions.

We have attempted to maintain a strategy that imposes the lowest impact in terms of deployed equipment, opting to take advantage of available devices such as smart phones in the early stages so that benefits, while perhaps not as complete as could be achieved with fully embedded vehicle systems, can be realized early on, thus motivating evolution and growth of the system. We have also assumed the use of communications media that is already deployed and easily available as a way to bootstrap the system (since DSRC equipped vehicles and terminals may not be commercially available or cost effective for many years.) The strategy does, however, assume evolution toward DSRC based solutions, so that as this technology becomes more commonplace, the Rural Connected Vehicle system can add features facilitated by DSRC, and can acquire enhanced performance provided by DSRC. The system does, however, maintain a specific character that is distinct from conventional (urban oriented) connected vehicle systems in that it is specifically designed to provide useful services without assuming dense connectivity (from widespread cellular service or from dense DSRC roadside equipment deployments). Instead it takes advantage of the relatively sparse road network that is characteristic of the rural environment, and uses this to determine what information to deliver to which users so that they can be well informed without requiring dense and frequent connectivity.

System Concept Overview

The rural connected vehicle system is composed of several overlapping elements intended to provide roadway information and connected vehicle services for rural travelers on an opportunity basis. i.e., when connectivity is available. The system relies on the observation that rural roads, by definition, are relatively sparse, so a traveler moving along a particular corridor is likely to continue along that corridor for some distance, and there are few opportunities for the road network to branch significantly. This means that the system can deliver information to the traveler when connectivity is available (for example at rest stops or gas stations), and since there is a relatively limited variety of routing options, the system can deliver information for all options in that vicinity, and then the user's system can present the information as it becomes relevant based on the user's location. This approach eliminates the need for connectivity at every location information can be used.

By way of an example, at a rest stop the user's device (smartphone, car system or dedicated device) would connect using WiFi, and request traveler information for the region around that rest stop. The system would provide roadway information for all of the road segments ahead[1] up to the next known connectivity point. As the user traveled along the road network, the received information would be presented based on the user's current location.

The system contemplates at least WiFi and cellular connectivity, so when there is cellular coverage, the user's device will connect periodically to obtain updates, and when there is WiFi connectivity, it will use that link to obtain updates. The updates will include any information relevant to the road and traveling environment up to the next known connectivity opportunity along each of the roads in that section of the road network.

It is also anticipated that at these connectivity points the user's device will report out any collected probe data that it has gathered during the most recent trip. This information may then be used to generate and update some portion of the information provided to other motorists in the area.

Required Components

As is described in the Connected Vehicle Reference Implementation Architecture documentation the system includes a mobile segment, a roadside or field segment, and a center segment. The field equipment may be existing RWIS installations, or it may be roadside equipment in the form of WiFi hot spots located in places where vehicles are likely to stop briefly, for example rest areas, gas stations, etc. This is illustrated below. We have assumed that the mobile element is implemented by some sort of hand held device such as a smartphone. This does not preclude the use of installed equipment in vehicles, but it appears more realistic to begin the deployment with so called Nomadic Devices that are carried into the vehicle by the user.

[1] Note, if the system can determine the direction of travel, then this can be provided as part of the request and the system will not deliver information about the portion of the road system behind the traveler. If this information is not available, then the system will deliver roadway information about all road segments in all directions, and some of this information will simply not be used.

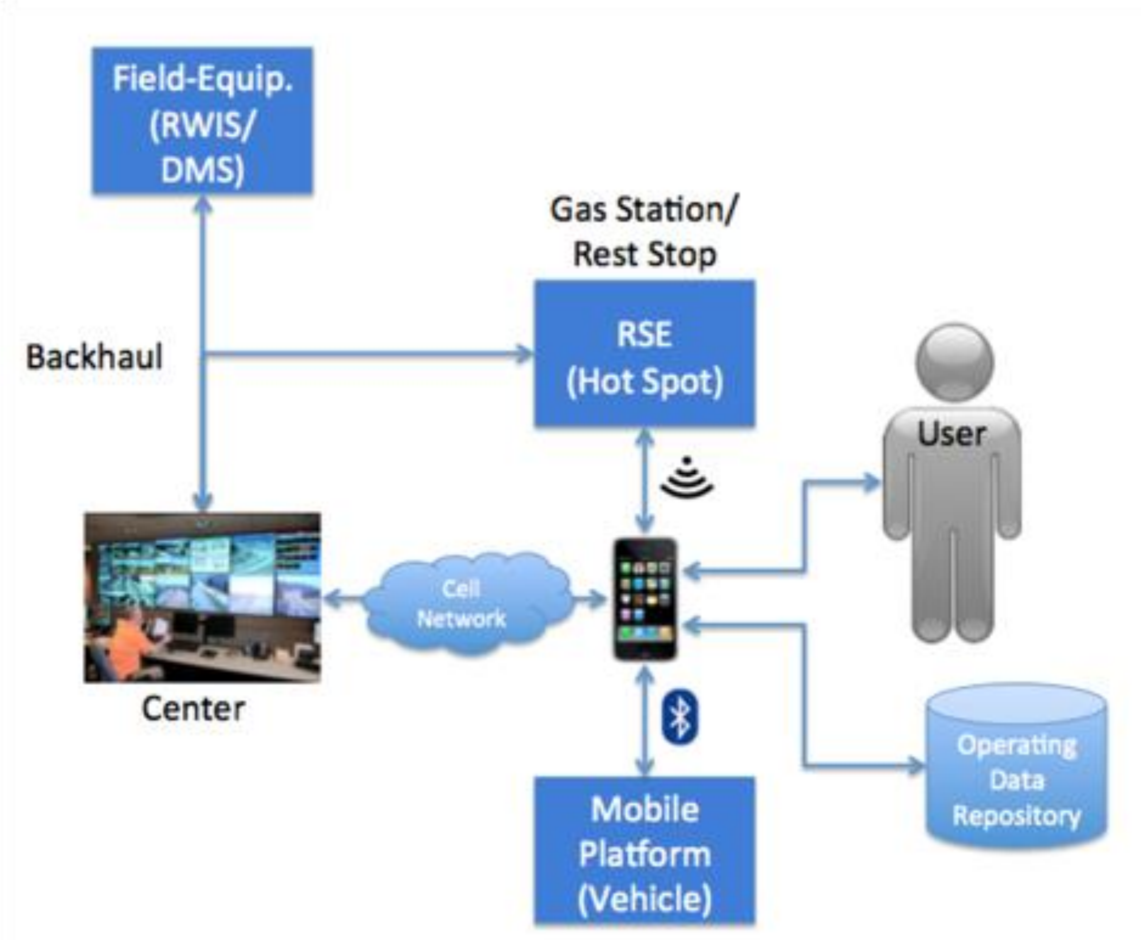

Figure 1 Conceptual System Diagram

This nomadic device may have an interface to the vehicle systems, for example via the On Board Diagnostic (OBD-II) connector, MirrorLink or Apple's CarPlay. This interface makes it possible for the mobile device to collect vehicle operating parameters, which may be useful to determine road conditions on the road network. The center element then takes this data, together with RWIS and other data to generate road conditions and alerts arranged according to road segments and regional network areas.

Communications between the mobile element and the center is provided by the cellular system (when and where available), and by roadside hot spots located and convenient locations along the road network. In areas where these roadside units and/or cellular coverage is more dense, the information provided by the center for that location will be consequently less geographically broad (i.e. more focused), and where the roadside and cellular network is more sparse, the information will be more geographically broad.

Thus, at a high level, deployment of the system requires that the center element be available, that cellular and potentially WiFi or DSRC (and other emerging technology) communications with supporting backhaul to the center is available over at least some of the road segments and major junctions of the road network, and that mobile devices are available and configured to access the center element when connectivity is available. These elements are described in greater detail below.

Center Element

The center element is a server configured to respond to requests from mobile devices. These requests will generally include the location of the mobile device. In some cases additional information such as the direction of travel may also be provided. On the basis of the location, the type of vehicle and the direction of travel, the server will respond to the request by providing a bundle of roadway, incident and weather information and alerts associated with road segments reachable from that location.

The roadway information, weather and incident information will either need to be generated by the server itself, or it will be provided from other systems. For example the RWIS systems may provide geo-coded weather information, and the server itself may generate travel times, traffic data and incident data based on information received from vehicles out on the road.

The center element is thus primarily a server, wherein the information provided to requesters is organized by location and road segments reachable from that location between known connectivity opportunities. This is illustrated notionally below.

Center elements with these capabilities are currently deployed in some 511 systems. We envision the capabilities of these systems are significantly enhanced and directed towards rural needs identified in the needs document. The basic technology is familiar to many state DOT's.

Mobile Element

The mobile element provides communications, location, a user interface, and a platform for supporting application processes. In some cases it may also support an interface to the vehicle through which applications running on the platform can access vehicle data. The mobile terminal may be an in-vehicle device, but it may also be a consumer device such as a smartphone running appropriate applications. As such, while the specifics of the hardware may be different and may change over time, the key functional aspects of the mobile device are communications capability, and applications to both connect to the center element, to provide information to the center element, and to make use of information obtained from the center element.

Key to this deployment plan is that it supports the evolution of mobile elements from existing smart phones in widespread use today to embedded systems using DSRC communications and having the complete functionality envisioned for connected vehicle systems.

Roadside Element

The primary roadside elements expected in the Rural Connected Vehicle system are simply communications access points. It is expected that over time these access points may evolve to use DSRC (802.11p), but near term they are expected to use WiFi. WiFi is available and in common use today, and it is generally available on consumer platforms such as smartphones, and is inexpensive and relatively easily deployed in the field. Because WiFi is relatively short range and uses IP communications, it is not suitable for transient data exchanges such as those that would be associated with a vehicle passing the hot spot at high speed. As a result, the roadside equipment for the initial deployment is likely to be located in areas where mobile terminals are likely to be relatively stationary and are likely to remain in the hot spot for a sufficient time period to allow the mobile terminal to access the center to provide and obtain information. It is expected that these access points will be located at rest areas, truck stops, gas stations, and other related facilities.

Other options for roadside element to vehicle communications include LTE direct. This is an emerging standard which enables low latency data transfers over short range using cellular devices. This may form an intermediate step between Wi-Fi and DSRC, potentially enabling data provisioning at shortstops, such as traffic lights, or even while vehicles are moving.

Field Equipment

Field equipment is not directly a part of the rural connected vehicle system, but it is expected to be a source of information that the system will use. For example, the center element will derive and generate weather and roadway information messages for different road segments in part from information received from roadside systems such as RWIS. There are also likely to be traffic signals and other field locations with existing ITS resources which may provide power and communications for a roadside element.

Recommended Deployment Strategy

NHTSA is moving towards a mandate for DSRC technology and associated processing in vehicles[2]. This will likely involve every new vehicle being so equipped starting about 2020, thus DOTs can be assured there will be a growing audience for data that supports connected vehicles. However, because the annual new vehicle build (~12M units) represents only a small fraction of the vehicle fleet (~250M units) the growth of fully equipped vehicles will be relatively slow. In the short run other existing devices, communications, and data processing technologies can be used as surrogates. These surrogates will not have the full capabilities of an embedded system, nor will they require the same level of integrity and reliability, but they will serve to validate functionality at the center and field elements in anticipation of a fully capable service, and they will provide early benefits to rural users who might otherwise be under served by urban focused DSRC-only solutions.

We recommend that the initial deployment of the system will take place using existing consumer devices such as smartphones and other devices capable of supporting application downloads and at least WiFi communications. This strategy, based on the realities of the deployment environment and time scales, means that there is no hardware development required initially to deploy the system. Instead, the system can be initially deployed using mobile and fixed equipment that is commercially available at consumer price points today. In order to realize this it is expected that the primary development work required to deploy the system is the development, distribution and deployment of application and access software. This is discussed in greater detail below.

[2] See NHTSA's Advanced Notice of Proposed Rulemaking for Vehicle to Vehicle Communications Technology.

In summary the deployment strategy is:

- Rely on available mobile consumer devices and available existing communication channels/media
- Develop center based services (e.g., web service) providing road and weather data on a location request basis. This data is aggregated according to the road segments that can be reached from the requester's location between known connectivity opportunities (hot spots, cellular coverage, etc). Development of coverage models can be based on data collected from vehicles.
- Develop and publish the access protocol for the center server
- Establish and deploy a suitable, secure WiFi (and other) hot spot access protocol to allow mobile devices to access roadside access points without undermining the security and integrity of the backhaul and center system
- Establish policies governing privacy and the use of data
- Establish end user license and system use agreement that resolved any liability issues associated with using the system or any of its application software
- Provide reference application and interface software to allow smartphones to access the WiFi access points and to obtain access to the server via either WiFi or cellular links:
    - Hot Spot access and user authentication
    - Server access and user authentication
    - User application for request and location based presentation of information provided by the center element
    - User application for establishing interface to vehicle and for collecting vehicle information and delivering it to the center
- Establish roadside access points and associated backhaul to the center element
- Evolve the system to provide access via DSRC based roadside equipment (not necessarily limited to low speed/stationary sites (e.g. at intersections and road junctions vs rest areas).

The relationship between the Rural Connected Vehicle System and other connected vehicle systems (for example a wide scale urban deployment of DSRC) is illustrated in the figure below. The key difference between this system and other connected vehicle systems is that it is assumed that this system will initially be V2I only, and because of the communications constraints it will be a request/response system.

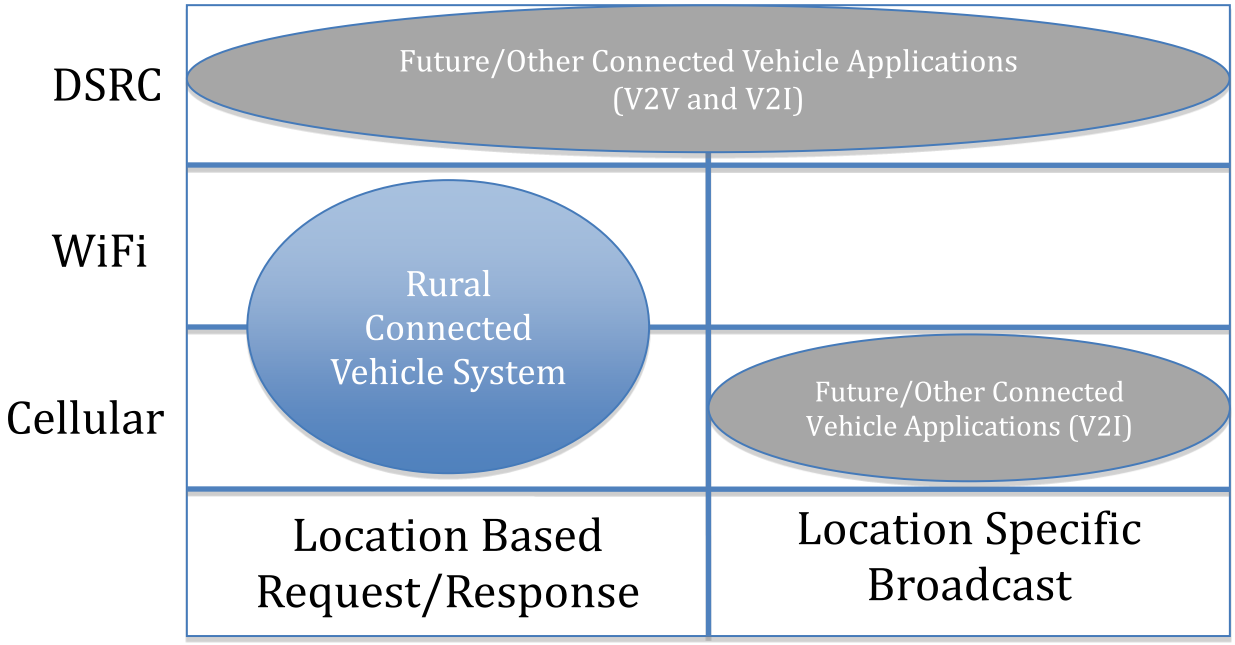

Figure 2 Near Term Rural Connected Vehicle Functional Implementation

Over time, DSRC equipment will become increasingly available. As these DSRC based systems emerge the Rural Connected Vehicle system can add DSRC roadside equipment to provide roadside access so that the existing request response services can be provided at additional points along the roadside (e.g., for moving vehicles), and various V2V services not currently anticipated for connected vehicle, but potentially useful in the rural environment. This is illustrated below.

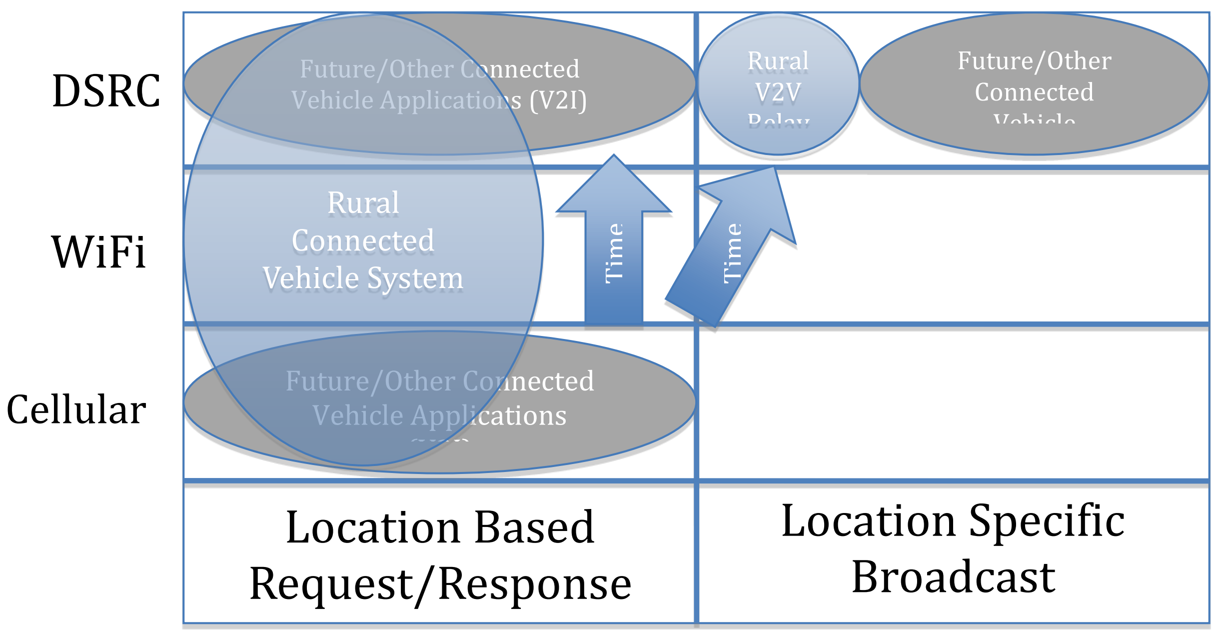

Figure 3 Longer Term Rural Connected Vehicle Functional Implementation

Examples of this are V2V relay, where information can be carried by vehicles out into the road network where it can be broadcast to vehicles that may not have yet received such information. This approach creates what might be considered a "virtual roadside unit" that can deliver timely information in an area as long as there is some modest level of traffic to maintain the message.

Recommended Technical Sequence for Deployment

1. Decide on reference applications for support of rural needs (recommended ATIS application which is already fairly mature possibly providing weather over a mountain pass). Identify a major corridor with at least intermittent connectivity. Additional applications may be added to the package as they become available. Likely a strictly opt-in application initially with mobile unit providing path information for evaluation purposes migrating to an optional opt-in.
2. Develop prototype Center application (or modify an existing application) and Mobile application for iOS or Android using existing CV standard. The mobile application requests data for its location and also provides some data on recent driving history and the previous use of the app.

   Additions to existing applications include:
    a. Location based request for information
    b. Information on past vehicle path
    c. Provisioning information based on expected path (e.g. different information sets for vehicles going different directions, where known)
    d. Feedback on actual path and information usage (e.g. did the vehicle go where expected? Did it use the information?)
3. Validate operation within cellular coverage.
    a. Tailoring of data package to effectively meet the needs of drivers.
        i. Develop algorithms for efficiently providing data relevant to imminent travel.
    b. Data usage once provisioned.
        i. Determine usage by the subjects.
    c. Collection of data from vehicles.
        i. Determine the value of preceding vehicles for provisioning.
        ii. Data aggregation and processing to build various models of traffic, hazards, weather, etc. (models likely supplied from other projects)
        iii. Validate business models for data processing (TMC? PPP? Private contractor? Commercial entity?)
    d. Validation of message standards.
4. Extend operation to Wi-Fi or LTE direct hotspots along a roadway with poor cellular coverage (preferably one with frequent rest stops having power). Possibly multiple deployments with different partners.
5. Validate operation using intermittent hotspots as for cellular. In addition:
    a. Determine back end connectivity requirements based on vehicle counts.
    b. Validate partnership models for deployment
    c. Identify ancillary services that may aid in deployment (financial, public acceptance)

6. Deploy DSRC hotspots at key roadway junctions with connectivity as identified above.
7. Upgrade the application to support critical services such as curve warning.

A general timeline for a possible deployment is illustrated in Figure 4.

Example Deployment Timeline

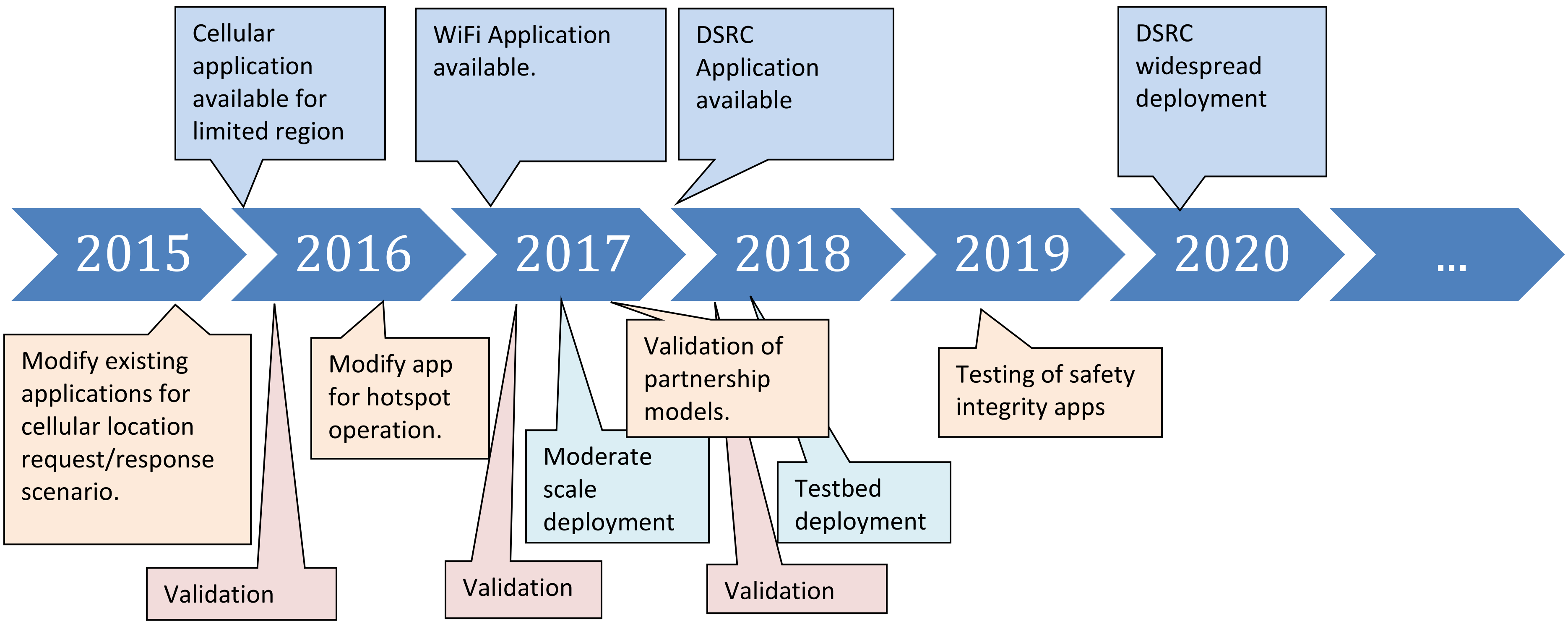

Figure 4 Example Deployment Timeline

Potential Applications

The applications associated with the Rural Connected vehicle system are similar in function to those for an urban system, but they have important differences.

Specifically, information delivery related applications must deliver information for all of the road segments ahead of the user vehicle that lie in non-coverage communications zones. This means that the messages may contain more data than their urban counterparts, and the user side applications must be able to select and present from this larger body of content as the user moves along the road network within the non-coverage zone.

Similarly, data collection applications (e.g., probe data) must collect data over longer distances than might be used in an urban environment because the road network between coverage zones may include significantly longer road segments. For example, the urban version of a probe message might limit the scope of the collected data to a 2 Km segment to preserve privacy and to limit the volume of the data collected between upload points. In the rural environment, coverage zones may cover tens of miles or more, and such policies would mean that the probe data collection would only address the edges of the non-coverage zone. This may impose some privacy issues which are discussed in greater detail elsewhere in this report.

An initial set of these applications are described briefly below.

Road Conditions:

This application is similar to ATIS and road hazard information, except the messages are tailored to the user's direction of travel, and they contain hazard information for all road segments (for which there is hazard information) in the non-connectivity zone ahead of the user (i.e. between the user's current location and the points where any of the road segments in the non-connectivity zone re-enter another connectivity zone.)

The types of data expected to be provided are detected incidents (e.g., accidents) , hazards such as rocks, trees, dust, flooding, ice and snow; potential hazards such as animal crossings , low grip, traffic, etc.

Weather Conditions

This application is similar to the road condition application above, except it concentrates on weather conditions, typically over a larger area, and it is not necessarily focused on the road condition itself. Examples include wind, rain tornadoes, etc.
The basic operational nature of the application is the same as the road conditions application.

Data Collection

This application is similar to the probe data application described in the literature for urban applications. Key differences are that the geographic distances involved are potentially much larger, and the types of data may be different. The increased reporting distances may raise privacy concerns since the user could theoretically be tracked over a larger distance. This is discussed in the Issues and Open Questions section below. As for different data parameters, a key objective of the data collection for rural applications is to detect road conditions out in distant, and unsensored areas of the road network. Since the vehicles are actually on those roads, they have some ability to report on the condition of those roads. The result of this will be that this application will be more focused on detecting and reporting anomalies in vehicle operation. For example if all vehicles traveling on a segment swerve relative to the road path near the same location then this may mean that there is some sort of hazard at that location. Depending on other data collected from the vehicle it may also be possible to infer the nature of the hazard.

The data collection element of the system may thus be more focused on reporting on anomalies, and the center based analysis elements of the system will likely be more focused on correlating reports and inferring causes so that they can then generate road and weather condition reports for use by the other applications in the system.

Drive Plan

A unique rural application is the “drive Plan”. Like an aircraft flight plan, or a boat float plan, the drive plan allows a user to check-in at locations where they have connectivity, and to indicate the approximate location and time that they expect to re-enter connectivity elsewhere in the road network. If the user has not checked in within some interval from the expected time, then the authorities are alerted and they can determine the best action to take.

This application carries some potentially significant privacy issues that are discussed below.

Ideally, once activated in a rural region the application would also operate somewhat autonomously (to avoid the situation where authorities are alerted because a user forgot to check-in.) So, for example the application might include a map of known connectivity and activate a check-in or check-out message based on location. It could also maintain some measure of connection integrity and check out or in when it sensed that it was nearing the edge of connectivity or was re-entering a connectivity zone.

Virtual RSE

While not specifically an application, the virtual RSE concept supports the Road Conditions and Weather Conditions applications. This application depends on some form of local communications capability (e.g. either DSRC or LTE Direct). In concept, a user’s system would receive information at some location where it had connectivity. It would then re-broadcast that information according to rules such that the message would propagate down the road network until it reached the location where it was relevant (for example the vicinity of a hazard). The message would then be re-broadcast and saved by user systems in the area, so that new users entering that area would acquire that message. It would then be presented to the user, and also re-broadcast to other users. In this way, the message travels down the road network to a location, and it then persists there as long as there are user systems in the area. This is, in effect, a virtual RSE that provides services with no localized roadside equipment and no backhaul communications.

Potential Deployment Partners

There are two large classes of potential deployment partners for the technology envisioned herein. The partnerships come into play with the move to hotspot technologies since cellular capabilities are already well-established and partnerships are not required.

Technology Partners.

These partners are primarily concerned with deploying connectivity technologies and stand to benefit from the greater availability and use of connectivity applications, such as those we propose. Obvious examples are Verizon wireless and AT&T, although there may also be significant appeal to cable providers and other wired communications companies which have the technology to access the hotspot, and may not care about the mechanism for short range wireless connectivity. Technology partners are looking for utilization of their technology and popular applications that might drive adoption. Wi-Fi technology is widely available and not proprietary so there is little benefit to any partner for the use of this technology. This is good from a DOT perspective because the technology choice does not limit the clientele thus limiting risk of being accused of commercial favoritism. Incentive to deploy hotspots with this technology would be to provide visibility for other services such as Internet connectivity. This is consistent with AT&T strategy of building a Wi-Fi network across the country with full accessibility only for AT&T customers.

Verizon supports Wi-Fi but also has an interesting play in the deployment of LTE direct technology. This is a technology that works with the basic cell phone standards and would be available on any Verizon cell phone. While the business models for this technology have not been completely developed, it appears that Verizon will not charge customers for this service, but will charge companies that deploy LTE direct hotspots since they are accessing Verizon customers. Verizon might be willing to eliminate or reduce fees for the deployment of transportation hotspots with the understanding that they bring visibility to the system, possibly requiring some advertising or other indication of Verizon support at the hotspot locations. This technology provides a good surrogate for DSRC and is likely to be entering the market in late 2015.

Commerce Partners.

Many rural areas work hard to get drivers off of the through roads and onto city streets in order to provide goods and services. This function is often embodied in a city or regional Chamber of Commerce. They are looking for ways to capture drivers approaching their town, and would welcome an upstream mechanism for advertising. They are very likely to be very receptive to installing a hotspot by the roadside as long as they can also provide advertising services. These advertising services could be provided through a different application, although some driver related services could potentially be provided through a DOT service (much as roadway signs for gas and lodging are enabled today).

Another approach is to work with a company like Trip Advisor which is actively seeking delivery mechanisms for their content and could be a very good fit with traveler information.

These partners are likely to provide financing and possibly build out of various hotspots in conformance to, or least compatible with, DOT specifications.

Open Issues and Questions to be Resolved

As described in the system design report, rural areas are characterized by fewer sensors and less capability for data collection. In order to overcome this constraint existing sensors, i.e. those on vehicles driving rural roads, must be used more effectively than the sensors on cars in urban areas. This can be done by vehicles collecting and storing much more information in rural environments and carrying that data (data caching) to connectivity zones where it can subsequently be communicated to the center element. This approach has significant implications for user privacy which must be addressed in order to enable optimum performance in rural ITS applications.

In most connected vehicle work to date the goal has been to implement a system where privacy and anonymity are insured by the system itself. This constraint severely limits the effectiveness of rural connected vehicle applications. For example, the Drive Plan application which provides an origin and destination to authorities in order for the authorities to ascertain the vehicle has arrive safely at its destination, and to find the vehicle if it does not arrive safely, has significant privacy implications. However, we believe this application would provide significant peace of mind to many rural travelers, especially in mountainous areas or in extreme weather conditions. Rural areas do not provide the crowds that enable easy anonymity, or ensure another driver is there to help when you need them, and the distances are necessarily larger, so it is unclear if these sorts of application changes (more data over larger areas, divulging origin and destination, etc) actually impact privacy in any substantive manner, and it is unclear how much users may be willing to impact whatever level of privacy may exist in order to obtain greater peace of mind.

Commercial applications have shown that many drivers are willing to give up some modicum of privacy in return for better services. Governmental agencies have different requirements for privacy than commercial entities. It may be the case that governmental privacy constraints severely cripple their ability to provide rural ITS services, in which case certain aspects of the deployment may need to be left to commercial entities.

Any deployment of these applications must squarely address the issue of what data is considered personally identifiable information, the degree to which such information may be collected from willing participants, and what restrictions must be imposed to assure that such information is protected.

Best practices for data privacy are becoming widely accepted and should be evaluated for use by rural ITS service providers. To the extent that these constraints are not acceptable to DOTs, they may consider outsourcing some or all of the services to private companies that are more accepting of this risk, and for whom establishing a trusted relationship with a user is a matter of conventional business operations.