



IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)— Resource Manager

IEEE Vehicular Technology Society (VTS)

Sponsored by the
Intelligent Transportation Systems (ITS) Committee

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IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)— Resource Manager

Sponsor

**Intelligent Transportation Systems (ITS) Committee
of the
IEEE Vehicular Technology Society (VTS)**

Approved 15 September 2006

IEEE-SA Standards Board

Abstract: This standard specifies a wireless access in vehicular environments (WAVE) dedicated short-range communications (DSRC) application, known as the WAVE resource manager (RM), designed to allow applications at remote sites to communicate with devices known as onboard units (OBUs), which are mounted in vehicles, through devices known as roadside units (RSUs), which are mounted on the roadside. The WAVE RM, acting like an application layer, multiplexes the communications of multiple remote applications, each communicating with multiple OBUs. The purpose of the communication is to conduct information interchange, needed to implement the requirements of the remote WAVE DSRC applications.

Keywords: DSRC, WAVE, resource manager

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Introduction

This introduction is not part of IEEE Std 1609.1-2006, IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)—Resource Manager.

This standard is based on IEEE Std 1455TM-1999 [B4]^a but intended for the 5.9 GHz frequency band. Several changes have been incorporated to accommodate the new requirements of the communication stack described in the associated standards (IEEE Std 1609.2TM,^b IEEE P1609.3TM, and IEEE P1609.4TM [B3]) and the User Datagram Protocol (UDP) described in IETF RFC 768. As well, some inconsistencies and errors in IEEE Std 1455-1999 have been addressed.

This standard specifies a wireless access in vehicular environments (WAVE) application, known as the *resource manager* (RM), designed to allow applications at remote sites to communicate with devices known as *onboard units* (OBUs), which are mounted in vehicles, through devices known as *roadside units* (RSUs), which are mounted on the roadside. The RM, acting like an application layer, multiplexes the communications of multiple remote applications, each communicating with multiple OBUs. The purpose of the communication is to conduct information interchange, needed to implement the requirements of the remote WAVE applications.

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^aThe numbers in brackets correspond to the numbers of the bibliography in Annex E.

^bInformation on references can be found in Clause 2.

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IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)—Resource Manager

1. Overview

There are two types of wireless access in vehicular environments (WAVE) devices. The first type, referred to as the *roadside unit* (RSU), is stationary while in operation and usually permanently mounted along the roadside. The second type, known as the *onboard unit* (OBU), may operate while mobile and is usually mounted onboard a vehicle (see Figure 1 in 4.1). Typically, the stationary devices host an application that provides a service, and the mobile devices host a peer application that uses this service. There may also be applications on devices remote from the RSU, whose purpose is to provide services to the OBU. This standard describes a WAVE application that resides on the RSU but is designed to multiplex requests from remote applications, providing them access to the OBU.

This standard specifies the WAVE application known as the *resource manager* (RM), which resides on, for example, the RSU, and its peer known as the *resource command processor* (RCP), which resides on the OBU. Remote from the RSU, the other applications, known as *resource manager applications* (RMAs), communicate with the RCP through the RM. This standard describes how the RM multiplexes requests from multiple RMAs, each of which is communicating with multiple OBUs hosting an RCP. The purpose of the communication is to provide the RMAs access to “resources,” such as memory, user interfaces (UIs), and interfaces to other onboard equipment controlled by the RCP, in a consistent, interoperable, and timely manner to meet the requirements of RMAs.

The RM uses the concept of all of the communication being initiated from an entity known as a *provider*, which issues requests to an entity known as a *user*, which responds only to requests that it receives. Within this standard, the RM is the provider of a service (as a representative of the RMAs), and RCP the user of a service (representing the resources to be managed). Either the RSU or OBU can operate as the provider; in other words, either device type can host the RM. The device, either RSU or OBU, that is hosting the RM will be referred to as the *provider device*.

1.1 Scope

The scope of this standard is to specify the services and interfaces of the WAVE RM, including protective mechanisms for security and privacy, applicable and available to all users of DSRC and WAVE mode

operations in the 5.9 GHz band authorized by the Federal Communication Commission (FCC) for intelligent transportation systems (ITS).

NOTE—This version of the standard does not specify explicitly the details of the security interface. Security provisions are in IEEE Std 1609.2TM,^{1, 2}

1.2 Purpose

The purpose of this standard is to enable complete interoperability of applications using WAVE in a manner that simplifies the onboard vehicle systems, reducing cost and improving performance. Effective use of the memory pages by applications can also minimize configuration management issues over the life of a system.

This standard is intended to enable a wide range of applications to be supported by an OBU of the lowest possible cost. The low cost is enabled by removing the need for the OBU to interpret application messages. There is no OBU software representing applications using RM; thus the processing, memory, and configuration management requirements are removed from the OBU. Instead of putting such processing requirements on the OBU, they are placed on the RSU or an application processor remote from the RSU. The only processing requirement is that of interpreting the specific commands and message headers defined herein, which is application independent. The OBU merely serves as a mobile mailbox to carry application messages and data from one RSU to another or as a common interface point to transfer data to other onboard systems.

By allowing memory to be assigned to an application at any time during the life of the OBU, future applications can be developed and deployed without onboard hardware or software modification.

For applications using RM as a mobile mailbox, with no onboard use of the data stored in memory, there are significant security advantages. By having the OBU treat each application's messages as a bit-stream to be saved and later retrieved from memory, such data can be encrypted in a manner that is not known to the OBU. There is no need for the OBU to support the encryption schemes used by these applications, and such security schemes can be under the total and absolute control of each of these applications.

2. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE P1609.3TM, Draft Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)—Networking Services.^{3, 4, 5}

IEEE Std 1609.2TM, IEEE Trial-Use Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages.

IETF RFC 768, User Datagram Protocol.⁶

¹Information on references can be found in Clause 2.

²Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement this standard.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

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3. Definitions, abbreviations, and acronyms

For the purposes of this standard, the following terms and definitions apply. The glossary in Annex D and *The Authoritative Dictionary of IEEE Standards Terms* [B1]⁷ should be referenced for terms not defined in this clause.

3.1 Definitions

3.1.1 application class identifier (ACID): A code that identifies a class of applications.

NOTE—See IEEE P1609.3.

3.1.2 application context mark (ACM): A code that identifies a specific instance of an application within a class.

NOTE—See IEEE P1609.3.

3.1.3 application protocol data unit (APDU): Packets of information transmitted over the communication media between the RMA and RM by the application service layer.

NOTE—See protocol data unit (PDU) in Annex D.

3.1.4 onboard unit (OBU): A wireless access in vehicular environments (WAVE) device that can operate when in motion and supports information exchange with roadside units (RSUs) and other OBUs.

NOTE—See onboard equipment (OBE) in Annex D.

3.1.5 provider: The part of an application that provides services.

3.1.6 provider service table (PST): The collection of data describing the applications that are registered with and available through a wireless access in vehicular environments (WAVE) device, with supporting channel information.

3.1.7 response to provider service table (RPST): A data structure returned to the wireless access in vehicular environments (WAVE) application from an onboard unit (OBU), upon receipt of a provider service table (PST) identifying a resource hosted by the OBU.

3.1.8 roadside unit (RSU): A wireless access in vehicular environments (WAVE) device that operates only when stationary and supports information exchange with onboard units (OBUs).

NOTE—See roadside equipment (RSE) in Annex D.

3.1.9 wireless access in vehicular environments (WAVE) device: A device that contains a WAVE-conformant medium access control (MAC) and physical layer (PHY) interface to the wireless medium.

NOTE—See IEEE P802.11pTM [B2].

3.2 Abbreviations and acronyms

ACID	application class identifier
ACM	application context mark
APDU	application protocol data unit
ASDU	application service data unit

⁷The numbers in brackets correspond to the numbers of the bibliography in Annex E.

ASN.1	Abstract Syntax Notation One
CVO	commercial vehicle operations
HEX	hexadecimal
IP	Internet Protocol
ITS	intelligent transportation systems
MIB	management information base
MSB	most significant bit
OBU	onboard unit
PDU	protocol data unit
PST	provider service table
RCP	resource command processor
RF	radio frequency
RM	resource manager
RMA	resource manager application
RPST	response to provider service table
RSU	roadside unit
SAP	service access point
SDU	service data unit
UDP	User Datagram Protocol (IETF RFC 768)
UI	user interface
WAVE	wireless access in vehicular environments
WBSS	WAVE basic service set
WME	WAVE management entity (defined in IEEE P1609.3)

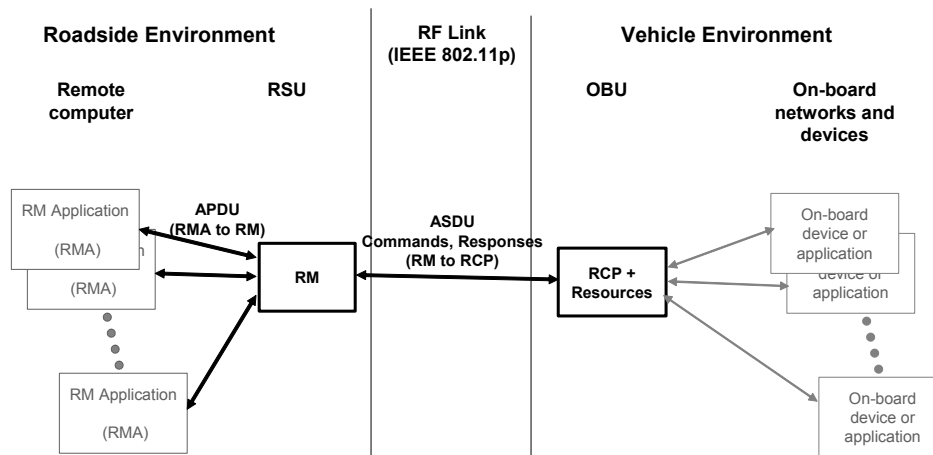
4. Architecture and communications flow summary

4.1 General

This standard describes one specific WAVE application consisting of the RM and its partner, the RCP, that provide services to a remote entity, an RMA. The RM (or provider) relays commands received from the RMA to the RCP (or user). In turn, the RCP executes the commands it receives and returns responses to the RMA via the RM. Whereas the RCP resides on an OBU, the RM may reside on an RSU or OBU.

Implemented as a WAVE application from the perspective of IEEE P1609.3, the RM provides services that allow RMA to access the memory and UIs within the OBU as well as interfaces to other onboard equipment controlled by the RCP. As such, the RM acts as if it were an application layer to an RMA.

In general, RMAs communicate with one or more RMs over a secure wired network, whereas an RM communicates with an RCP over the wireless link on which the security may be lacking. The RM multiplexes the communication sessions of multiple RMAs in a manner that allows each RMA to communicate end-to-end with RCPs as illustrated in Figure 1. For simplicity, this figure shows the RM hosted by an RSU as part of the roadside environment, but the RM may also be hosted by an OBU, a scenario not shown in this figure.



Elements covered by this standard are dark and in bold text,
elements not addressed by this standard have light lines and text

Figure 1—Components addressed in this standard

In general, each RMA uses a set of commands (executable by each RCP) to

- Store information in, and retrieve information from, OBUs
- Request the use of UI resources on OBUs (not to be confused with the vehicle's UIs)
- Access specific networks interfaced to OBUs
- Interrogate optional security devices hosted by OBUs

This standard refers to “managing resources” hosted by OBUs, where these resources consist of, but are not limited to,

- Read/write memory
- UIs that are included as part of the OBU
- Specialized interfaces to other onboard equipment
- Optional vehicle security devices interfaced to the OBU

This standard specifies

- The services provided by the RM to the RMA
- How the services provided by IEEE P1609.3 are used to advertise the presence of the RM and RMAs to OBUs
- How the RCP recognizes and responds to the presence of the RM and each of its associated RMAs to complete an application process or transaction
- The managed memory-based resources hosted by OBUs and how they are used to store and retrieve information and control OBU UIs and other equipment interfaces
- The command set available to RMAs to manage these resources, how these commands and their responses are interchanged between RMAs and the RM and RCPs over a secure WAVE radio frequency (RF) link
- The use of specialized read/write memory resources that allow the transfer of data to other equipment interfaced to the OBU and controlled by the RCP

4.2 Application component references

This standard governs the

- Managed resources hosted on the OBU (Clause 5)
- Commands and responses used by the RMAs to manage these resources (Clause 6)
- Management services and data transfer services provided to the RMAs by the RM (Clause 7)
- Interface to the lower layer services (Clause 8)

4.3 WAVE RMA data transfer and management services

As illustrated in Figure 1, the RM provides services to applications known as RMAs. These services, provided through a standardized interoperable interface, allow the implementation of low-latency applications.

An RMA, in its simplest form, retrieves data in blocks of memory that reside on the OBU. These blocks of memory are known as *pages* and are part of the OBU RCP resources.

All remote access to pages is via a secured RF link. Some pages are accessible to all RMAs; others are registered to a specific RMA and accessible only to that RMA. Such registration is in accordance with Annex B. Registered pages are allocated to a specific RMA across a set of OBUs and are considered resources accessible to the RMA to which they are registered. The management is done using the set of commands specified in Clause 6. Some of the pages are defined so that storing data on, and retrieving data from, them performs the management of UIs that are part of, or connected to, the OBU. These pages are said to be *memory-mapped* to the UI. Some pages are defined so that they act as a communication buffer between the OBU and onboard equipment or network interfaced to the OBU. These pages are known as *transfer pages*. Writing data to transfer pages initiates the transfer of these data to the associated equipment or network. As well, the equipment or network associated with the interface may write data onto this or another page allowing these data to be read by the associated RMA to complete the interchange.

This standard, by defining a command set that provides access to pages and by specifying that each resource be mapped to a page, allows any RMA, by the use of the command set, to manage in a standardized and interoperable manner all OBU RCP resources to which it has access.

Figure 1 illustrates that there is a two-stage process involved in the interchange of commands and responses. One stage is from RMA to RM via defined application protocol data unit (APDU); the other is from RM to RCP through a set of commands and responses. Commands, encapsulated and transmitted by the RMA in APDUs over a network, are received by the RM. Upon receipt, the RM extracts the commands and encapsulates them in User Datagram Protocol (UDP) packets that it transmits, via the RF link, to the specified OBU's RCP. Upon receipt, the RCP executes the commands and returns the appropriate responses to the RM, encapsulated in UDP packets. The RM, in turn, extracts and reencapsulates the responses in APDUs for transmission to the RMA. The APDUs are described in Clause 7. The commands and responses are described in Clause 6.

4.4 Data structure representation

Data interchanged between the RM and RCP over the RF link are encapsulated and transmitted between the RMAs and RM in packets of information known as *application protocol data units* (APDUs). Data interchanged between layers of the protocol stack within the RSU or within the OBU are transferred as *application service data units* (ASDUs).

4.4.1 Protocol data units (PDUs)

PDUs are data transmitted in both directions across the communication media and are said to be *visible*. The open, visible transmission requires that all implementations create PDUs that adhere to a specified structure. Abstract Syntax Notation One (ASN.1) is used to define the structure of each PDU and each component within the PDU. Packed encoding rules, aligned, (PER-Aligned) are used to convert ASN.1-defined structures to transmission format. The convention used in this standard for ASN.1 structure is as follows:

```
<ComponentStructureType> ::= SEQUENCE
{
  <descriptive-tag1>          <SubComponentStructureType1>,
  <descriptive-tag2>          <SubComponentStructureType2>,
  etc.
}
```

4.4.2 Service data units (SDUs)

SDUs specify parameters to services provided by one protocol layer to another in the same device. Generally SDUs are implemented by a software mechanism such as a function call. SDUs are used to pass information across a software interface known as a *service access point* (SAP). As such, SDUs are said to be not visible, and the data fields may be transferred between internal layers in an implementation-specific manner. To distinguish SDUs from PDUs, this standard will adopt the following (non-ASN.1) format for the specification of an SDU:

```
<SDU-NAME<.request>|<.confirmation>|<.indication>|<.response>>
( <ASN.1 parameter1-type>      <parameter1-name>,
  <ASN.1 parameter2-type>      <parameter2-name>,
  etc.
)
```

All services have four basic forms: request, indication, response, and confirmation. These services may be used in confirmed mode, nonconfirmed mode, and locally confirmed mode. Figure 2, Figure 3, and Figure 4 illustrate the concepts.

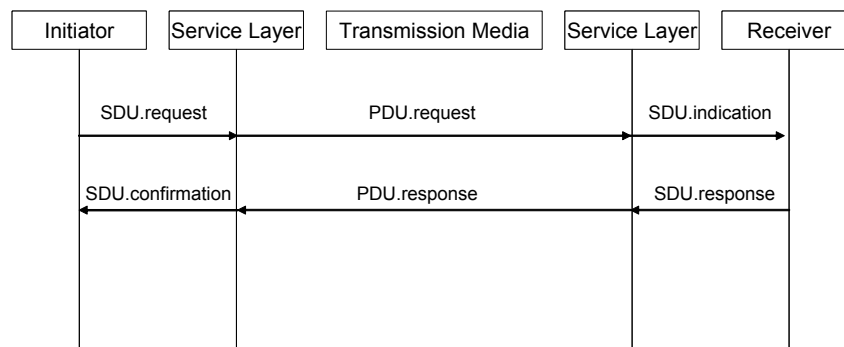


Figure 2—Services in confirmed mode

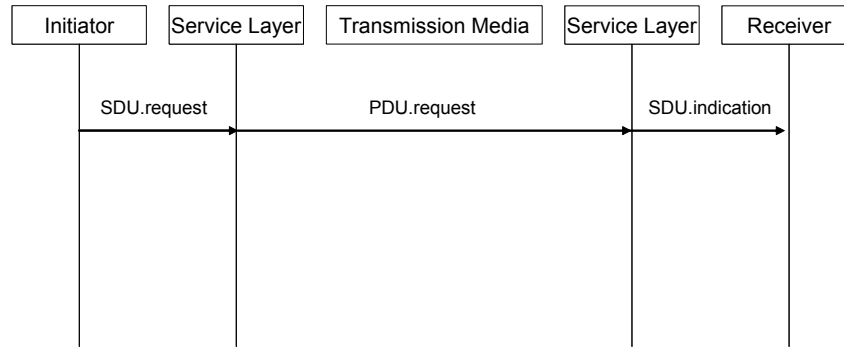


Figure 3—Services in nonconfirmed mode

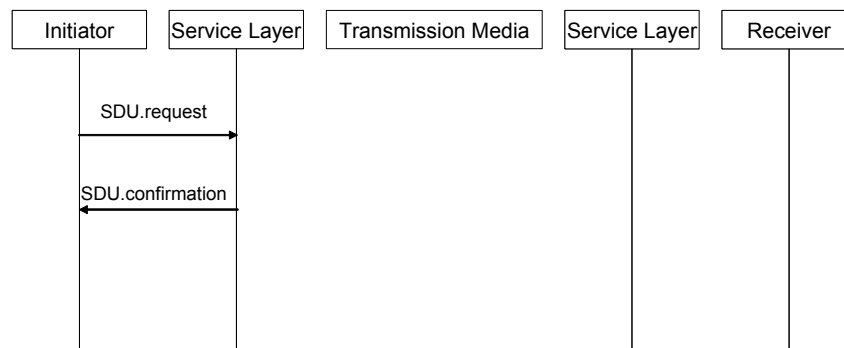


Figure 4—Services in locally confirmed mode

4.5 Summary of operation

The sequence diagrams of Figure 5 and Figure 6 use two approaches to showing the basic end-to-end flow of the application’s data interchange. The details are described in subsequent clauses of this standard or in related standards. A simplified explanation of the operations shown in Figure 5 and Figure 6 are found at the end of this clause. Specific names of data units and structures will be described in subsequent clauses or in related standards.

A summary of the operation is as follows:

- Each RMA shall be registered with the RM with which it will be interacting. This registration includes a list of the OBU RCP resources to which access is desired.
- A list of the resources of interest to the RMA is incorporated into the application context mark (ACM). The RM creates the ACM in accordance with the ASN.1 definitions of Annex A (RM-ApplicationContextMark). There is an upper bound on the size of the ACM, described in IEEE P1609.3, which may not be exceeded.
- Each RMA, when ready to begin processing transactions, requests that it become “active” (see 7.4.1). In the activation, it specifies the OBU RCP resources in which it has interest (i.e., the pages to which it requires access). The RMA also specifies in the activation an optional auto-command sequence that the RM executes on its behalf upon receipt of a response to provider service table (RPST).

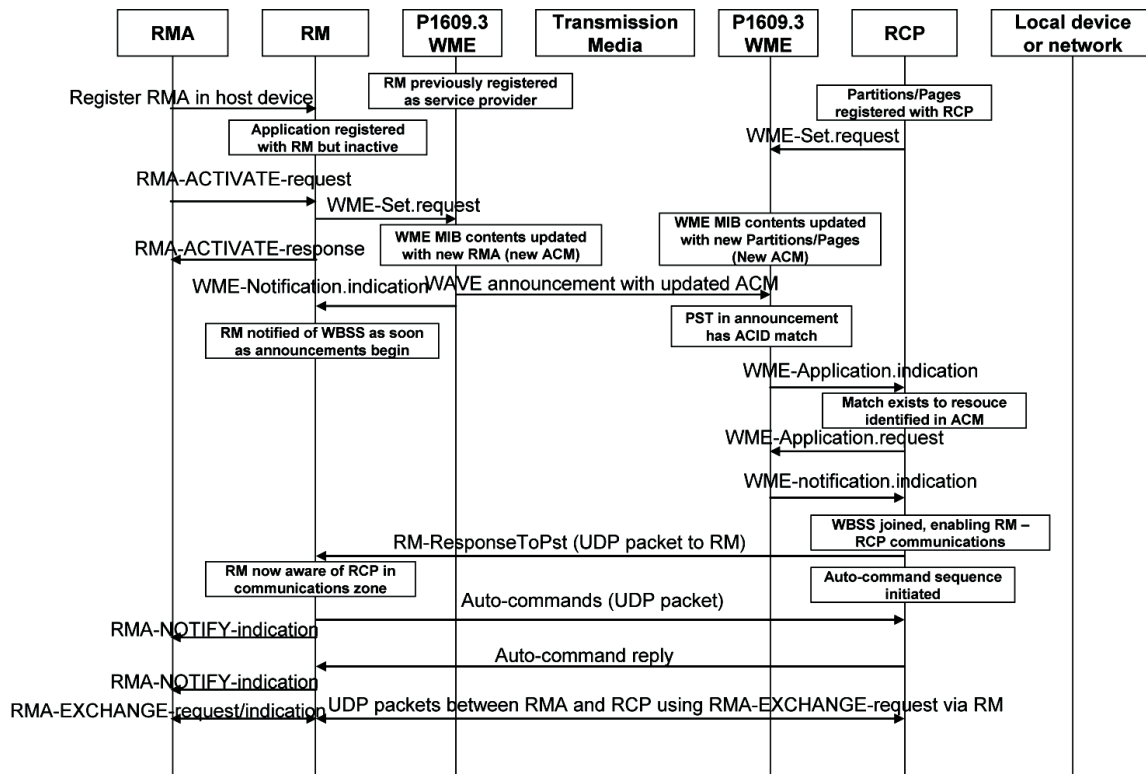


Figure 5—Data flow and management update operations in RMA/RM/RCP communication

- The RM and RCP (being WAVE applications) register with the WAVE management entity (WME) as specified in IEEE P1609.3. The RM registers so that it is incorporated into the application list sent in the provider service table (PST) that includes its ACM created above. The RCP on the OBU registers with the WME as a user application.
- Upon receipt of a PST by the WME on the OBU, the RCP is notified that it is in the presence of an RM and receives, with the notification, access to the contents of the ACM.
- The RCP scans the ACM for a match on any resource that it hosts. If there is a match, it generates a RPST and, after requesting that the WME join the WAVE basic service set (WBSS, defined in IEEE P802.11p [B2] and IEEE P1609.3), transmits it directly to the provider RM.
- Upon receipt of this RPST, the RM notifies each associated RMA that it is in the presence of an OBU RCP hosting resources to which it has access, after the possible transmission of an auto-command sequence (see 7.4.1.3, 7.4.3.4, and 8.7) registered by the RMA.
- After this interchange is complete, the RMA, using the services of the RM, may request that commands be transmitted to the RCP using the exchange request service as specified in 7.5.1.
- As responses to these commands are received, the RM relays them in exchange responses to the correct RMA.
- The session is then formally terminated at the application level. The RMA terminates the session by transmitting a Sleep Transaction command, described in 6.4.5, to the RCP and a terminate session indication, described in 7.4.5, to the RM on the RSU.

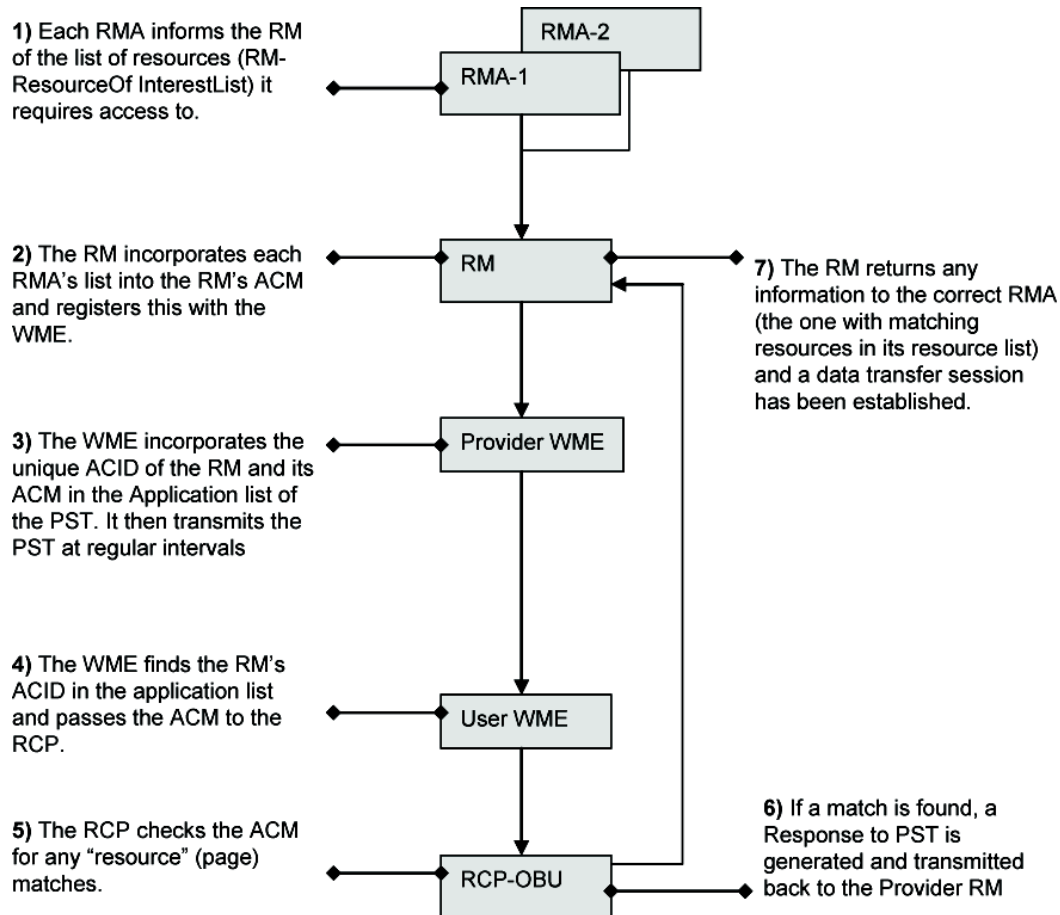


Figure 6—Steps in establishing a data transfer session between RMA and RCP

5. OBU resources

5.1 General

All OBUs will include memory in accordance with 5.2, but may also include additional resources such as UIs, equipment and network interfaces, and security devices. All resources provided shall be capable of being controlled by the RCP using the commands defined in Clause 6.

5.2 Memory

WAVE devices conforming to this standard provide memory, subdivided into addressable blocks known as *pages*. These pages are used by RMAs to store (write) and retrieve (read) data using the RM command set defined in Clause 6.

Pages in this standard are of the following types:

- Storage pages (general purpose read/write)
- Memory-mapped pages (e.g., UI)
- Transfer pages (to/from external interfaces)

When a page is reserved using the Reserve Memory command described in 6.4.6, the page type is specified by the enumerated value RM-PageType (defined in Annex A). Page types “storage” (type 0), “mapped” (type 1), and “transfer” (type 2) may use either an application-controlled format or the RM-Message format data structures. Page types “storageInsert” (type 128), “mappedInsert” (type 129), and “transferInsert” (type 130) shall use the RM-Message format data structure defined in 5.4.

Memory on the OBU that is accessible to RMAs shall have the following properties:

- It shall be capable of being subdivided into partitions (having the unique identifier “RM-partition” in Annex A) and addressable pages within each partition (having the unique identifier “RM-Page” in Annex A).
- The size in bytes of each partition shall be specified by a 16-bit integer (see 6.4.8), limiting them to 64k bytes.
- The size in bytes of each page shall be specified by a 16-bit integer (see 6.4.6), limiting them to 64k bytes. This size is further limited by the fact that several pages may be contained within a single partition.
- Page 0 in partition 0 shall be reserved for implementation-specific usage, and attempts to access its content shall be considered invalid.
- Partition 0 shall be mandatory, whereas the provision for defining other partitions is optional.
- An RMA may reserve, via an offline registration process, pages within the mandatory partition 0 or, if supported, a partition within which it may allocate pages used for its own specific purposes. This assures that each OBU that has been provisioned by any supplier acts as a virtual private device to multiple RMAs. The current allocation of pages in partition 0, and partitions, is found in Annex B.
- Memory-mapped pages, if provided, shall have the capabilities described in 5.2.2.
- Transfer pages, if provided, shall have the capabilities described in 5.2.3.

All partitions and all pages are identified by a 16-bit identifier. The currently defined identifiers for partitions and pages are provided in Annex B.

5.2.1 Storage pages

The most general type of page is the application-controlled storage page. A page of this type is used by an RMA to store and retrieve data. Usually, the implementor of an RMA requests that a population of OBUs be manufactured within which their specific page is reserved. This may be done by the manufacturer, using the Reserve Memory Page command, or at a facility operated by the implementor of the RMA. Subsequently, the RMA uses the services of the RM to store and retrieve data using its page. The data are stored in a format specific to the RMA and are not modified in any way by the RM or RCP.

5.2.2 Memory-mapped pages

The OBU may provide any combination of the UI devices described in this subclause. The availability of these devices accessible to an RMA shall be specified in a data field described in 8.5.2. If present, these UI devices shall be controlled using the Set User Interface command specified in 6.4.4. UIs are controlled by writing data to, or reading from, special memory pages referred to as *memory-mapped pages*. These memory-mapped pages act as buffers to the specific UI associated with each such page. The data written to one of these pages shall be used when a Set User Interface command (6.4.4) is given to transfer these data to the associated UI. In the case of data coming from the UI, such as a keypad, the data written to this page may be retrieved by a Read Memory Page command (6.4.1) to transfer these data to the RMA associated with this page. Memory-mapped pages are preassigned the identities in Table B.1.

5.2.3 Transfer pages

Pages designated as transfer pages may be provided as a means of interfacing with onboard equipment and networks. These pages shall be associated with a specific external interface controlled by the RCP if the interface is present. If an authorized RMA writes data to one of these pages, the data shall be transferred to the associated interface. The details of the transfer mechanism are implementation specific. The format of the data stored is defined when the specific application is designed. A means of storing data received from interfaced onboard equipment or networks onto these transfer pages may be provided to create a two-way communication path to the RMA.

5.3 User interfaces (UIs)

5.3.1 Visual displays

The OBU may provide visual displays such as colored light emitting diodes (LEDs). There may be up to three, with each being a different color. The acceptable colors are red, green, and yellow or their closest equivalent depending on the display technology.

5.3.2 Buzzers (audible alert)

The OBU may provide a buzzer used to alert the user with an audible signal.

5.3.3 Enunciators

The OBU may provide an enunciator. Enunciators are capable of simulating speech or music whereas a buzzer is limited to on/off fixed tones. The enunciator shall be used to present messages that have been written to the corresponding memory-mapped page (see Note 5 and Note 6 in 6.4.4).

5.3.4 Character readout

The OBU may provide a character readout. The character readout shall be used to display text messages that have been written to the corresponding memory-mapped page (see Note 5 and Note 6 in 6.4.4).

5.3.5 Keypad

The OBU may provide a keypad. The keystrokes that are entered using this keypad shall be inserted as a message into the corresponding memory-mapped page. This page may then be read by authorized applications allowing them access to the data that were entered.

5.3.6 Future UI resources

Future revisions of this standard may provide for additional UI resources. The extensibility of the OBU Configuration field (8.5.2) allows for the definition of bits that indicate the presence of new resources.

5.4 Data formats for memory resources

If interoperable applications are to share information with each other via the storage and retrieval of data, the format and content of the data shall be defined by a standardized message format (the RMA message format defined in this subclause). When interoperability with other applications is not required, this standard permits data to be in any format, including proprietary, and what is standardized is the means of storing and retrieving the data (see Clause 6).