CONCEPT

It is suggested that, by 2012, the market for vehicular communication networks will be a billion-dollar industry. The technology necessary for the implementation of vehicular communication networks is currently under development, and has been drafted under the IEEE 802.11 standard as draft amendment 802.11p. The 802.11p standard relates specifically to the emergence of V2V (Vehicle to Vehicle) and V2R (Vehicle to Roadside) communications. The 802.11p standard has also been referred to as WAVE (Wireless Access in a Vehicular Environment) and promises to deliver an exciting new range of communication devices and applications for use in a vehicular environment. In this report, I will examine the 802.11p standard. 802.11p is a fundamental part of the US Department of Transportation's DSRC (Dedicated Short Range Communications) project. DSRC supports a bandwidth of 75MHz and operates in the 5.9GHz frequency band. It's approximate range is some 900 - 1100m[1]. But why develop such a technology? The main ap plications of WAVE will be relating to that of driver safety; with drivers allowed to be notified of accidents, motorists able to forewarn other motorists of their intentions when merging etc. I will examine these applications in further detail later on in the report after my technical examination. There has been a family of standards devised by the IEEE to deal with the security and management of vehicular communications. These are the 1609.1, 1609.2, 1609.3 and 1609.4 specifications. These specifications relate to Resource Management, Security Services for Applications and Management Messages, Networking Services and Multi-Channel Operations respectively[2][8].

CHALLENGES

Obviously, technology of this scale and nature is going to be inherent with problem s that need addressing if it is ever going to be deemed as a success. Several of WAVE's issues have already been indentified and are currently been dealt with. These issues include;

SECURITY | As with all network technology, data security is a key issue. Security is presenting a considerable challenge to WAVE, as is anonymity. Drivers will not likely utilise this standard if they are not fully comfortable of their privacy and the security of their data. There are also of course legal requirements when it c omes to privacy and data protection. In order to accomplish a secure environment in which users data can be safe and secure, a system of digital signatures and certificates will be implemented. Doing so will ensure that data is transmitted safely, that pac kets cannot be retrieved by unintended recipients, and that users won't receive transmissions from malicious sources. WAVE has addressed this issue, and authentication will be implemented using PKI (Public Key Infrastructure). PKI uses certificates with pr ivate and public keys to authenticate.

ECONOMIC | There is always an economic factor to take into account. If a new technology is not financially viable it will fail, regardless of its innovation and intuitiveness. It is crucial that WAVE provides a wor thwhile expenditure for its users, as well as being an attractive proposition for those who will have to implement it. To gain the market penetration necessary to make WAVE economically viable, it is suggested that it will have to support standard internet protocols. In other words, general internet access and family orientated applications will have to be made available if it is to attract consumers. One must also consider that not all cars will be equipped to utilise the technology. While such leading car manufacturers as BMW and Daimler Chrysler have stated that they have in fact included built -in WAVE systems in their future design models, the reality is that in 2012 not everyone is going to be driving a new car from BMW or Chrysler[3], or a new car from any manufacturer for that matter. Plentiful cars on the road will still be old, so even when this technology is rolled out fully, it will take a few years before everyone is driving cars with the electronics to support it.

BANDWIDTH & CONGESTION | One of WAVE's primary purposes is that of car safety, as will be looked at later on in this report. However, for it to achieve an effective level of service in this area, it needs to be guaranteed a certain amount of available bandwidth. If applications that are not specific to safety operate off of the same frequency band, like general internet usage, then safety features may be compromised by latency. When the safety features are needed, if it is contesting with other bandwidth intensive applications, one may f ind that WAVE's primary function is in fact unable to be utilised to its full potential; a situation that would not bode well for the further advancement of the technology. To combat this, it is expected that transmissions related to safely will be made using dedicated channels. Also, internal transmissions can use the 802.11 a/b/g standards. With V2R networks, there is also going to be issue with congestion control as WAVE is build on CCH (control channel) communication. As the number of participating stat ions increases, so too will the level of congestion and the volume of collisions. Latency will increase, and transmissions will be delayed and lost. To counteract this issue, EDCA (Enhanced Distributed Channel Access) will be deployed. EDCA was instigated with the 802.11e amendment that sought to modify the MAC layer with a set of enhancements for use in wireless environments. EDCA works by assigning traffic periods of time called transmit opportunities, with stations holding higher priority data given long er intervals. In this way, high priority traffic is given precedence. If an effective EDCA scheme can be implemented, there will be fewer contention windows, and thus CCH congestion will be avoided. If there is to be successful roll out of vehicular communication networks, somebody will have to assume responsibility for the crucial issue of congestion control. The MAC layer is vital in the battle for effective congestion control, and it will be through the MAC layer that occupancy time shall be measured. If congestion is detected, it will be MAC layer that rejects transmission, and so is crucial to the operation of vehicular communications.

ENVIRONMENTAL CONSIDERATIONS | This technology will have to be scalable, extremely scalable, for the simple fact that the environment in which it will be utilised is one that is constantly in motion. V2V systems will have to account for traffic density. On motorways there may be plentiful cars in surround, where as in other areas the roads may be sparsely populated. Traff ic jams, accidents, the unforeseen that we meet on the roads every day, driver speed and direction, weather effects; these will all have to be able to be taken into account. With respect to V2V communications, forming an ad-hoc network between two vehicles requires very specific routing mechanisms. To achieve what is set out by the standard, both single and multi-hop routing will be supported. It will do this by utilising a packet forwarding scheme that routes packets through nodes closest to the destinatio n. A problem that can arise out of this is packet loss, particularly in an urban area where there is undoubtedly going to be numerous obstructions and forms of interference. To address this issue, the following solution has been proposed; Nodes will transm it beacons, allowing other nodes to construct and implement and table of its neighbours, similar to how a CAM table would function. The issue with this is, the nature of V2C communications is such that nodes are constantly in motion, and this neighbour table would have to be updated every few seconds. This would result in a high amount of beacon transmission, which could possibly lead to further congestion issues.

WAVE'S SYSTEM ARCHITECTURE

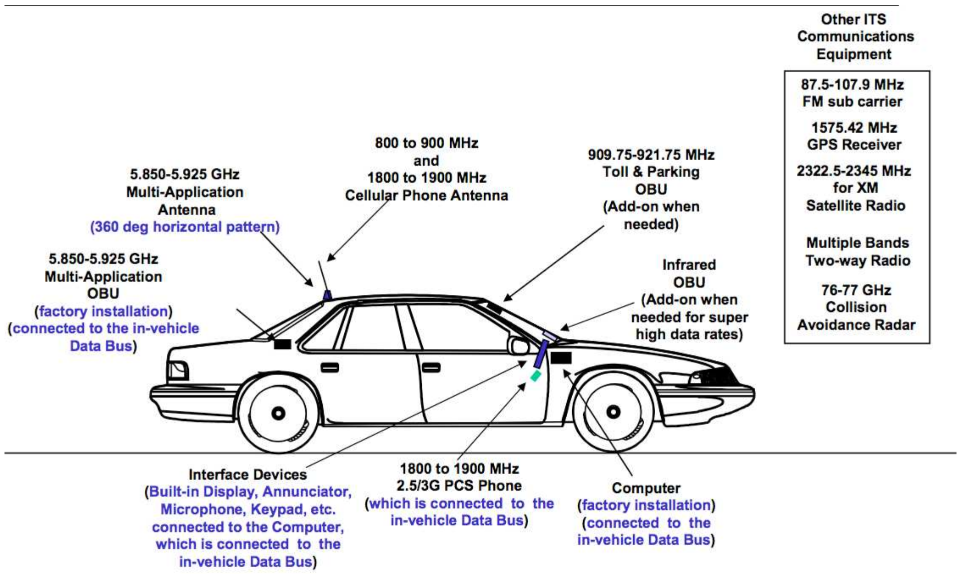
Having looked at the issues faced by the development of WAV E, I will now conduct a technical examination of this technology.

Vehicular communication transmissions will be sent and received using an OBU (onboard unit). Any vehicular communication devices in a car will also receive data via an ad-hoc connection to this unit. While the OBU will conduct its V2V and V2R transmissions via the 802.11p standard, it will also feature 802.11 a/b/g standards so that it can function with other end user devices such as laptops and PDAs. Of course, the inclusion of such will more-than-likely be vendor specific. The OBU will be picking up transmissions from an RSU (roadside unit) that will be placed in those locations deemed necessary by businesses implementing the provision of V2R services.

In order to facilitate this, the 802.11p standard sees changes made to both the MAC and PHY layers.

PHYSICAL LAYER | The 802.11p PHY layer is quite similar to that of IEEE's 802.11a standard. There are some differences however [4]. WAVE's frequency band will be divided into channels, from which all safety messages will be broadcast from the centre channel. Remaining channels will be used amongst various other applications. The 802.11p standard will also see all parameters in the time domain doubled to reduce interference caused by multi-path propagation. As a result of this, 802.11p's data rate will be halved compared to the 802.11a standard. The frequency bands upon which it will operate are 5.9GHz in the United States, while in Europe the 10MHz band from 5.895 to 5.885 GHz will be assigned to saf ety and traffic applications. Other applications will func tion within 5.885 to 5.895 GHz[5][6]. Data rates of up to 27Mb/s will be supported, with 6Mb/s being the default rate.

MAC LAYER | The MAC layer relates to media access; how accessed is gain ed to a medium. IEEE 802.11p will define a MAC layer that supports two different stacks; IPv6 and WSMP (WAVE Short Mesage Protocol). 802.11p will work off of the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) algorithm as defined in the 802.11 Media Access Control standard, while 802.11p will also utilise channel access that will be prioritised using EDCA as devised by the 802.11e standard. This will see the MAC layer give precedence by assigning different access categories dependent on the type of traffic. Another difference with 802.11p's MAC layer is that there are no restrictions on transmission intervals[2]. Essentially, because of the nature of vehicular communications, the MAC scheme will delay transmission if there is a risk that any such transmission may impede on another. The changes to the MAC layer will also allow nodes to operate and transmit without the need to know each other's location. This will be done using a series of circular transmissions consisting of Request to Send, Clear to Send and ACK packets[9]. Antenna's utilised by this direction will be omni -directional, which will better facilitate for simultaneous transmission. The following image demonstrates, e ssentially, how a vehicle's medium configuration will appear once WAVE is implemented[7].



APPLICATIONS

There will be a range of applications provided by vehicular communication networks. Many of these will depend on what vendors and manufacturers deem as worthwhile implementations, most likely from an economic point of v iew. However, the primary application of WAVE, and the chief reason for its development, will address issues of motorist safety. The main advancement that WAVE will offer in respect to safety will be its driver awareness functionality. V2V communication wi ll essentially allow drivers to be made aware of the intentions of another driver before any action is made. Essentially, a vehicle that is changing lanes will be able to broadcast such to all vehicles within a certain transmission area. In this instance, we are seeing an example of V2V broadcast communications, but WAVE will also afford the opportunity for V2V unicast transmissions. This will essentially allow two vehicles to form a direct connection. This application operates off of four phases; Discovery, Connection, Maintenance and C losure[5]. Discovery is the phase initiated when one vehicle wishes to make a connection with another of which its presence it is aware. This is then followed with the Connection phase, which is essentially a request for connection. If the vehicle receiving the request accepts the connection, both vehicles enter the Maintenance phase, which essentially means that a secure connection has been established between them and they can transmit data. When one of the vehicles wishes to break the connection, they enter the Closure phase. Environmental notifications will also be possible. For example, if a roadway is blocked or closed for any particular reason, transmissions containing this information can be broadcast to all nodes in the surrounding area, before these nodes then repeat the transmission, continually reaching nodes further from the actual incident or hazard. Of course, with this application of wave, one must consider the issues examined earlier where the number of cars with vehicular communication devices may hinder the initial implementation for a few years. These application focus on V2V communications, but there will also be V2R applications which will allow roadside units to broadcast to surrounding vehicles. An example of how this application could be implemented would be in the notification of speed limits. Rather than looking out for small road signs, that often go unnoticed and are too sparsely populated, drivers could have speed limitations displayed to them directly within the their vehicles. The same could be said for situations where road works, traffic layouts, hazards and any other unusual driving conditions apply. Vehicular communications will allow for a complete overhaul of traffic management systems. Further down the line, traffic lights could function on the basis of how many wireless nodes they are detecting from any given direction, allowing them to calibrate their colour changes depending on which roads have the higher density of traffic build -up. Emergency services could be accommodated, allowing for drivers to be given advance warning of routes being taken by ambulances or fire services. Policing of the roads will be made far easier for the authorities, while businesses will have the opportunity to offer paid services to drivers. Users would undoubtedly be willing to pay for applications of convenience, such a parking assistance and payment. Drivers would be able to check for the cheapest current fuel costs in an area, or pay their tollbooth fees electronically without having to alter their speed or loose time from their journey. The scope for applications of WAVE is considerably vast.

MAJOR EUROPEAN & AMERICAN PROJECTS

Here in Europe, Conférence Européenne des Administrations des Postes et des Télécommunications are currently working on the allocation of WAVE's frequency bands, while the ETSI (European Telecommunications Standards Institute) have initiated various projects in the field of vehicular communications over the last few years. In the US, the Department of Transport have already allocated frequencies, and are currently working through a variety of projects aimed at field testing V2V and V2R technology. Some of the largest car manufacturers pioneering the use of WAVE, namely Daimler Chrysler, General Motoring, Toyota, Nissan, Volkswagon, Ford and BMW, have established a group known as the Vehicle Safety Communications Consortium. The group initiated the Vehicle Safety Communications Project, a two and half year program started in May of 2002. The aim of the project was to *"facilitate the advancement of vehicle safety through communication technologies."* This project included the advancement of DSRC standards, as well as the development of a testing system for WAVE. The group are currently engaged in a number of projects which have taken the results of this further. They have established testing facilities at General Motoring's Proving Ground in Milford, Michigan, as well as their Desert Proving Ground in Yuma, Arizona. They are currently working on projects targeted at testing the effectiveness of vehicular communication safety applic ations, as well as the highly anticipated Cooperative Intersection Collision Avoidance Systems, in cooperation with US Department of Transportation.

When the concept of vehicular communications matures, the potential for high end applications and devices is considerable. Today's cars are already equipped with very powerful radios and digital equipment. Implementing V2V and V2R networks into these devices could bring m otorists into an age of technological convenience the likes of which they have never seen. Mobile network gaming, video streaming, accessing eMail and other data on the move - the list is endless. Navigation tools can be implemented with wireless updates, perhaps even factoring in real time on-road events. Considering that most cars have a powerful source of energy, the level of devices and interactivity in vehicles could increase considerably when this technology reaches fruition.

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