Vehicle-to-Vehicle Communication for Enhanced Traffic Safety

Abstract

Vehicle-to-Vehicle (V2V) communication promises a new wave of innovation from traffic efficiency, traffic safety, infotainment, and enhanced services. This paper presents traffic safety as the market driver for enabling V2V communication to gain criticality. It also examines specific solutions to bridge the current gaps in enabling V2V communication.

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Section I: Introduction: Hypothesis and Topic

It could be argued that the incorporation of advanced technology into consumer products is a market driven phenomenon. Build a better mousetrap and they will come. It is the American way. It is the very definition of capitalism as one of the cornerstones of the U.S. economy. From iPhones, to memory chips to refrigerators, we see this dynamic playing out. There are however segments of the U.S. economy where alternate motivations for technology incorporation exist; the automotive industry has proven a leader in this regard.

Consider concerns in the 1970s regarding American dependence on foreign oil: a situation with political, economic, and practical dimensions. This phenomenon, when combined with various environmental concerns came together to motivate the U.S. Congress to develop and promulgate the so-called Corporate Average Fuel Efficiency (CAFÉ) standards. These standards drove American and ultimately foreign auto producers to spend billions of dollars developing and improving technology affecting automotive fuel efficiency. Today, automotive consumers around the world enjoy fuel efficiencies called impossible only a few decades ago.

Another example of somewhat unique motivation for technology incorporation in consumer products is the concern for safety – and again in this case, in the automotive segment of the economy. Forty years ago, antilock brakes (ABS) began appearing as optional features in high-end cars. Today, over 90% of cars sold in the U.S. have ABS systems. This is even more interesting when we examine the array of studies done on the efficacy of ABS systems. While results vary, several studies have concluded that while ABS systems have had significant impact on the frequency and severity of highway crashes involving commercial multi-axle vehicles, the effect on light-duty vehicles (is essentially trivial. Yet in spite of these findings, year by year, we see increased adoption of ABS systems into every segment of the automotive market. Clearly, the U.S. concern for safety, whether it is consumers worried about it, or auto companies using it as cornerstones in advertising, or insurance companies building it into their rate structures, has proven itself as a standalone motivation for the incorporation of advanced technology into American automobiles.

Today, we are confronted with the idea of the internet of things (IOT). It is a concept that dazzles the mind – in product features, in commercial possibilities, in social implications, and on and on. If we consider how this IOT concept can get focused on the internet of cars (IOC) and even more focused on vehicle to vehicle (V2V) communications, we quickly grasp several key dimensions or enablers which bound this argument and which will provide a basis to move this technology forward.

These key dimensions include consumer demand, government mandates and standards, technical capabilities, physical infrastructure, and key social factors. Our hypothesis lies on traffic safety as the market driver for enabling V2V communication to gain criticality. In the following sections, we will examine these factors as we examine the evolution of V2V communications.

Section II: Market Overview

While there have been several pilots and studies, there is no solution currently available that allows one vehicle to "talk" to another vehicle. There are few available as applications on smartphones, which can serve as approximations. But, as vehicle systems are not integrated with smartphones, the functionality available in these solutions is limited to sharing of data input by users. Additionally, information reported must round-trip through the Internet. While they cannot provide rapid in-situ safety features that true V2V can, their features and usage can be instructive in terms of the value and adoption rates of products with demand side economies of scale.

Waze

Waze is a smartphone-based navigation application that uses crowd-sourced data to provide better traffic information. It also allows users to report road hazards (weather, accidents, construction, police activity, etc.). These reports are immediately visible to other Waze users nearby. Other users can use this crowd-sourced data to modify their behavior, therefore increasing safety.

In June, 2013, Waze was acquired by Google, Inc for $996M. [1] At that time, there were approximately 50 million active users of Waze worldwide. [2].

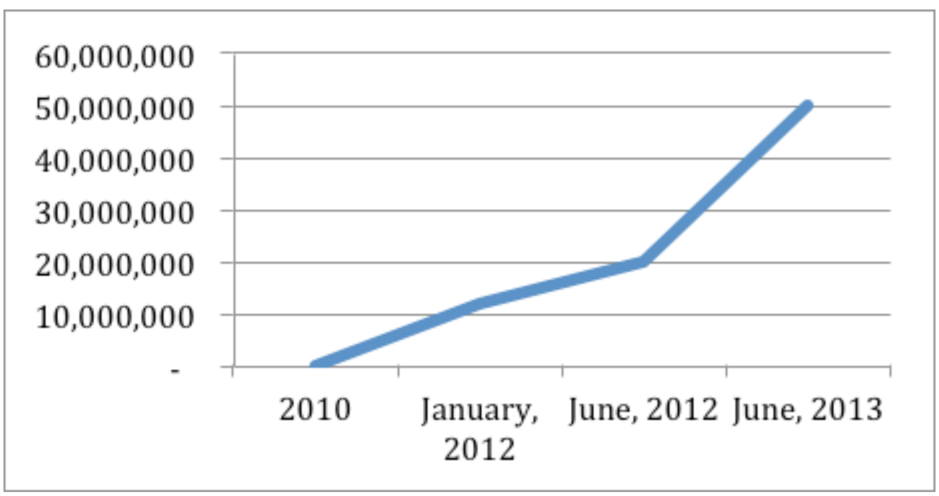

Figure 1-1: Active Waze Users over time [3]

Escort Live!

Escort Live is a service that integrates certain radar detectors manufactured by Escort Incorporated with a user's smartphone. The primary goal of the system is to provide users of these products increased police presence information in order to avoid traffic citations. When police radar is detected, the event and location is automatically sent to other users of this system.

There is no publically available information regarding the number of users of Escort Live!. There is also no indication that Escort Live! has gained enough users to see the effect of demand-side economies of scale.

As stated, these offerings are at best approximations of the benefits of automatic V2V safety technology. These systems cannot provide automatic and time-critical safety features (see details in Appendix) that true V2V safety systems promise, such as:

1. EEBL: Emergency Electronic Brake Lights
2. FCW: Forward Collision Warning
3. BSW: Blind Spot Warning
4. LCW: Lane Change Warning
5. LTA: Left Turn Assist
6. IMA: Intersection Movement Assist
7. DNPW: Do not pass warning

Section III: Technology

There has been an active work on Vehicle-to-Vehicle communication for the past 15 years with participants from government, and regulatory agencies, Standards organizations, most of the key automobile manufacturers, leading players in the silicon industry for communication and hardware platforms, and leading global software players.

The U.S. Department of Transportation (USDoT) has been one of the leading drivers in this space. Many other countries follow the USDoT's lead in research and technology directions to chart / mirror their own paths. The research arm of the USDoT, RITA (Research and Innovative Technology Administration), has been publishing reports for more than 10 years on the subject of V2V communication and innovations related to this technology. The communication technologies driven by Standards organizations within IEEE, ISO, and other as well as industry consortiums have culminated in technologies for short, medium and long range communication. These technologies are used for V2V, V2I (infrastructure), V2R (road side equipment), and other infrastructure related communication requirements. An important shift that RITA has highlighted in recent years is that communication to the vehicles, due to new disruptive technologies, will be the driving force for this technology rather than infrastructure development along roads [4].

There are still a number of open areas for innovation especially in the end-end verticals. Figure 3-1 provides a snapshot of the current players in this technology space

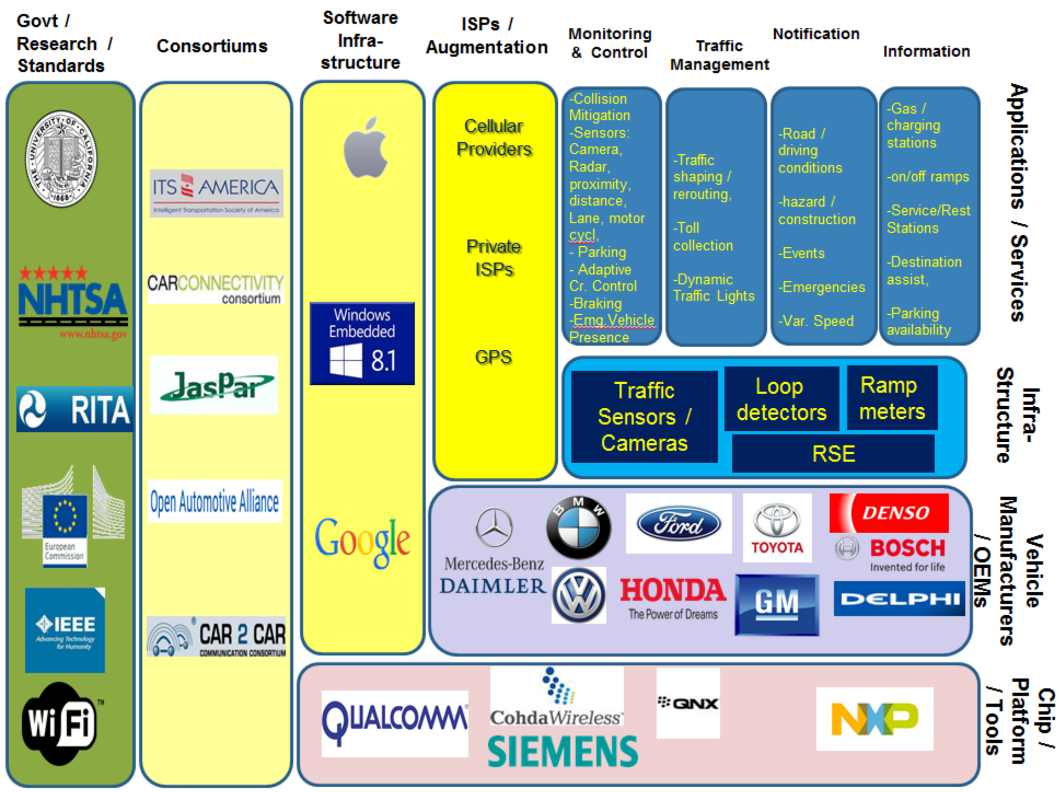

Figure 3-1: Vehicular Communications Space Technology Players and Segments

End-End Solutions with Intelligent Transport Systems

Vehicular communication is largely motivated by the need to provide an Intelligent Transport System (ITS) [5], an effort initially lead by the USDoT. ITS are advanced applications to provide innovative services, traffic monitoring and management, information updates, and increase safety through smarter use of the transport network [6]. ITS has expanded and is more global in nature today with national and international organizations spanning the U.S. Europe and Japan.

ITS utilizes a number of technical areas that spans communication technologies, sensor, detection and positioning technologies, and platform and computational technologies. Artificial intelligence is thought to be an important corner stone amongst computational technologies. ITS communication encompasses short, medium and long range technologies. IEEE 802.11p with DSRC/WAVE has emerged as the main short range technology. Cellular communication technologies such as GSM, 3G/4G LTE are proposed for long range. Traditional GPS can provide position information. Position information can also be obtained by cheaper methods utilizing triangulation or vehicle identification by RSE sensors (Road-Side Equipment). Camera and roadside loop sensors are also used to gain vehicular information.

A driving force in ITS application is traffic safety and traffic monitoring and management.

Traffic safety can be significantly enhanced by information that alerts drivers on the presence of other traffic, safe traffic movement alerts (e.g. moving into an intersection), notification of traffic slow down, accidents, construction, and weather conditions. Traffic safety also includes emergency calls, especially automated.

Traffic monitoring is partially motivated by the need to monitor larger security issues (e.g. by the department of homeland security), but also to enhance eventual traffic safety (e.g. requirement of traffic signals, road expansion, HOV lanes requirements, etc.). Traffic monitoring will be a critical part of traffic control and shaping to allow better overall flow of traffic (providing alternate routes, variable speed limits, detection and enforcement of road usage rules violation). Traffic control is also crucial for emergency vehicles and traffic prioritization.

Enhanced services in ITS has a lot of financial potential from toll collection, pay to use priority lanes, advertisement services for local facilities, etc. Enhanced services could also provide information for fuel/charging stations, on/off ramp information, parking facilities, parking slot availability, etc.

The potential application space that vehicular communication opens up is large. A lot of innovative work is still open for new players.

Communication Technologies and Standards

The most critical component for vehicular end-end solution was the definition of Standards based communication technologies that would interoperate. Vehicular communication spans communication between vehicles (V2V), communication between the vehicle and back end infrastructure (V2I), and communication between vehicles and roadside equipment (V2R) which do not necessarily have to be communicating to the back end infrastructure. An example of such communication is shown in Figure 3-2 [7]

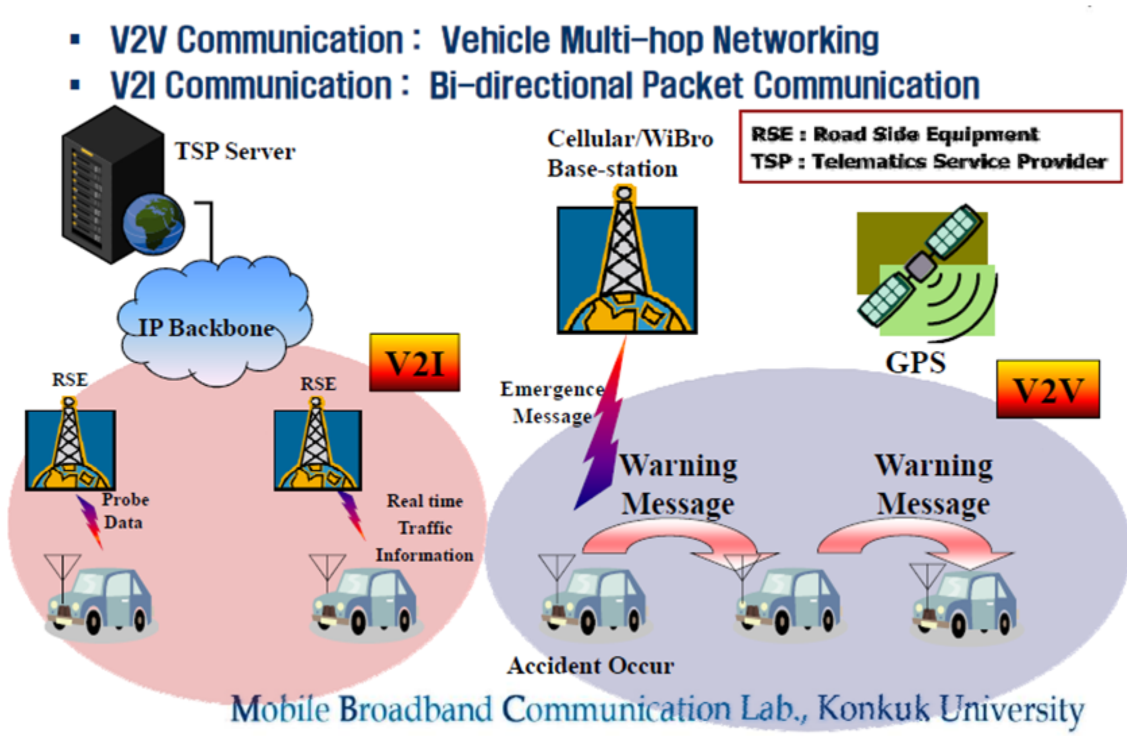

Figure 3-2: Example of Vehicular Communications

DSRC (Dedicated Short Range Communication) started out as a project within the USDoT to address the short range communication. It culminated in the adoption of IEEE 802.11p (an extension of IEEE 802.11) operating on the 5.9GHz band. It is now an approved WAVE (Wireless Access in Vehicular Environments) technology used to support ITS for vehicular communications. IEEE 1609 standards provided upper layer management support for the communication in DRSC and WAVE[8,9]. DSRC/WAVE is the primary communication protocol to be used for short range V2V and V2I communication.

Rounding out on the communication technologies, ISO (TC 204/Working Group 16) has lead an initiative called CALM [10] that defines an architecture that defines a set of wireless communication protocols that spans multiple modes of communication and multiple methods of transmission to be used for ITS. Figure 3-3 provides a picture of the layers that the different V2V technologies address.

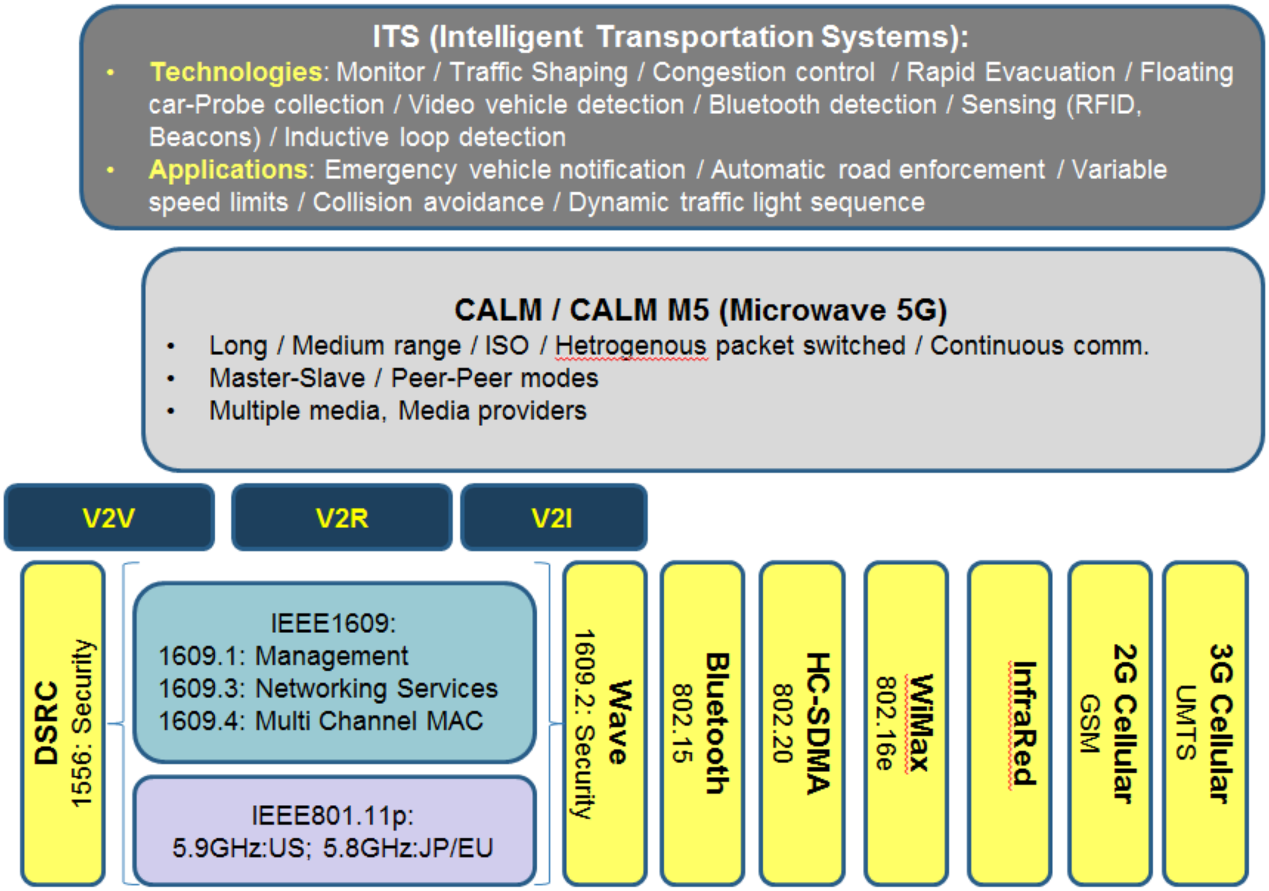

Figure 3-3: Next Generation Vehicular Communication Technology Dependencies

On-Board Diagnostics Vehicle Interface

Since early 1970 computers have started appearing in vehicles to efficiently control systems within. A natural progression of computers in vehicles was their use for diagnostics and the emergence of the OBD interface and associated protocols. By the late 1990s the current standardized form (ISO and SAE) of the OBD-II started appearing in vehicles [11]. OBD-II has since expanded to cover more than diagnostics, such vehicle identification, telematics, speed, RPM, fuel levels etc.. The relatively recent explosion in mobile/cellular and tablet based personal computers has spawned an entire industry of applications available on them that provide very user friendly information about the vehicle. The OBD-II interface provides an immediate access to first generation devices that can be used in vehicular communication without being fully integrated into the vehicle by the manufacturers

Section IV: Broad Contextual Factors

On February 3, 2014, the U.S. Department of Transportation's (DOT) National Highway Traffic Safety Administration (NHTSA) announced that it will begin taking steps to enable vehicle-to-vehicle (V2V) communication technology for light vehicles [12]. This announcement, indeed, provides a strong signal that the U.S. government plans to use IT to improve road traffic safety and utilization. However, there are multiple factors to consider for the V2V market to be successful.

Regulatory/Certification

- Timeline for legislation: NHTSA stated that only after a pilot study, they will then begin working on a regulatory proposal that would require V2V devices in new vehicles. Estimated timeline for legal requirement approved is around 2018. The uncertainty in timeline will affect the investment plan from auto-vendors and the market penetration of V2V applications.
- Timeline for deployment: Before any deployment, a V2V device certification program must be established to ensure V2V devices from different vendors are compliance to the standards as well as interoperable. One possible entity for enabling such certification is the Wi-Fi Alliance. However, it takes time to commence a certification program as well as to establish test-labs.

Technology Variant

It is likely that the underlying V2V communication technology is based on the dedicated short-range communication (DSRC) protocol working in FCC allocated 5.9 GHz band with bandwidth of 75 MHz and range of approximate 1 Km. However, it might also include traditional Wi-Fi as well as cellular such as 3G/4G LTE. This may need an interworking solution but will open up a bigger market penetration as well as quicker adoption of V2V applications.

Global Adoption

The DOT's action is the earliest globally among government entities, and is likely to accelerate the public policy decision-making of other countries that are evaluating or piloting technologies as well as to positively impact other technologies that will affect automobiles and road infrastructure, including e-call functions, vehicle-to-infrastructure communications and self-driving vehicles [13]. This will probably lead to economy of scale of adoption and market penetration.

Consumer Demand for Road Traffic Safety

Every year, there are about 34,000 traffic fatalities in the US. Studies showed that 60% accidents were avoidable with ½ sec prior warning [14]. Furthermore, V2V can affect > 82% non-impaired crashed over 16% for V2I. A recent study [15] showed that more than 80% of drivers would like to have some advanced V2V safety warning systems (see Table 4.1). As such, there is an immediate consumer demand for V2V warning systems and insurance company rate discounts could cause additional impetus.

Table 4.1: DRIVER ACCEPTANCE AS A FUNCTION OF SAFETY FEATURE

Features	Acceptance Ratio
EEBL: Emergency Electronic Brake Lights	91.4 %
FCW: Forward Collision Warning	90.5%
BSW/LCW: Blind Spot/ Lane Change Warning	90.9%
LTA: Left Turn Assist	83.8%
IMA: Intersection Movement Assist	95.5%
DNPW: Do Not Pass Warning	88.6%

Automakers/After-Market Suppliers Push

Automakers and after-market suppliers are working on various initiatives to push adoption for V2V technology:

- Work with regulatory to define a deployment timeline for V2V based on their in-vehicle technology roadmap.
- Enrich the V2V safety warnings by introducing additional active safety systems (such as automatic braking)
- Appeal to consumers' need to extend their digital lifestyle to vehicle (e.g., link their smartphone to the in-vehicle systems)

Section V: Current and Future Opportunities

Opportunities

As part of the Internet of Things (IoT) and connected economy trends, connected cars offer huge commercial opportunities. Although estimates vary widely, they are usually in the order of billions of dollars. Just safety applications alone represent a major opportunity given the number of cars on the road. Improving safety is a key driver to getting vehicle connected because saving lives is something consumers, governments and businesses given their interests are all aligned. As we saw earlier in this report, there are major pushes from governments and businesses (automakers and equipment makers) on the adoption of V2V communication. Once cars become connected, beyond safety applications, many value-added services such as infotainment can be added to the offering. Below is a graph [16] illustrating various commercial opportunities.

Figure 5-1: Next Generation Vehicle Communication Enablement Opportunities

Achieving Network Effect

However, like any network, the benefits and values of connected cars are only achieved when critical mass is achieved via network effect [17]. The key challenges to wide adoption of V2V communication are: a) costs and b) convenience of installation. Even though car makers are looking to build in V2V communication capabilities into new cars, these features are likely to be only available in high-end cars first and are likely to cost thousands of dollars. Also, a key to adoption is availability of aftermarket equipment that can be installed into existing cars. After-market adoption will be slow as we have seen with technologies like CD player and GPS. This is because it takes years to get a wide network of equipment installers trained in all local markets. Also, for consumers to install V2V equipment into their cars, they need to be convinced the benefits justify the costs and inconvenience. While consumers wait for costs to come down and see tangible benefits, they are waiting for others to be the first to cross the chasm of the technology adoption curve.

In order to accelerate the adoption of V2V technology, one possibility is to leverage and enhance existing technology and build on top of an existing user base. Since smartphones are now ubiquitous, V2V technology such as DSRC can be built into smartphones [18]. The computing capabilities of a smartphone provide a nice user interface to the driver. Once a few popular models of smartphones have V2V technology, a network is instantly created, especially in densely populated metropolitan areas. Benefits of V2V technology will become apparent, which will then cause more smartphones to adopt this technology. The snowballing effect will start to occur as more and more people adopt V2V communication using their smartphone and realize the benefits. This will eventually make V2V communication a standard feature.

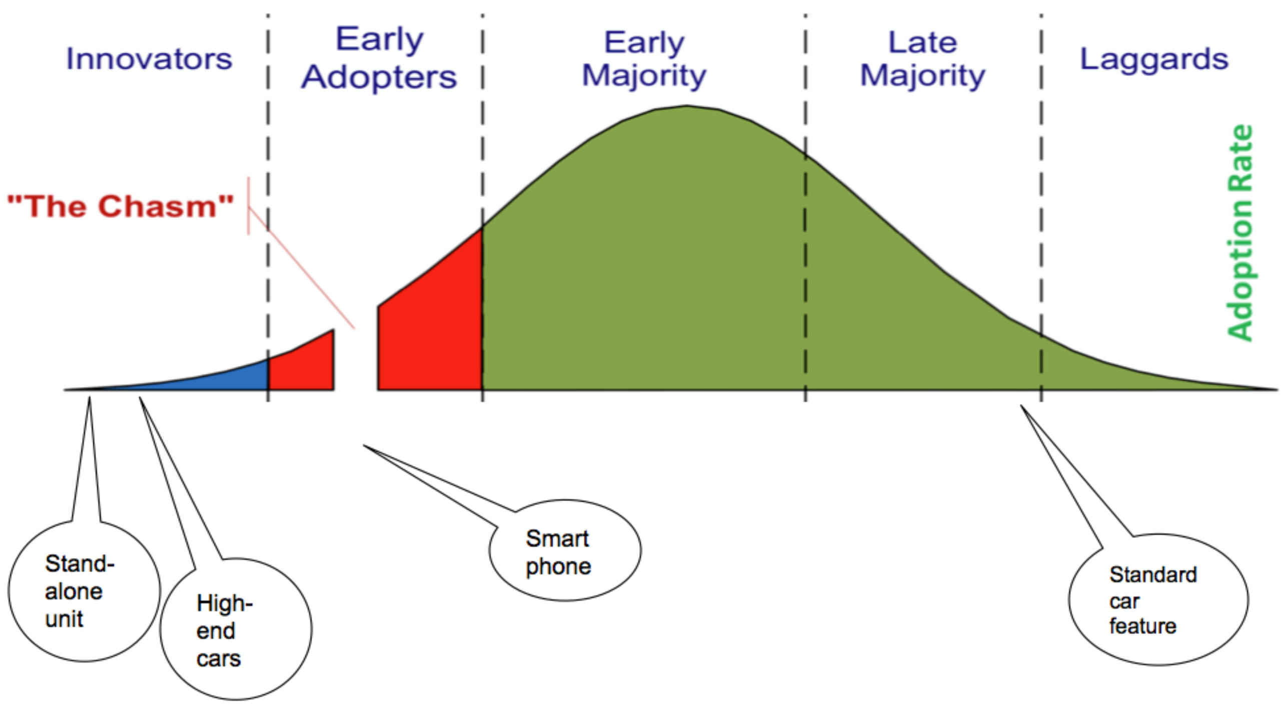

Figure 5-2: V2V Market Enablement Prediction Path

Section VI: Summary

It is clear that vehicle to vehicle (V2V) communication is a complex and broad subject. It is also clear that the foundation for each of the key technology and commercial enablers is either in place today or is getting sufficient attention so that any barriers to implementation are being addressed and resolved. From government standards and mandates, to technical capabilities, to viable economic models, V2V communications are on the near term horizon.

If any arguments could be mounted based on a lack of maturity, lack of infrastructure, lack of economic basis and so on, they would be quickly dispatched given the track record of the adoption of safety related technology in the American automotive market.

From ABS systems to seat belts to airbags, we see that once the American car buying public adopts the idea that some key pieces of safety technology is the right thing to have, what we typically think of as key adoption prerequisites get marginalized as mere details. V2V communication will become ubiquitous within several years; the enabling infrastructure and technologies are mere details.

Appendix: Definitions of V2V Traffic Safety Features

- **EBL: Emergency Electronic Brake Lights =** enable a vehicle to broadcast a self-generated emergency brake event to the surrounding vehicles. Upon receiving such event information, the host vehicle determines the relevance of the event and then provides a warning to the driver if appropriate (particularly useful when the driver's line of sight is obstructed by other vehicles or bad weather conditions)
- **FCW: Forward Collision Warning =** warn the driver of the host vehicle in case of an impending rear-end collision with a vehicle ahead in traffic in the same lane and direction of travel. (help drivers in avoiding or mitigating rear-end vehicle collisions in the forward path of travel)
- **BSW/LCW: Blind Spot Warning/ Lane Change Warning =** warn the driver of the host vehicle during a lane change attempt if the blind spot zone into which the host vehicle intends to switch is, or will soon be, occupied by another vehicle traveling in the same direction. Also, provide advisory information to the driver whenever a vehicle in an adjacent lane is positioned in a blind spot zone of the host vehicle.
- **LTA: Left Turn Assist =** warn the driver of a host vehicle when making a left turn that it may not be safe to proceed because of oncoming traffic.
- **IMA: Intersection Movement Assist =** warn the driver of a host vehicle when it is not safe to enter an intersection due to high collision probability with one or more remote vehicles in cross traffic
- **DNPW: Do Not Pass Warning =** warn the driver when a slower moving vehicle cannot be safely passed using a passing zone which is occupied by vehicles with the opposite direction of travel

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