PO Box 122, Trabuco Canyon, California USA 92678

17 March 2003

Federal Communication Commission
Notice of Proposed Rule Making
Dedicated Short-Range Communication Services in the 5.850 –5.925 GHz Band

Re: In the Matter of Amendment of the Commission's Rules Regarding Dedicated Short-Range Communications in the 5.850-5.925 GHz Band (5.9 GHz Band), WT Docket No. 01-90.

Comments of: 'Highway Electronics' a Nevada Corporation prepared by Roger O'Connor

Dear Commission Members:

Highway Electronics has reviewed the Federal Communication Commissions (FCC) Notice of Proposed Rule Making (NPRM) labeled FCC 02-302, WT Docket No. 01-90, ET Docket 98-59 RM-9096 released on November 15, 2002. Based on this review Highway Electronics would like to comment on some of the areas that are key to a successful allocation.

Highway Electronics has been a continuous participant in the ASTM/IEEE standards efforts since 1992. During the last four years, Highway Electronics has provided technical assistance and guidance in the development of standards for the 5.9 GHz ITS Radio Service band. Highway Electronics has selected several areas for its comments. These areas have been selected because their acceptance by the FCC is critical to the success of the national Dedicated Short Range Communications (DSRC) standardization and interoperability efforts. The American Society of Testing and Materials and the Institute of Electrical and Electronic Engineers (ASTM/IEEE) are leading these standardization and interoperability efforts. There are many other items in the FCC's request for comments that are of the 'it would be nice' and 'it would help wide scale deployment' nature, however the DSRC standardization and interoperability effort can continue without their acceptance. The 'must have items' are listed below with an explanation of why they are so critical. These items are not listed in any particular order since they have almost equal impact on the standardization and interoperability efforts.

1) Band Plan - - The Band Plan that was submitted to the FCC by ITS America was based on three major considerations. First, it reflects a harmonization with our North American neighbors. It evaluated the spectrum allocation issues in both Canada and

Mexico in the development of this plan. Second, it provides a division into channels that are adequate to support the fundamental band communications needs. These include a Control Channel needed for channel allocation and control, a High Power Channel needed for long-range public safety applications, and a High Availability and Low Latency Vehicle Safety channel that can be used for data intensive safety critical communication requirements. Third, it supports the spectral mask requirements necessary for the interference free adjacent channel operation of multiple Roadside Units (RSU) and On Board Units (OBU).

2) Interoperability - - The required use of the ASTM/IEEE standards in the band supports the interoperability of all OBUs and RSUs in North America. Current DSRC systems in North America support, at the most, only regional and segmented ITS application interoperability. The acceptance of the ASTM/IEEE standards in the FCC rules will help in the development of interoperability in all regions and all system segments. The International Bridge, Tunnel, and Turnpike Association (IBTTA) has gone so far as to create a new nonprofit entity called OmniAir™ whose mission is the certification of OBUs and RSUs as 'standard compliant' and 'interoperable'. Without the frame-work provided by the ASTM/IEEE standard the OmniAir™ mission will be almost impossible.
3) Industry Consensus Communication Standard - - As a part of the ASTM/IEEE standards development process, three DSRC technologies were evaluated. Tests, analysis, and simulations were performed on these three technologies. This included evaluations using various propagation, vehicle traffic conditions, and different ITS Application data loading. This effort required over two years of effort, ending with a near unanimous (20-2), selection of the IEEE 802.11a communication standard based technology. The IEEE 802.11 technology is the defacto standard for Wireless Local Area Networks (WLAN). Sister 802 technologies are becoming the standard for wired Local Area, Medium Area, and Wide Area Network (LAN, MAN, WAN) implementations. The required use of this technology in the ITS Band will support the seamless extension of the LAN, MAN, and WAN systems into the WLAN mobile environment.
4) Shared Band - - The ASTM/IEEE standards support a sharing of the ITS Band among Public Service and Private Service ITS applications. The sharing methods provide a Quality of Service (QoS) for all ITS applications and priority access for Safety ITS applications. In addition, the ASTM/IEEE standards use of the Control Channel architecture supports the development of 'Dual Band' units that allows RSUs and OBUs to also operate in the Unlicensed National Information Infrastructure (UNII) band. In this manner these 'Dual Band' units not only support the Public Service and Private ITS applications in the ITS Band but also support Commercial unlicensed ITS applications that will operate in the UNII band. A detailed explanation of the utilization of the Control Channel is presented in the attached White Paper Report prepared by Highway Electronics and submitted to the ASTM/IEEE standard's

writers. This report is submitted for reference information and is not intended for direct inclusion in FCC rules.

5) Licensed Operation - - As we have seen in the ISM Bands at 900 MHz and 2450 MHz, unlicensed bands can soon create self-interference problems that defeat the QoS methods required for effective Public Service and safety related communication systems. A license by rule and site license approach in the ITS Band will help assure that the ASTM/IEEE standard QoS parameters will be achieved and the communication needs of the Public Service and Safety ITS applications are fulfilled.

As mentioned earlier, while there are many 'it would be nice' requests that were presented to the FCC, this list of five represents the core requests that are needed to support National interoperability and the Public Service and Safety ITS application communication missions.

If you have questions please contact me by voice at 949-589-4149, fax at 949-589-4189, or email at rjoconnor@highwayelectronics.com.

Sincerely,

Roger J O'Connor

Roger O'Connor
Highway Electronics

Attachments: Control Channel Operation in the ITS Radio Services (ITS-RS) Band

PO Box 122, Trabuco Canyon, California USA 92678

CONTROL CHANNEL OPERATION IN THE ITS RADIO SERVICES (ITS-RS) BAND

12 March 2003

Roger O'Connor

Abstract

This report discusses the Control Channel concept that has been developed by the American Society for Testing and Materials (ASTM) and Institute for Electrical and Electronic Engineers (IEEE) standards writers for use in the ITS Band being considered by the Federal Communication Commission (FCC). The Control Channel concept provides a method that enables the sharing of this ITS Band between Public Service and Private ITS Applications on a non-interference basis. This report describes the Control Channel concept and how it provides a Quality of Service (QoS) to all its users. The Control Channel provides Public Service ITS Applications priority access over Private ITS Applications. The Control Channel also supports the priority interruption of a Private ITS Application by a Public Service ITS Application. The report explains how Public Service ITS Applications can establish a communication link, even when Private ITS Applications are in process, using a priority interruption capability. The report also discusses ongoing analysis and simulation efforts that are being used to verify and quantify the concept's operation during highly stressed communication conditions.

Report

The Intelligent Transportation Systems (ITS) Band is divided into seven (7) channels. One of the channels is designated as the Control Channel. The Control Channel's main function is to support the establishment of communication links, called sessions, between Dedicated Short-Range Communication (DSRC) Units. These DSRC units can be Roadside Units (RSU) or On-Board Units (OBU) and the communication sessions can be established between an RSU and OBU(s) or between OBUs. The Control Channel operates using a set of rules to provide a Quality of Service (QoS) that includes access time, access priority, and channel capacity services to all units. As stated earlier, the main Control Channel function is the establishment of communication sessions between DSRC units using these rules. The following paragraphs describe how this function is accomplished.

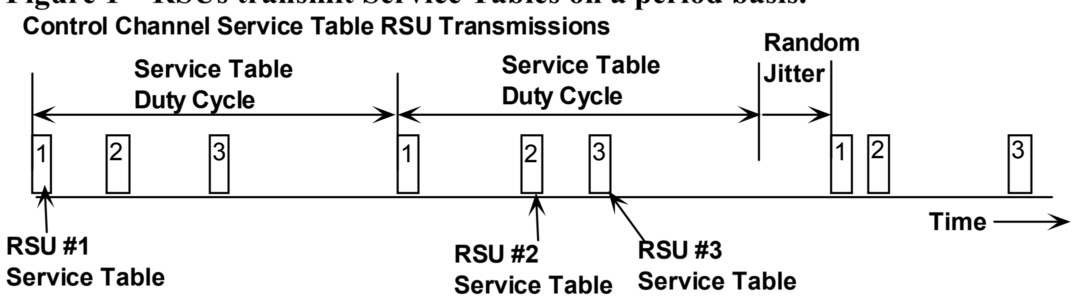
Control Channel Operation

Typically DSRC Units start by using the Control Channel to establish communication links. The OBU's continuously monitor the Control Channel listening for transmissions from other DSRC units. Since there are two types of DSRC Units (OBU & RSU), there are two types of Control Channel transmissions. The following paragraphs will discuss these transmissions.

RSU Service Table Transmissions

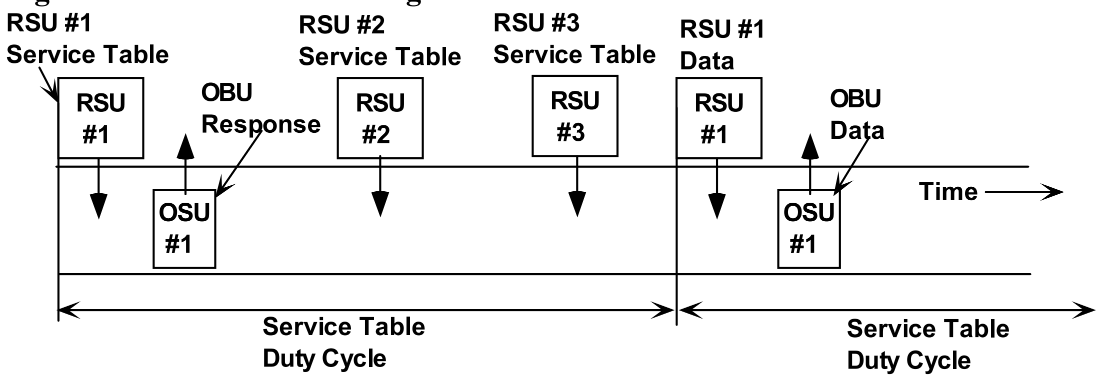
RSUs are typically Service Providers, i.e. they provide different types of ITS services to OBUs that are typically Service Users. These services can be Public Service or Private Service in nature. ITS Applications that provide these services register with an RSU and provide it with information about the ITS Application that includes an application identification (ID) number, priority information, and application type (Public or Private). The RSU uses this information to generate a Service Table. The RSU transmits the Service Table, along with RSU identification information, at periodic intervals on the Control Channel. RSUs may have overlapping communication zones so the IEEE 802.11 protocol's, 'listen before transmitting' and Media Access Priority are used to mitigate collisions between transmissions. The Control Channel also uses randomized Service Table transmission times to mitigate any potential 'hidden node' generated interference. Figure 1 shows a set of Control Channel transmissions that might result from overlapping RSU communication zones. The figure shows the minimum periods between an RSU's Service Table transmissions and the randomized spacing between these transmissions.

Figure 1 – RSUs transmit Service Tables on a period basis.



OBUs are typically ITS Application Service Users and when an ITS Application is connected to an OBU, it provides information, including its ID, that is used to create an Applications of Interest (AOI) Table. All OBUs continuously monitor the Control Channel listening for Service Tables. When they enter an RSU communication zone, they receive the RSU's Service Table. The Service Table is processed and compared against the AOI Table. If a match is found the OBU transmits a response to the RSU indicating that it is interested in a particular ITS Application's or group of ITS Application's services. The OBU response can also be used to start a Communication Session on a Service Channel. That process will be discussed later in this report. Figure 2 shows an RSU Service Table transmission followed by an OBU response. The OBU also uses the IEEE 802.11 protocol's 'listen before transmitting' and the RSU's ITS Application's access priority in transmitting its response.

Figure 2 – RSU/OBU Exchanges on Control Channel.



OBU Control Channel Service Table Transmissions

In addition to OBU responses to the RSU's Service Table, OBUs also transmit On-Board Service Tables (OST). The OST is used to establish vehicle-to-vehicle (V2V) communications links called sessions. When an ITS Application is used for V2V transactions it create a peer-to-peer communication session. In the peer-to-peer session the OBU is both a Service Provider and a Service User. Therefore, the ITS Application information is used to create two table entries, an OST entry and an AOI entry. The OBU Service Table, like the RSU Service Table, is transmitted at periodic intervals with randomized spacing. When an OBU receives an OST it also compares it with the AOI Table. If a match is found a response is generated. Based on the received OST content, this response can be used to start a Communication Session on a Service Channel. However, V2V Communication Sessions are not allowed on the Control Channel.

Control Channel Interference Mitigation

With multiple OBUs and overlapping RSU communication zones, a potential exists for interference between these units. The Control Channel rules are structured to mitigate this interference. First, the time interval between allowed Service Table transmissions is limited by a maximum duty cycle. This same duty cycle applies to RST to OST transmissions. Therefore, the number of transmissions per second from an RSUs and OBUs are limited. Second, the 802.11 MAC can be configured to limit the maximum transmission packet size. Third, if contention occurs, transmission repeats are delayed using the IEEE 802.11's channel access priority scheme combined with its 'listen before transmitting' protocol. This IEEE 802.11 MAC priority access technique provides a larger probability of channel access to higher priority ITS Applications. The ASTM/IEEE standard writers performed a simulation using these rules. The simulation used a 64-byte packet delivery by all DSRC units with a duty cycle of 100 msec as the communication data load. The data delivery delay time and number of required retransmissions of a data packet were the performance metrics. These metrics were monitored as the numbers of DSRC units were increased. When the simulation was loaded with 250 OBUs and 5 RSUs, no packets were lost and the average delivery delay was less than 2 msec. The ASTM/IEEE standards writers are currently running further simulations and performing parametric analysis on the Control Channel performance.

Service Channel Operation

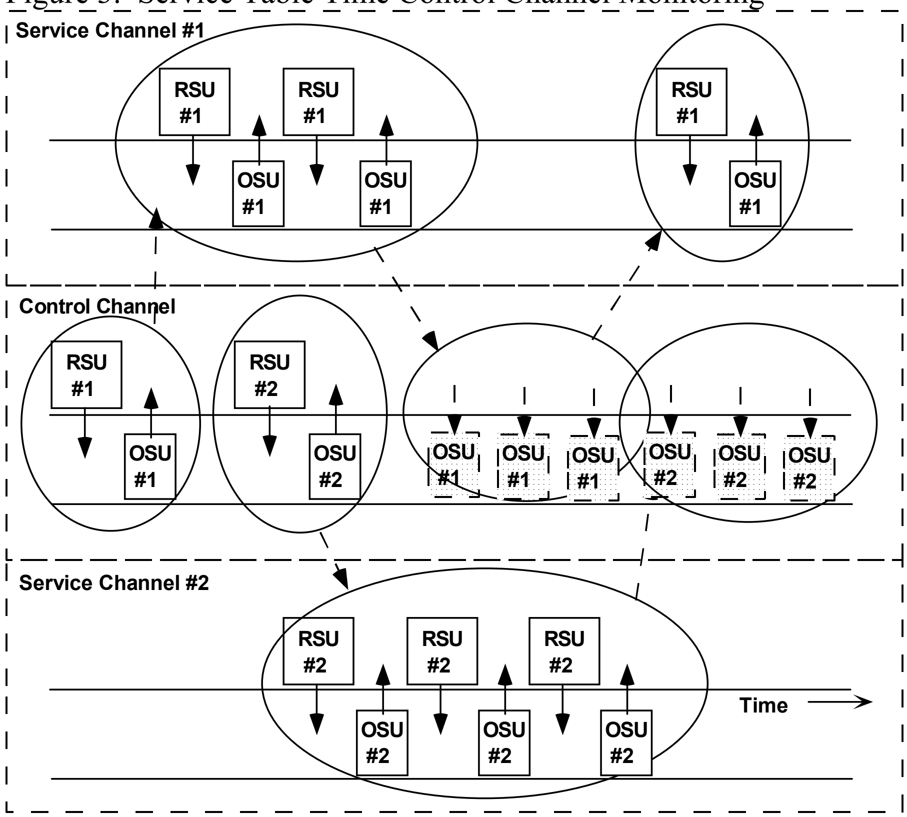
The Control Channel rules provide QoS access time and priority availability, however these rules also impact the efficient utilization of the channel's capacity and the execution of high speed, multiple exchange transactions between DSRC Units. These communication needs are addressed through the use of Service Channels. The ITS Band is divided into seven channels and since the Control Channel uses only one channel, the remaining six channels are designated as Service Channels. Communication between DSRC Units begins on the Control Channel but can be switched to any of the Service Channels for extended, multiple exchange transaction sessions. As discussed earlier, DSRC units transmit Service Tables (RSU & OBU) at periodic intervals on the Control Channel. When the ITS Application services defined in these table requires the use of extended transactions a Communication Session can be executed on a Service Channel. The RSU and OBUs use the Service Table transmissions to identify the need for a Communication Session. The DSRC units then switch to the designated Service Channel and execute the extended transaction session. The Control Channel rules do not apply to the Service Channel and therefore its channel capacity can be more fully utilized. When the DSRC Units' extended transaction session has been completed they return to the Control Channel and resume the transmission and monitoring of Service Tables.

Service Channel Time

The use of a Service Channel to execute an extended DSRC Unit transaction session effectively uses that channel's capacity. However, during the time the DSRC Units are engaged in the transaction session, they are not monitoring the Control Channel for higher priority Service Table transmissions. To address this issue, the uninterrupted duration of a Service Channel transaction is time limited. When a Service Channel transaction is started, a timer, called the Service Channel Timer, is started. If the transaction is completed before the timer expires, no action is taken since the DSRC Unit returns to the Control Channel. If the transaction is not completed and the timer expires, the OBU suspends the transaction and automatically returns to the Control Channel. The DSRC Unit monitors the Control Channel for time duration equal to or greater than the Service Table repeat interval. This is called the "Service Table Time" method of monitoring the Control Channel. If during the Service Table Time, the OBU does not receive a Service Table with a higher priority ITS application, it can return to the Service Channel and continue the transaction. An illustration of the Service Table Time Control Channel Monitoring approach is shown in Figure 3,. The Control Channel monitoring does decrease efficient use of the Service Channel capacity when a one-to-one relationship exists between an RSU and OBU. However, an RSU Service Provider typically provides transaction services with multiple OBUs and the overall channel use efficiency is increased as the number of OBUs increase. The monitoring of the Control

Channel by the OBUs obtaining services can overlap, and while one OBU is monitoring the Control Channel other OBUs are executing transactions.

Figure 3. Service Table Time Control Channel Monitoring



Optional Control Channel Monitoring Methods

In some situations a more efficient utilization of the Service Channel is required The standard provides optional methods of monitoring the Control Channel that provide higher Service Channel efficiency. The following paragraphs describe these optional methods.

Control Channel Probe Option

The standard allows the use of a Control Channel Probe Option. This method of Control Channel monitoring provides higher Service Channel efficiency. OBU Probe Option method is described in the following paragraphs.

Description: When a DSRC Unit executes a transaction on a Service Channel that exceeds the Service Channel Time, it will return to the Control Channel and transmit an OBU Probe that is similar to an OBU Service Table transmission. The OBU Probe has added information that identifies the ITS Application with which the DSRC Unit is executing a transaction and its priority. The OBU waits on the Control Channel for the OBU Wait Time and then returns to the Service Channel to continue the transaction. If during the OBU Wait Time a Service Table with high priority is received, the OBU will execute a transaction with the high priority ITS Application.

Advantages/Disadvantages: The implementation is simple. A timer is used to monitor the Service Channel Time and the OBU Wait Time. The transmission of the OBU Probe is the same as the OBU Service Table with additional information in the transmission's tables. This method can provide increased utilization of Service Channel capacity for OBU/OBU and OBU/RSU transactions. As an example, if the Service Table transmission rate is 100 msec, and a Service Channel Time is 90 msec and the OBU Wait Time is 1 msec, then the Service Channel utilization will be 99%. The use of the Service Channel for multiple RSU/OBU transactions will not change the overall Service Channel efficiency. The disadvantage of this method is that, on the Control Channel, the OBU transmit range may not be adequate to reach an RSU that is transmitting a Service Table. This will not be a problem with OBU/OBU reception of an OBU Service Table since the communication range between OBUs is already limited by the OBU transmit power. This will not be a problem for OBU/RSU interactions since they will also be limited by the OBU transmit power limitations. The limitations will occur only with RSU Broadcast Service Table announcements that are beyond the reply range of an OBU. This method has little if any impact on Control Channel contention and media access. An OBU using this Control Channel Monitoring will transmits its probe, assuming it exceeds the 100 msec Service Channel Time, every 90 msec. However if the OBU remained on the Control Channel it would transmit its Service Table every 100 msec this small increase should have no impact on Control Channel access performance.

Figure 3 shows an example of a Control Channel/Service Channel transaction session. The Control Channel is in the center of the figure and RSU#1 and OBU#1 execute an interrupted transaction on Service Channel #1. The figure also shows RSU#2 and OBU#2 executing an uninterrupted transaction on Service Channel #2. In the figure RSU#1 transmits it Service Table and OBU#1 responds, both events occur on the Control Channel. The RSU#1 Service Table transmission dictated a Service Channel transaction. The OBU#1 response, confirming the start of a transaction, triggered both the RSU#1 and the OBU#1 to switch to the Service Channel #1 defined by the RSU#1 Service Table transmission. The RSU#1 and OBU#1 execute the transaction on Service Channel #1. The transaction requires a number of exchanges and before it is fully completed, the Service Channel Time is exceeded. The timer is maintained in both the RSU and OBU, therefore the RSU expects the loss of communications with the OBU when the timer expires. The OBU#1 switches back to the Control Channel and transmits an OBU Probe. In this case it received no DSRC Unit response to the probe and switches back to Service Channel #1 and continues the interrupted RSU#1 and OBU#1 transaction. The figure also shows a Service Channel transaction between RSU#2 and OBU#2 on Service Channel #2. In this example, the transaction was completed on Service Channel #2 before the Service Channel Time was exceeded and the OBU#2 returns to the Control Channel at the end of the transaction. Since the OBU#2 was absent from the Control Channel for a period of time, it transmits an OBU Probe when it returns.

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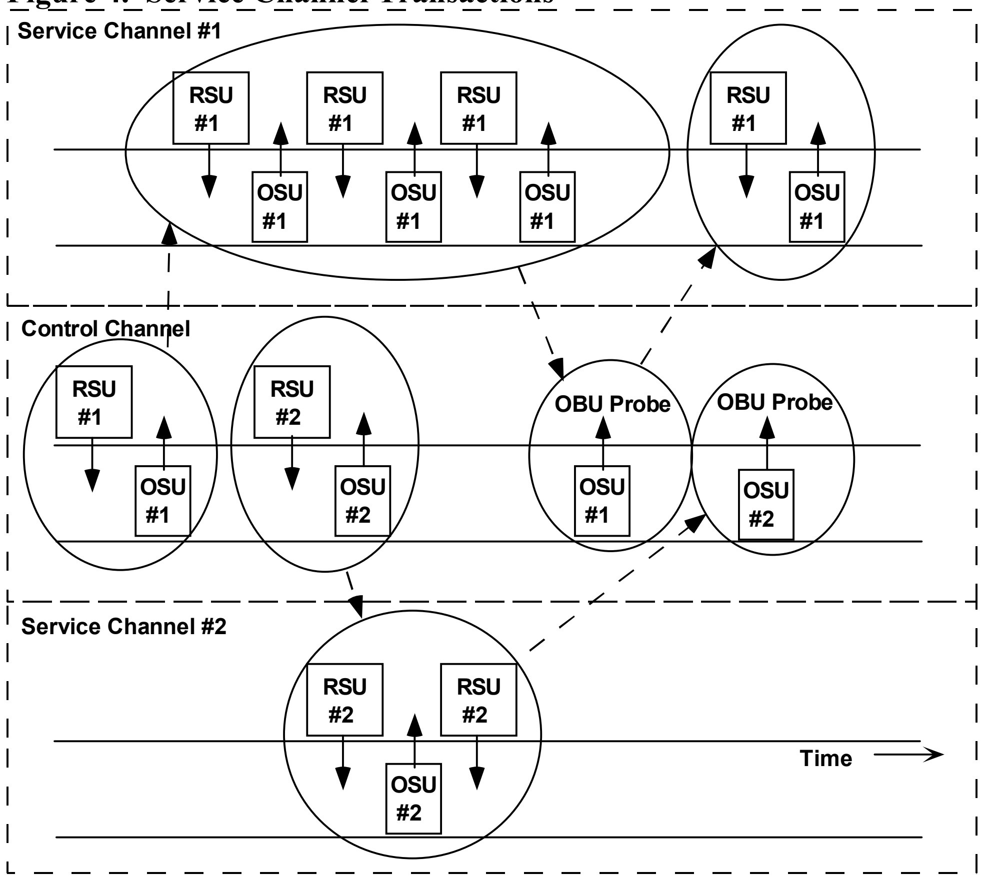
Figure 4. Service Channel Transactions



RSU Monitoring Option

This Control Channel monitoring option allows the RSU to monitor the Control Channel rather than the OBU. This optional method is described in the following paragraphs.

Description: This is also a simple implementation for the OBU but does add complexity to the RSU. In this method the RSU monitors the Control Channel rather than the OBU. When a Service Channel transaction is started the RSU informs the OBU that it will monitor the Control Channel and instructs the OBU to disable its Service Channel Timer. If the RSU receives a Service Table (with a higher priority) on the Control Channel, it informs the OBU(s) on the Service Channel. The OBU is not required to return to the Control Channel until the Service Channel transaction has been completed.

Advantages/Disadvantages: The method adds no complexity to the OBU. The OBU can execute an unlimited duration transaction with the RSU. The Service Channel efficiency is 100%. The disadvantage with this method is the added requirement that the RSU must monitor the Control Channel during the RSU/OBU transaction. Another limitation is the possibility of a 'hidden node'. The RSU may not receive all Service

Table transmissions on the Control Channel since its reception may be blocked by some object or vehicle resulting in the 'hidden node' problem. The RSU Control Channel antenna must also provide omni coverage so it can receive all Control Channel transmissions. This approach does not address OBU to OBU communications on a Service Channel since there is no RSU available to monitor the Control Channel. This method cannot be used alone and must be combined with another method for the effective monitoring of the Control Channel.

Network Monitoring Option

This Control Channel monitoring option allows a network of OBUs to monitor the Control Channel rather than all OBUs providing independent monitoring. This optional method is described in the following paragraphs.

Description: This method is similar to the RSU Monitoring and is used for OBU/OBU network communications. It relies on the OBU Network to assign the Control Channel monitoring to one of its members, presumably on a shared basis. The 'assigned OBU' would return to the Control Channel after a Service Channel Time and use either the Service Table Time or the OBU Probe methods to monitor the Control Channel before returning to the Service Channel Network.

Advantages/Disadvantages: The method adds no complexity to the OBU processing but requires an extra algorithm implementation for networked OBUs. The OBUs in the network can execute an unlimited duration transaction among themselves. The 'assigned OBU' utilization of the Service Channel would be limited by its time on the Control Channel. If the monitoring was randomly shared by all network OBUs then the impact on Service Channel efficiency would be reduced and, depending on the number of OBUs, could be close to 100%. Again this approach cannot be used alone since it does not address OBU/RSU communications and still requires the 'assigned OBU' to execute either the Service Table Time or OBU Probe method. This method only addresses OBU networks and does not address RSU/OBU communications therefore another method must be used for RSU/OBU communications.

Multiple OBU Monitoring Option

Another Control Channel monitoring option uses multiple OBUs in vehicles to monitor the Control Channel. This method is described in the following paragraphs.

Description: This method requires the use of multiple OBUs on a vehicle. One OBU is continuously monitoring the Control Channel while other OBUs are executing transactions with an RSU or other OBUs on Service Channels.

Advantages/Disadvantages: This method has the advantage of allowing one OBU to continuously monitor the Control Channel while another OBU monitors a Service Channel. The two OBUs provide full receive coverage for both channels. This is a very effective method when transmissions on the Service Channels are infrequent, since the OBU monitoring the Control Channel will receive all RST and OST transmissions. However, if an RST or OST transmission on the Control Channel occurs simultaneously with a transmission on the Service Channel, OBU-to-OBU interference may occur. If the Service Channel transmission is shorter than a Service Channel time, and not repeated until another Service Channel time interval has occurred, then full Control Channel monitoring is still achieved. If however, the Service Channel OBU executes extended transactions that do not meet this requirement, RST or OST transmission may be missed. If these conditions exist, then OBU installations must provide enough RF isolation so that the Control Channel OBU can receive Service Table transmissions at the same time the other OBU is transmitting on the Service Channel. The ratio of power between the OBU transmits power (23 dBm) and the required receive sensitivity (-85 dBm) minus the adjacent channel rejection of 40 dB defines an isolation requirement of 68 dB. Therefore 68 dB or more of OBU to OBU isolation is required to assure that all Service Table transmissions are received.

Summary and Conclusions

The Control Channel operational rules, access priority, and Public Service priority interruption of Private ITS Application Sessions, assure that DSRC Units will receive and process higher priority Public Service ITS Applications. The RSU and OBU Service Table transmissions that are transmitted on a periodic basis provides QoS access times for all ITS Applications on the Control Channel. The use of Service Channels for extended RSU and OBU transactions removes this transmission load from the Control Channel and frees up capacity for the Service Table transmissions. The Service Time limit assures that an OBU will return to the Control Channel at periodic intervals, even when it is executing a long duration exchange with an RSU or other OBUs. The combination of these techniques provides the required QoS access time, access priority, and channel capacity required for effective ITS Band operations. These techniques also allow the ITS Band to be shared between Public Service and Private ITS Applications. Public Service applications are provided with timely access to all OBUs and channel capacity for distribution of their services on either the Control Channel or Service Channels. The Private applications can provide their services and not interfere with the operation of the higher priority Public Service ITS Applications. This method can also be used to support Private applications that operate in the UNII Band. A Private application obtains a license to transmit a Service Table in the ITS Band's Control Channel. It uses this transmission to switch the OBU to the UNII Band to receive its services. The Service Channel Time remains functional in the OBU and it will return to the Control Channel looking for Public Service, Service Table transmissions.

An analysis of this technique has shown that Control Channel QoS access times of 100 msec can be maintained and Service Channel efficiencies of greater than 90% achieved. Currently the ASTM/IEEE standards writers are performing additional analysis and simulation studies to further refine these results.

The optional Control Channel monitoring methods provide alternative techniques, supported by the standard, that provides similar functionality but allow for alternative system designs. All methods share one common attribute; they provide QoS access time, priority media access, and OBU availability to Public Service ITS applications. They also allow Private ITS applications to utilize the ITS Band's channel without interfering with these Public Service applications.