The Interaction between the V Protocol and the Q.2931 Protocol for the Interactive Video Network

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Abstract

There are many examples of interactive visual and multimedia applications including Movies on Demand, video conferencing, etc., which are emerging in trials and eventually in full service networks. Technology and standards are being developed for these services and networks. DSM-CC (Digital Storage Media Command and Control), a sub-group of MPEG, is one such standard. AT&T has been active in the DSM-CC sub-group, submitting its V Protocol in cooperation with other companies. The V Protocol is a message based session layer protocol with a defined set of procedures for establishing sessions and releasing sessions/resources across the Interactive Video Network (IVN) which could include an ATM network. We discuss the interaction between the V Protocol and the ATM Q.2931 network layer protocol to set up sessions over the IVN that require ATM switched virtual circuit connections. The ATM Q.2931 connection is treated as one of many possible resources for a given session. By having a clear separation between a session and its resources, the V Protocol is capable of supporting dynamic resource allocation in a distributed server environment.

1. Introduction

Movies on Demand, video conferencing, distance learning, and telemedicine are just some examples of interactive visual and multimedia applications that are rapidly approaching. They promise to enhance the quality of communication in the years to come. While there are many challenges to establishing an Interactive Video Network (IVN), the availability of enabling technologies and standards (e.g., SONET, ATM, and MPEG-2) are helping bring it closer to reality. One such standard is DSM-CC (Digital Storage Media Command and Control), a sub-group of ISO/IEC SC29 WG11 (i.e., MPEG).

The DSM-CC protocol [1] is a session layer protocol intended to provide the command and control functions for the management and operation of applications over a heterogeneous network environment. AT&T has been an active member in the DSM-CC sub-group where it submitted its V Protocol [2] in cooperation with other parties as the basis for the User-Network section of the DSM-CC standard.

After a brief introduction of the V Protocol, we discuss the interaction between the V Protocol and the ATM Q.2931 network layer protocol [3] to set up sessions over the IVN that require ATM switched virtual circuit (SVC) connections. The two signaling protocols are at different protocol layers (session vs. network) and are used for different purposes as described in their respective references.

2. Networks

This paper refers to two types of networks: the Interactive Video Network (IVN) and the ATM network. The V Protocol session layer protocol concerns the IVN, while the Q.2931 applies to the ATM network.

The IVN allows a subscriber to receive IVN services from one or multiple IVN service providers. Examples of IVN services are Movies on Demand, News on Demand, Electronic Mall, etc.. In this paper, the equipment residing in the subscriber's home is referred to as the Client. Some examples of Clients are set-top terminals, IVN-ready television sets, and IVN-capable personal computers.

The IVN service providers offer their services to the subscribers by hooking their computer complexes which

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contain the service applications into the IVN. In this paper, these computer complexes are referred to as the Servers.

The IVN is maintained by the IVN provider. In an FCC-regulated Video Dialtone environment [4], the IVN provider may not be the same as the IVN service provider. Central to an IVN is the concept of an IVN Manager which contains the intelligence on the overall IVN capabilities, network resources, information about clients, information about client application providers, IVN OAM&P, IVN control plane services, etc. In reality, this IVN Manager, owned by the IVN provider may be implemented in various architectures (centralized, distributed, etc.) to fit the needs of the IVN provider. To request a service, a Client communicates with the IVN Manager. To offer a service, a Server communicates with the IVN Manager. The V Protocol is a session layer protocol between a Client and the IVN Manager, and between the Server and the IVN Manager. Protocols between the Server and the Client are not part of the V Protocol.

The IVN, a logical network, is built on top of different physical networks. The most promising of all is the ATM network due to its flexible on-demand bandwidth. However, it is not required, from the philosophical point of view, to have ATM for IVN services.

The ATM network provides Asynchronous Transfer Mode (ATM) connectivity. The ATM network may provide connectivity end-to-end between the IVN subscribers and IVN service providers - this is the *baseband* approach [5]. The ATM network may provide connectivity for only part of the IVN i.e., between the IVN service providers and some IVN head-end equipments, and the remaining part is continued with radio frequency (RF) modulations - this is the *passband* approach.

In either the baseband or passband approach, if ATM SVC connectivity is available, it will be used by the IVN service providers' equipment (e.g., Servers) to send data to the subscriber's equipment (e.g., Clients). In the V Protocol defined IVN environment, this connectivity must be conducted under the auspice of a V Protocol session. How this is done is the main topic of this paper.

3. Signaling reference model

The V Protocol introduces a session layer set of messages and procedures that describe the process of establishing and releasing sessions/connections across the network. For networks that support switched services, the V Protocol provides a mechanism to utilize the Q.2931 messages at the network layer to establish specific virtual circuits. Figure 1 shows a signaling reference model for the IVN.

In reference to the model, both Clients and Servers interact with the IVN manager over a transparent transport network to establish sessions. For switched services, Q.2931 messages will be used to set up and release switched virtual circuits, under the direction of the V Protocol session control.

After a session is established, direct signaling between the Client and Server occurs via the User-User signaling protocol without the involvement of the IVN Manager. Video and data transfer takes place over a unidirectional pipe from the Server to the Client. User-User signaling protocol is beyond the scope of this paper.

4. V Protocol overview

The V Protocol is a message based signaling protocol that is used for the establishment, management, and tear down of sessions between service providers and subscribers over the IVN. The V Protocol resides at the session layer in the ISO stack, and it uses network layer protocols to establish connections across the IVN.

4.1 V Protocol principles

The V Protocol is based on the following principles:

- Network technology independence:
  The V Protocol is not linked to any particular network technology. It rather makes use of the underlying network and network level protocols to manage connections between end-points.
- Distinction between the concepts of *sessions* and *resources*:
  While a session is an association between two parties (a Server and a Client), a resource is a trackable "object" or "element" allocated and retrieved by the IVN Manager within the session. This distinction allows for the development and offering of advanced applications to the end-user.
- Abstract representation of resources:
  The V Protocol abstracts network resources and views them as objects having their unique characteristics. This abstraction of resources allows for the introduction of new network architectures and for the integration of new network elements into existing networks without the need for major changes to the protocol itself.

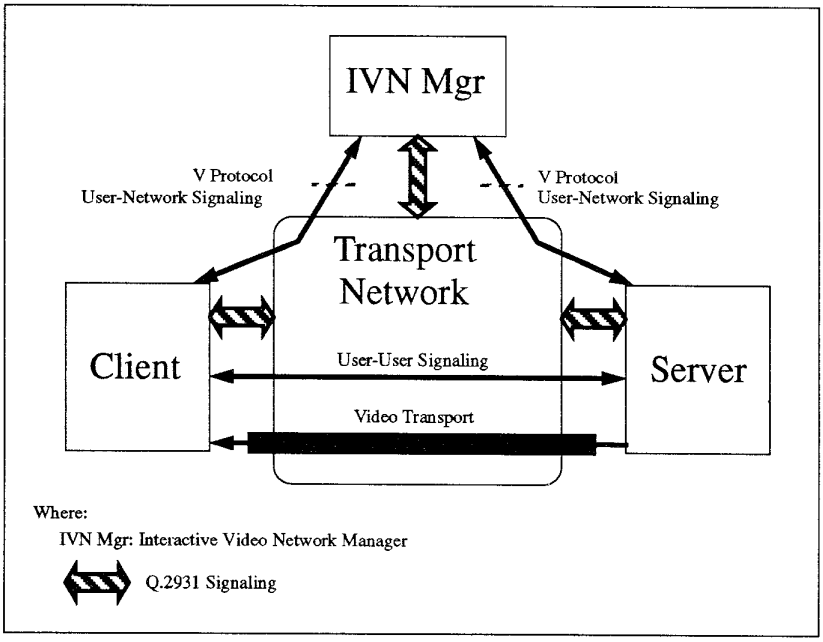

Figure 1. Signaling Network Reference Model

- Dynamic resource allocation:
  The V Protocol supports dynamic resource allocation during the life time of a session, where resources could be added to or deleted from an active session according to the needs of the client and server.
- Complementary role with other control protocol:
  The V Protocol provides the mechanism to support resource negotiation and advanced session features, while the Q.2931 protocol provides the mechanism to establish calls and switched connections[1]. The V Protocol and the Q.2931 protocol provide complimentary roles in supporting advanced interactive video services.

4.2 V Protocol functions

The V Protocol defines the messages and scenarios for supporting session-level management functions, such as:

- Session establishment and termination, as requested by the client or the server.
- Dynamic resource allocation/deallocation during the lifetime of a session, as requested by the client or the server.
- Forward and transfer of sessions and resources between servers and application. This allows for the

1. The ATM Forum defines a call as an association between two end users or between an end user and the ATM network to use the ATM network capabilities. A call can be associated with zero or more ATM connections.

   In the context of the V Protocol, a session is also an association but in broader terms. While a call is defined only in the context of an ATM network, a session associates a Server and a Client in the context of a IVN network which may include an ATM network as a sub-component. Therefore, the session association may include ATM transport resources, other (non-ATM) transport resources, and other types of resources that may not be related to the transport capability. Note that a session may not need any one-to-one connection at all, such as a "broadcast" session or a "datagram-type" session. For the IVN network provider, a session is used as the point of entry to implement high layer policy decisions, enhanced IVN services (such as "Session Transfer") and to monitor all resources related to a current session between a Client and a Server.

A connection represents a *transport resource* from the point of view of the V Protocol. There can be other types of resources, such as *addressing* resources, *MPEG-2* resources, etc.. which may be needed in order to support a application/service over the IVN network.

support of a distributed application environment.

- Status and other OA&M activities for monitoring the state of a session.

The above mentioned principles position the V Protocol as the preferred signaling protocol for the control and management of interactive sessions across a diverse transport network. Most of the principles of the V Protocol have been submitted to the standard bodies.

5. Resources in the V Protocol

The V Protocol User-Network messages are assumed to be apart of a larger protocol stack, operating at the session layer. They can be carried on top of various transport protocols (e.g., UDP or TCP), however, remain independent of any specific lower layer protocol. The User-Network messages are used to establish a session between a Client and Server. Resource descriptors are used to describe the network assignable resources which are needed for a given session. In general, they can be requested by either the Client or Server when either initiates a Request message. The IVN Manager responds to a Request message with a Confirm message. Indication messages are sent asynchronously to the Server or Client from the IVN Manager. A Response message is sent by the Server or Client in response to the Indication message.

Resources are abstracted in terms of resource descriptors. A resource descriptor is a data structure that contains the *request-id, request-type, resource-type, resource-id, and resource-data-bytes.* A *request-id* allows the Server to correlate the response from the IVN Manager with the Server's outstanding resource assignment request. The *request-type* identifies if the resource is negotiable, non-negotiable, or don't care. The *resource-type* is the type of resource being requested (e.g., upstream and downstream bandwidth).

A *resource-id* is a unique resource identifier assigned by the IVN Manager. Thus, if a Server (or Client) is re-negotiating a resource, it contains the existing *resource-id* and is replaced with a new *resource-id* by the IVN Manager if the resource is re-assigned. The *resource-data-byte* is a variable length field that facilitates the exchange of information pertaining to a given resource from one User to another.

6. V Protocol scenarios

6.1 Session set-up

In the IVN environment, before a Server can request an ATM SVC connectivity to the Client, it must have an IVN session. This session is either established by a request from the Client (Client Session Set-Up scenario) or from the Server itself (Server Session Set-Up scenario). As an example, the following description uses the Client Session Set-Up scenario, as shown in Figure 2.

A subscriber, viewing a list of IVN services on his television set, selects via a remote control an IVN service. His set-top terminal, acting as the IVN Client, sends a Client Session Request message to the IVN Manager. This message contains the *terminal-id* which identifies the Client and the *service-id* which identifies the selected IVN service.

The IVN Manager, upon receipt of this message, performs various high-level decisions, based on the policies set up by the IVN provider. For example, the IVN provider may reject requests from Clients of subscribers in arrears. Or it may reject requests to Servers owned by non-paying IVN service providers. As another example, an IVN service provider may have informed the IVN provider that one of its services is temporarily out, allowing the IVN Manager to reject a request to this service on the spot. After the IVN Manager has validated both the Client and Server, it contacts the indicated Server. The low level transport and network addresses of the Server (e.g., IP address or E.164 address) are kept by the IVN Manager - as far as the Client is concerned, it only knows about the high-level *service-id.*

Upon receipt of the Server Session Indication message from the IVN Manager, the Server verifies the *terminal-id* from the Server's point of view (e.g. "is this Client a valid subscriber of my service"), and makes the decision to accept or reject the request. If the Server rejects the request, it will send a Response message back to the IVN Manager with the cause of the rejection. The IVN Manager then informs the Client with a subsequent negative Confirmation message.

If the Server accepts the request, it collects any resources that it needs from the IVN in order to support the selected service. If the service needs one or more ATM SVC connections, the Server will embed the proper number of *ATM SVC resource descriptors* in the Server Session Response message. These resource descriptors can be tagged NEGOTIABLE or NON-NEGOTIABLE, and will contain sufficient information for the IVN Manager to later establish a non-associated connection between the Server and a downstream headend equipment.

The encoding of the *ATM SVC resource descriptor* is an interesting issue by itself. It has been suggested that

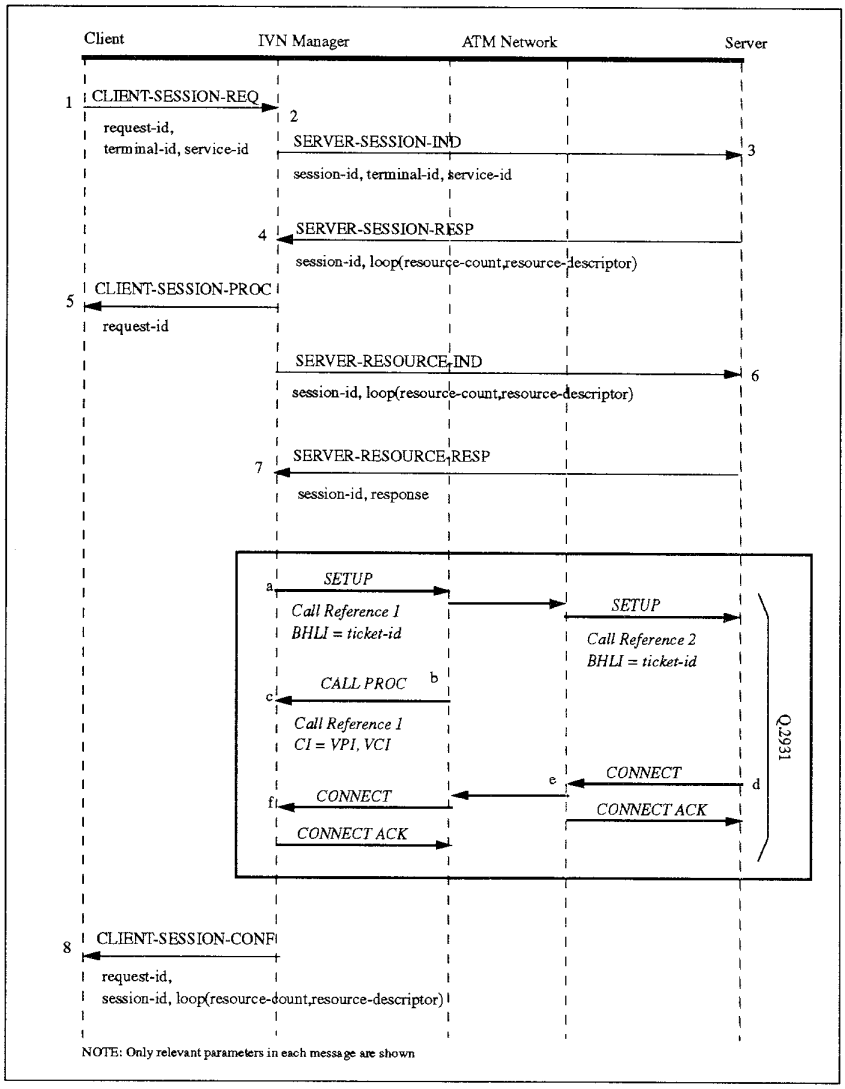

Figure 2. Client Session Set-Up

this descriptor must have low-level Q.2931 information, such as Called Party Number, ATM User Cell Rate, Quality-Of-Service (QoS) parameters, etc.. Another suggestion goes the opposite way and takes the higher view. It abstracts the connectivity through classes of services (CoS), such as a Movie-On-Demand CoS, with each CoS having its own requirements on connectivity (such as bandwidth and latency). With the CoS view, the *ATM SVC resource descriptor* may be replaced by a "CoS" resource descriptor. It is the job of the IVN Manager to translate the need of a CoS into physical connections. If the physical network is an ATM network, the proper values for the various Q.2931 information elements will be derived. If the IVN is based on a different network architecture, another translation will take place. The goal is to hide the IVN architecture from the Server's applications.

Upon receipt of the Server Session Response message, the IVN Manager will process the resource descriptors included in the message. For an ATM SVC resource (received directly from the Server or translated

through a "CoS" resource), the IVN Manager may verify the requested properties (e.g., User Cell Rate and QoS) against the static capability of the ATM switch as provisioned in the IVN Manager. If the *ATM SVC resource descriptor* is tagged as NEGOTIABLE and the requested properties cannot be satisfied, the IVN Manager may propose alternatives (e.g., different QoS, different bandwidths).

For any ATM SVC resource request that is not rejected, the IVN Manager constructs a replying resource descriptor. This resource descriptor will contain the normative *resource-id*. Note that the *resource-id* is unique per session (itself represented by a *session-id* which appears outside of the resource descriptor but inside the Indication message the IVN Manager is sending back to the Server). The *resource-data* field of the replying resource descriptor will contain a ticket identifier (*ticket-id*).

The *ticket-id* is a unique number generated by the IVN Manager to represent the combination of the *session-id* and the per-session *resource-id*. The Server should maintain the relation between the *ticket-id* and the *session-id/resource-id* pair in order to retrieve the latter from the former.

All the replying resource descriptors are collected in a Server Resource Indication message that the IVN Manager sends to the Server. The Server acknowledges with a Server Resource Response message. If the *response* field in the Server Resource Response message is positive, for each ATM SVC resource requested, the IVN Manager will initiate a Q.2931 non-associated Call/Connection Procedure.

The IVN Manager initiates a non-associated Call/Connection procedure by sending a Q.2931 SETUP message to its ATM User-Network Interface (UNI). The Call Reference used will be selected by the IVN Manager. The Calling Party Number is the ATM address of the Client as derived from the *terminal-id* field, while the Called Party Number is the ATM address of the Server as derived from the *service-id* field (or received from the Server Session Response message, as part of the ATM SVC resource descriptor - this feature allows a Server to redirect the recipient of the ATM call to any distributed endpoints it manages). The ATM Adaptation Layer (AAL) Parameters, ATM User Cell Rate and Quality-Of-Service Parameter contain values derived from the ATM SVC resource request descriptor.

The Broadband High Layer Information (BHLI) element will contain the *ticket-id* corresponding to this ATM SVC resource. The *ticket-id* can be encoded as part of the User Specific data, High Layer Profile data, Vendor-Specific Application data, or some new data type to be defined and proposed. The last alternative is preferred, but in the lack of, the recommendation is to use the Vendor-Specific Application type as a temporary method to send end-to-end information.

When the Server is informed of the SETUP on its ATM UNI, it will access the *ticket-id* from the BHLI information element. It uses this *ticket-id* to retrieve the *session-id/ resource-id* pair, and associates the Call Reference with this session layer's information. The Server maintains this association until the ATM SVC connection is released. The *ticket-id* is not used anymore.

The IVN Manager also maintains the relationship between the Call Reference at its UNI, and the *session-id/resource-id* pair so that it can retrieve one from the other and vice-versa. When the ATM UNI acknowledges the IVN Manager with a CALL PROCEEDING message, the IVN Manager extracts the assigned VPI and VCI values. These values will be used by the IVN Manager to connect the Client to the ATM SVC connection to be discussed later.

When the IVN Manager receives a CONNECT message on its UNI, it will reclaim the *ticket-id* for a subsequent ATM SVC resource request. At this stage, both the IVN Manager and the Server maintains a Call Reference and *session-id/resource-id* association so that one can be retrieved from the other. This association is the primary linkage between the session layer V Protocol and the network layer Q.2931 for ATM SVC resources.

At this stage, the first leg of the connection, between the Server and the ATM network, has been set up. Using the VPI/VCI values received from the CALL PROCEEDING message, the IVN Manager will establish the second leg of the connection, between the ATM network and the Client, and tie this leg with the first leg to form an end-to-end connection.

The exact procedure to connect the Client to the ATM network depends on the network architecture. In a baseband architecture, this procedure may involve the IVN Manager doing a Q.2931 SETUP using the above VPI/VCI with a downstream headend equipment which is acting as a "ATM switch" to the Client. However, in a passband architecture, this procedure may involve the IVN Manager translating the VPI/VCI value into an RF channel and other multiplexing information -such as MPEG-2 program number- which will be sent to the Client via the V session layer's Client Session

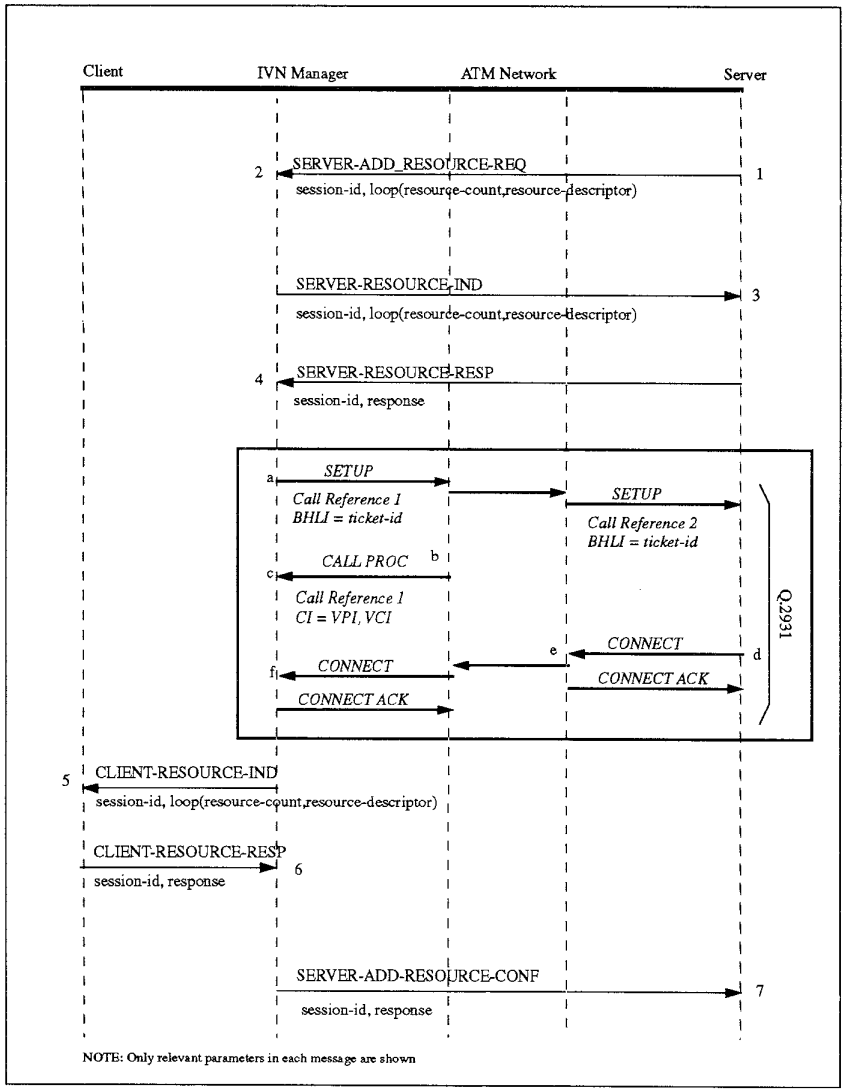

Figure 3. Server Resource Request

Confirmation message. The details of this procedure is outside the scope of this paper.

After all requested resources have been assigned, including the ATM SVC resources, the IVN Manager will inform the Client through the V Protocol session layer's Client Session Confirmation message. This message contains an assigned resource descriptor for each requested message.

6.2 Resource request

After a session has been set up between the Client and the Server, either the Client or the Server can later come back to the IVN to request new resources within the context of the established session. If the newly requested resource is an ATM SVC resource, the scenario follows this description:

Figure 3 describes a Server's resource request. A Client's request is handled similarly. The handling of an ATM SVC resource request in a Resource Request

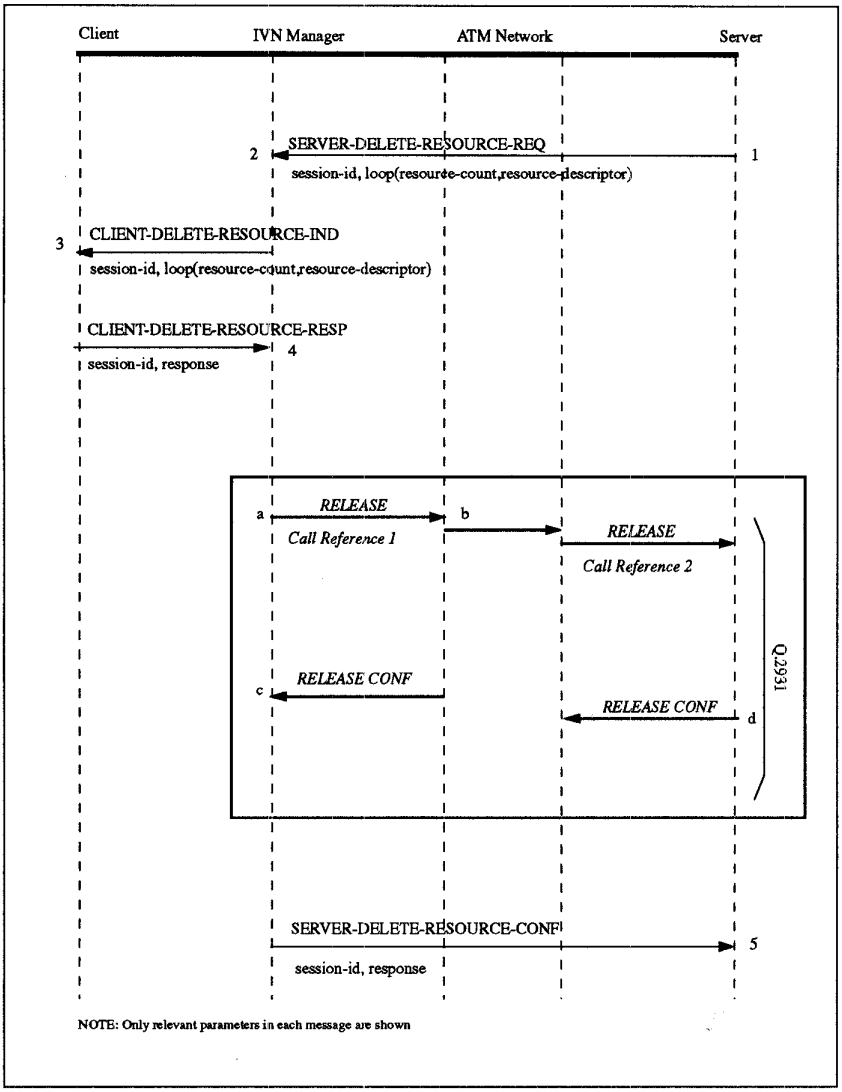

Figure 4. Server Resource Deletion

scenario is the same as in the Session Set-Up scenario described earlier. Upon successful negotiation of an ATM SVC resource request, a unique *ticket-id* is transferred inside a replied resource descriptor from the IVN Manager to the Server, via the Server Resource Indication message. After the Server acknowledges this message via the Server Resource Response message, the IVN Manager will initiate a non-associated Call/Connection Procedure at its ATM UNI, with the SETUP message containing the *ticket-id* in its Broadband High-Layer information element.

6.3 Resource deletion

After a resource has been successfully requested, either through the Session Set-Up scenario or the Session Resource Request scenario, the originator of the resource request (Client or Server) can later come back to the IVN to request that the resource is to be deleted. Figure 4 shows a Server's delete resource request. A Client's request is handled similarly. For an ATM SVC resource, the scenario follows this description:

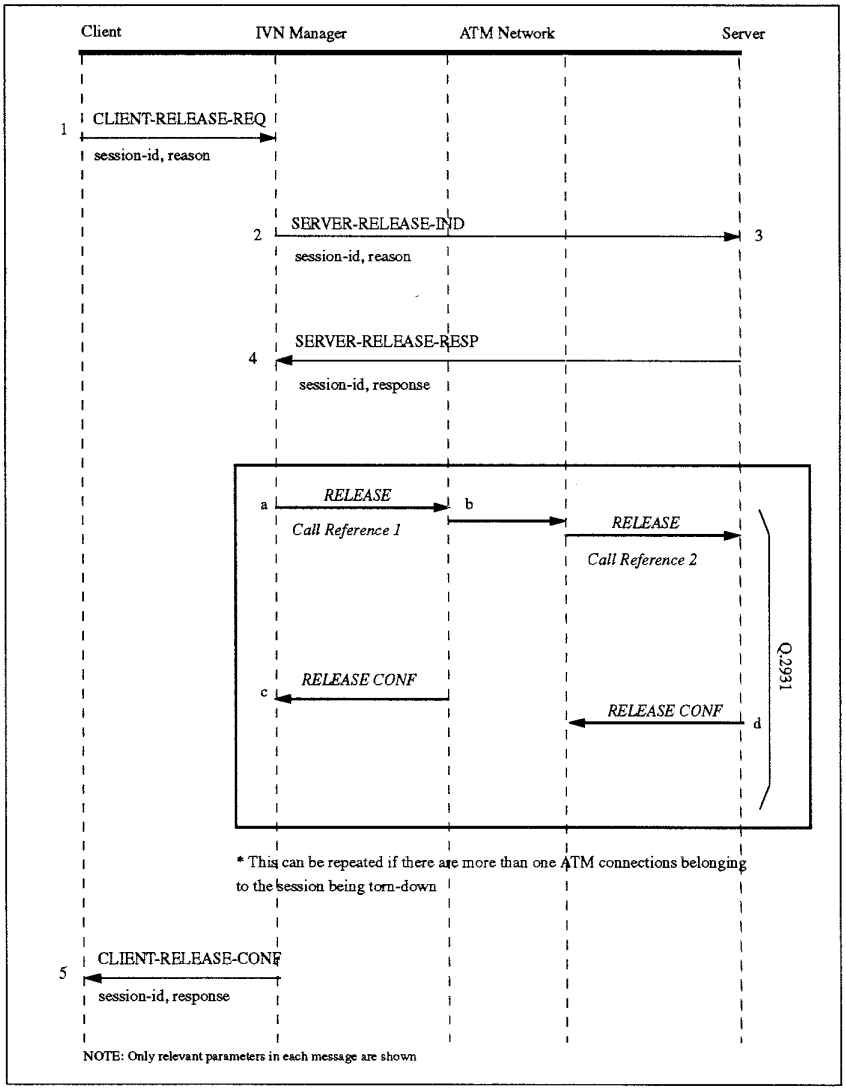

Figure 5. Client Session Tear-Down

First, the Server informs the IVN Manager of its request for deletion of one or multiple assigned resources via the Server Delete Resource Request message. The resources are identified by their corresponding *resource-id.*

The IVN Manager then informs the Client via the Client Delete Resource Indication message so that it can stop using the identified resources.

Upon receipt of the Client Delete Resource Response message, the IVN Manager will process the deletion of the identified resources from the established session.

If the IVN Manager detects a *resource-id* identifying an ATM SVC resource, it will retrieve the corresponding Call Reference and initiates a Q.2931 Call/Connection Clearing procedure at its ATM UNI with a Q.2931 RELEASE message.

When the Server receives the corresponding RELEASE message at its UNI, it retrieves the Call Reference from that message and from the Call Reference, the associated *resource-id* which is then given to the

session layer in the Server for housekeeping chores.

After all the resources have been deleted, the IVN Manager will inform the Server of the outcome of the operation via the Server Delete Resource Confirmation message.

6.4 Session tear-down

After a session has been established through the Session Set-Up, either the Client or Server can later come back to the IVN to request that the session is to be torn down. A Client's session tear-down request is shown in Figure 5. A Server's request is handled similarly. For a session containing an ATM SVC resource, the scenario follows this description:

The Client informs the IVN Manager of its request for session tear-down via the Client Release Request message. The IVN Manager then informs the Server via the Server Release Indication message. The Server acknowledges the request with a Server Release Response message.

Upon receipt of the Server Release Response message, the IVN Manager will retrieve all resources allocated to the identified session and proceed to delete those resources.

If the IVN Manager detects a an ATM SVC resource belonging to the session, it will retrieve the corresponding Call Reference from the *resource-id* and initiates a Q.2931 Call/Connection Clearing procedure at its ATM UNI. The description of this Call/Connection Clearing procedure is similar to the one in the Resource Deletion scenario.

After all the resources have been deleted, the IVN Manager will inform the Client of the outcome of the operation via the Client Release Confirmation message.

7. Standardization

AT&T contributed to DSM-CC by submitting the principles of the V Protocol to the DSM-CC sub-group in cooperation with other parties [6, 7, 8]. As previously mentioned, the V Protocol is AT&T's implementation of the DSM-CC User-Network messages which contains the functionalities described by DSM-CC in addition to extra capabilities that have not yet been submitted to the standard.

The DSM-CC concept originated in the activity that led to the standardization of the MPEG-2 Systems layer [9]. It was specified as a normative (i.e., required) annex of the MPEG-2 Systems layer until November 1994 when it became informative (i.e., an example). In this annex, the DSM-CC protocol, essentially provided motion control functions (pause, resume, stop, etc.) for a simple configuration of a user's system communicating with a single DSM device. Requirements were approved in July 1994 to extend the DSM-CC protocol to include "more diverse and heterogeneous network" such as those found in Movies on Demand applications. This extension of work brought about the need to clearly define the User-Network and User-User interfaces. Also in July 1994, a separate preliminary working draft was produced and later revised in October/November 1994.

The DSM-CC standardization work plan calls for the standard to be complete in early 1996. It is important for this interface to be open and standard in order to better ensure interoperability in the Interactive Video Network. We look forward to its use in many networks worldwide.

8. Conclusion

The V Protocol has been introduced by AT&T to support advanced interactive services for the interactive video network. It is a message based protocol that provides session level control functions. With a clear separation between the concepts of sessions and resources, the protocol is capable of supporting dynamic resource allocation in a distributed server environment. The V Protocol interacts with the Q.2931 protocol for establishing switched virtual connections over the broadband network. AT&T has submitted many of the V Protocol principles to the DSM-CC sub-group in cooperation with other parties with the aim of making the protocol an open industry standard for the IVN. AT&T has implemented the V Protocol / DSM-CC Protocol on its Video Manager product.

9. Acknowledgements

The authors would like to thank Shaun Ger for his review of this paper and helpful suggestions.

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