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Nag

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(54) **SELECTIVE ENCRYPTION OF APPLICATION SESSION PACKETS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 764 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Jul. 27, 2002**

Related U.S. Application Data

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(51) **Int. Cl.**
H04L 9/18 (2006.01)

(52) **U.S. Cl.** **713/154**; 709/226; 713/150; 380/217

(58) **Field of Classification Search** 713/150
See application file for complete search history.

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(Continued)

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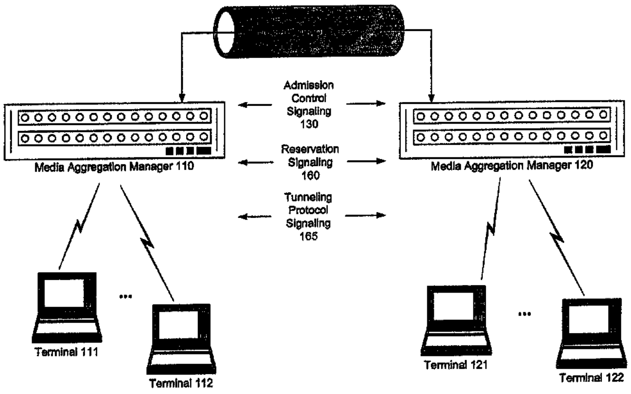
Assistant Examiner—Saoussen Besrour
(74) *Attorney, Agent, or Firm*—Ash Tankha; Lipton, Weinberger & Husick

(57) **ABSTRACT**

Apparatus and methods are provided for multiplexing and selectively encrypting application flows, such as VoIP services, over a pre-allocated bandwidth reservation protocol session. According to one embodiment, a pre-allocated reservation protocol session, such as an RSVP session, is shared by one or more individual application sessions. The reservation protocol session is pre-allocated over a path between a first network device associated with a first user community and a second network device associated with a second user community based upon an estimated usage of the path for individual application sessions between users of the first and second user communities. Subsequently, the one or more individual application sessions are dynamically aggregated by multiplexing application flows associated with the one or more individual application sessions onto the pre-allocated reservation protocol session at the first network device and demultiplexing at the second network device. Additionally, various levels of security may be selectively applied to the application sessions by performing encryption at the first network device and decryption at the second network device.

24 Claims, 14 Drawing Sheets


Admission Control Signaling 130
Reservation Signaling 160
Tunneling Protocol Signaling 165
Media Aggregation Manager 110
Media Aggregation Manager 120
Terminal 111
...
Terminal 112
Terminal 121
...
Terminal 122

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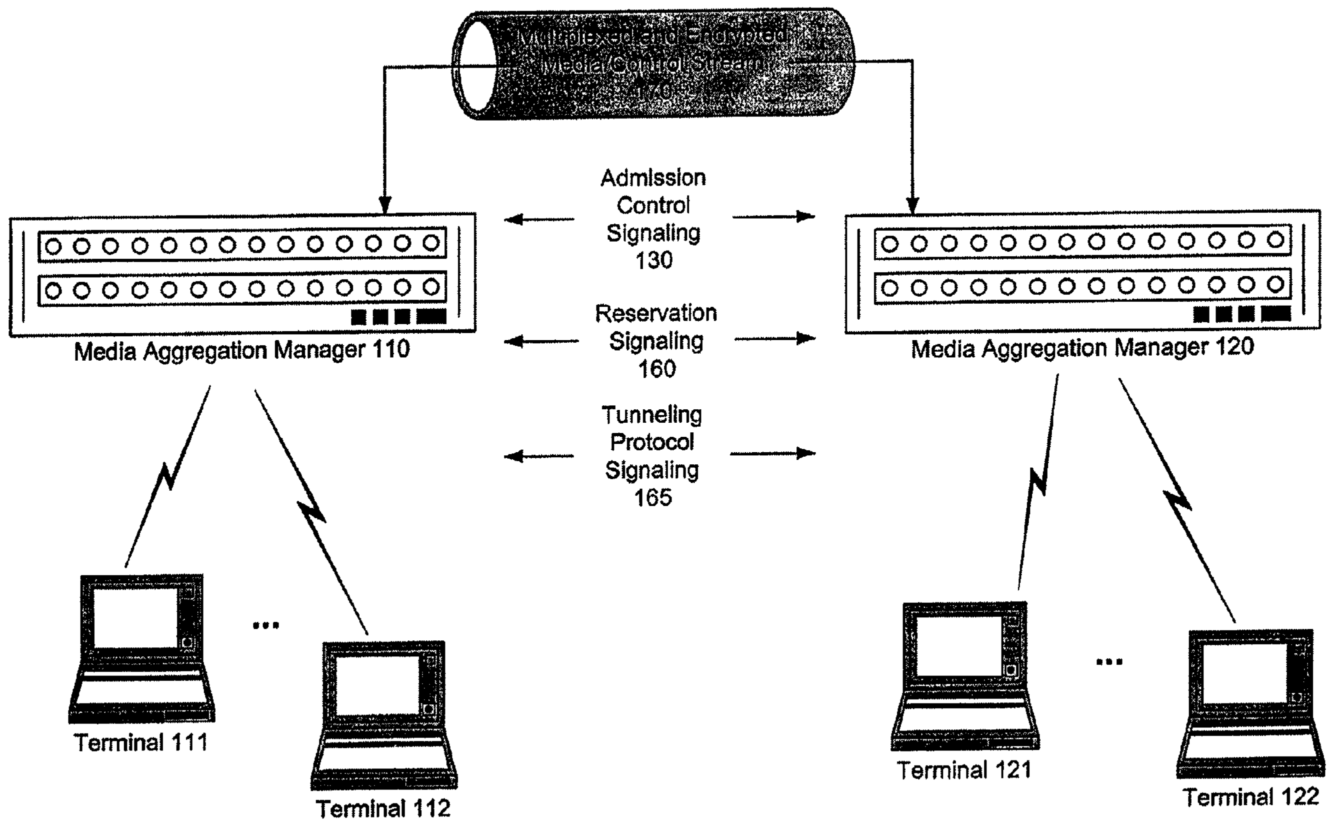
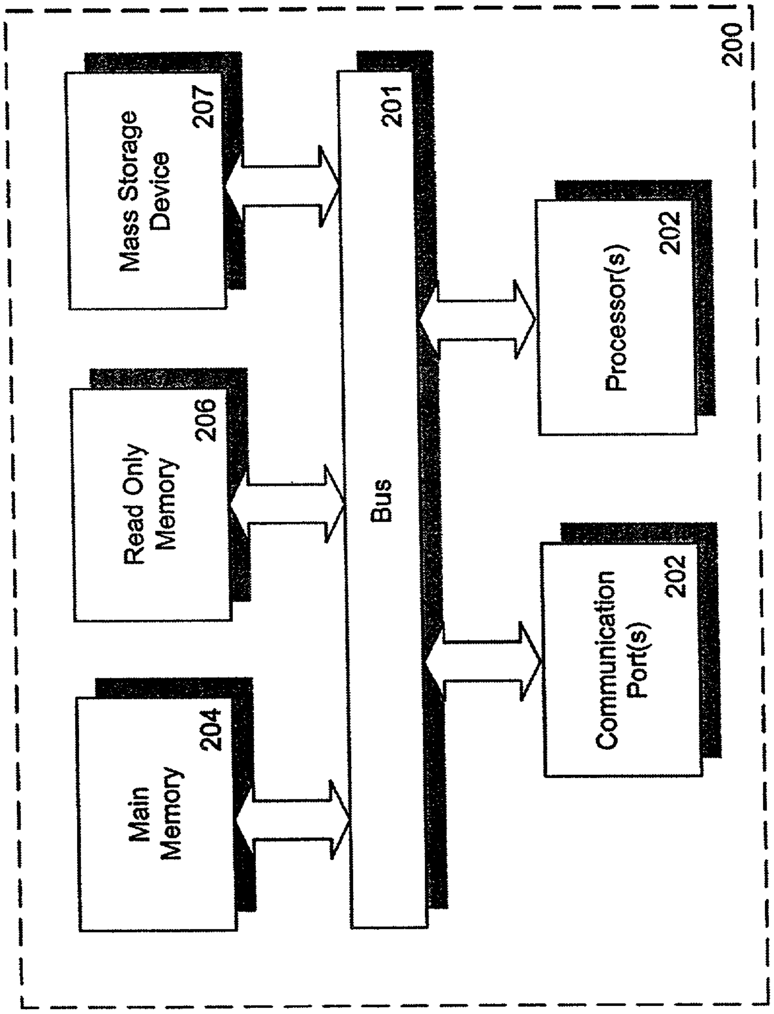

Multiplexed and Encrypted
Media/Control Stream
170
Admission
Control
Signaling
130
Reservation
Signaling
160
Tunneling
Protocol
Signaling
165
Media Aggregation Manager 110
Media Aggregation Manager 120
...
Terminal 111
Terminal 112
...
Terminal 121
Terminal 122

Figure 1



Mass Storage Device
207
Read Only Memory
206
Main Memory
204
Bus
201
Processor(s)
202
Communication Port(s)
202
200

Figure 2

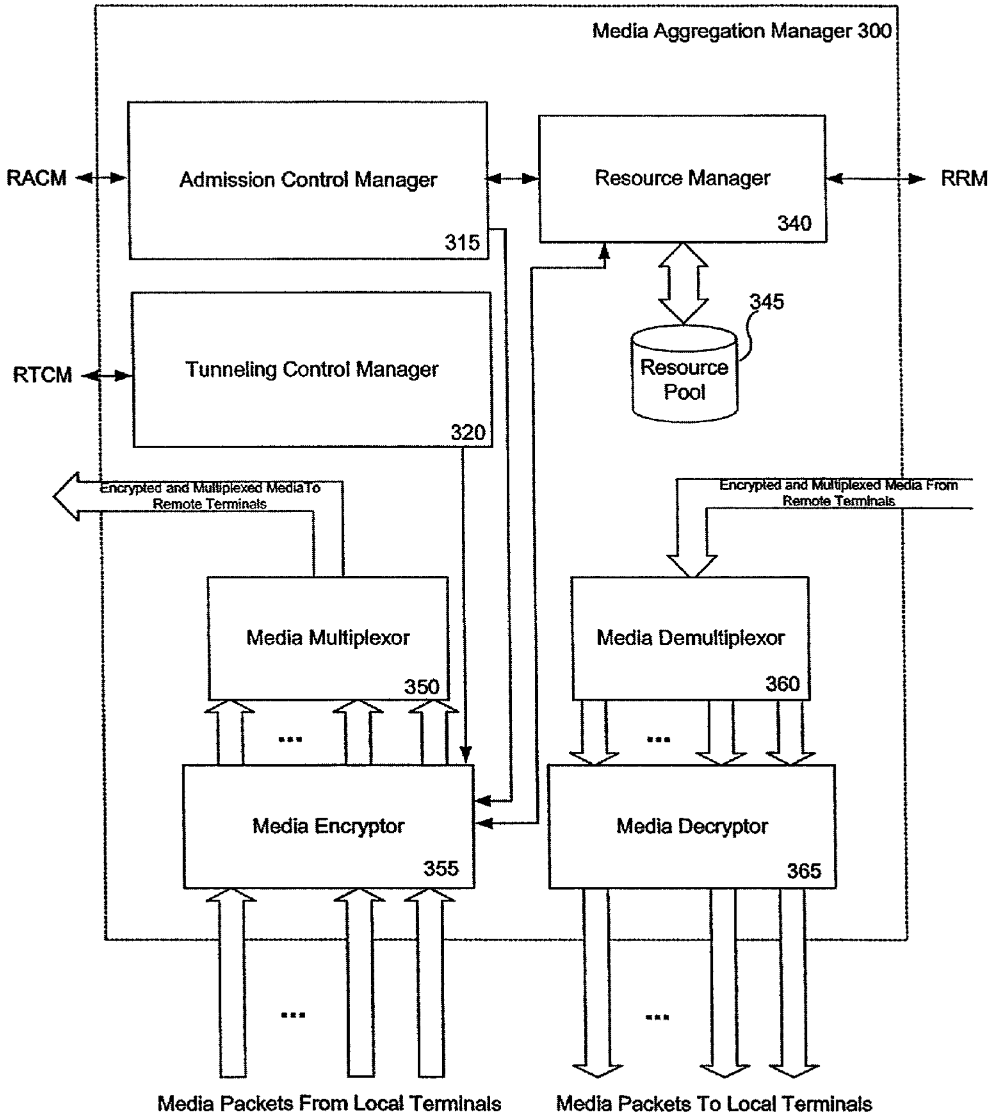

Media Aggregation Manager 300
RACM
Admission Control Manager
315
Resource Manager
340
RRM
345
Resource Pool
RTCM
Tunneling Control Manager
320
Encrypted and Multiplexed MediaTo Remote Terminals
Encrypted and Multiplexed Media From Remote Terminals
Media Multiplexor
350
Media Demultiplexor
360
...
Media Encryptor
355
Media Decryptor
365
Media Packets From Local Terminals
Media Packets To Local Terminals

Figure 3

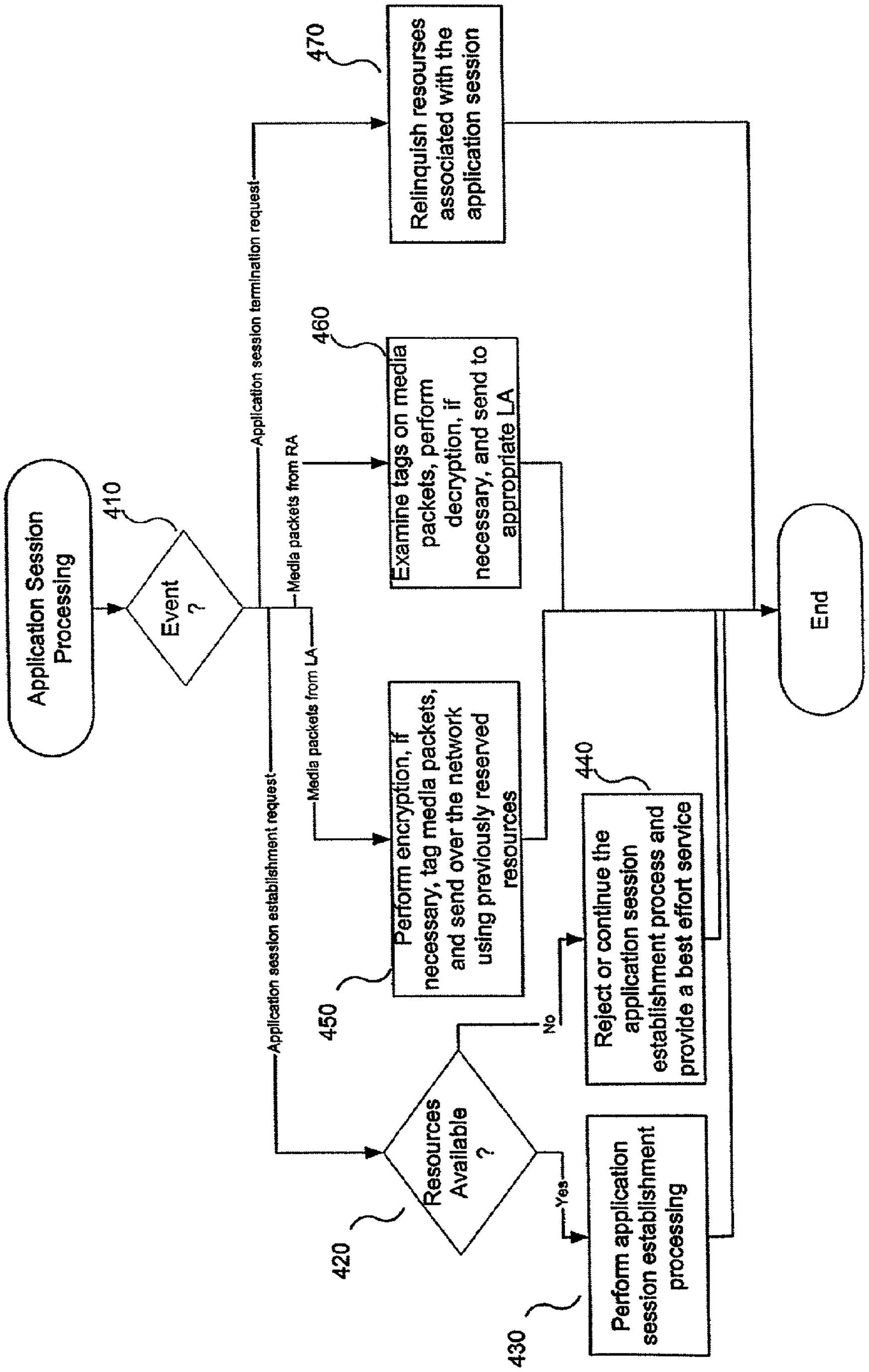

Application Session Processing
410
Event ?
Application session establishment request
Media packets from LA
Media packets from RA
Application session termination request
420
Resources Available ?
Yes
No
430
Perform application session establishment processing
440
Reject or continue the application session establishment process and provide a best effort service
450
Perform encryption, if necessary, tag media packets, and send over the network using previously reserved resources
460
Examine tags on media packets, perform decryption, if necessary, and send to appropriate LA
470
Relinquish resourses associated with the application session
End

Figure 4

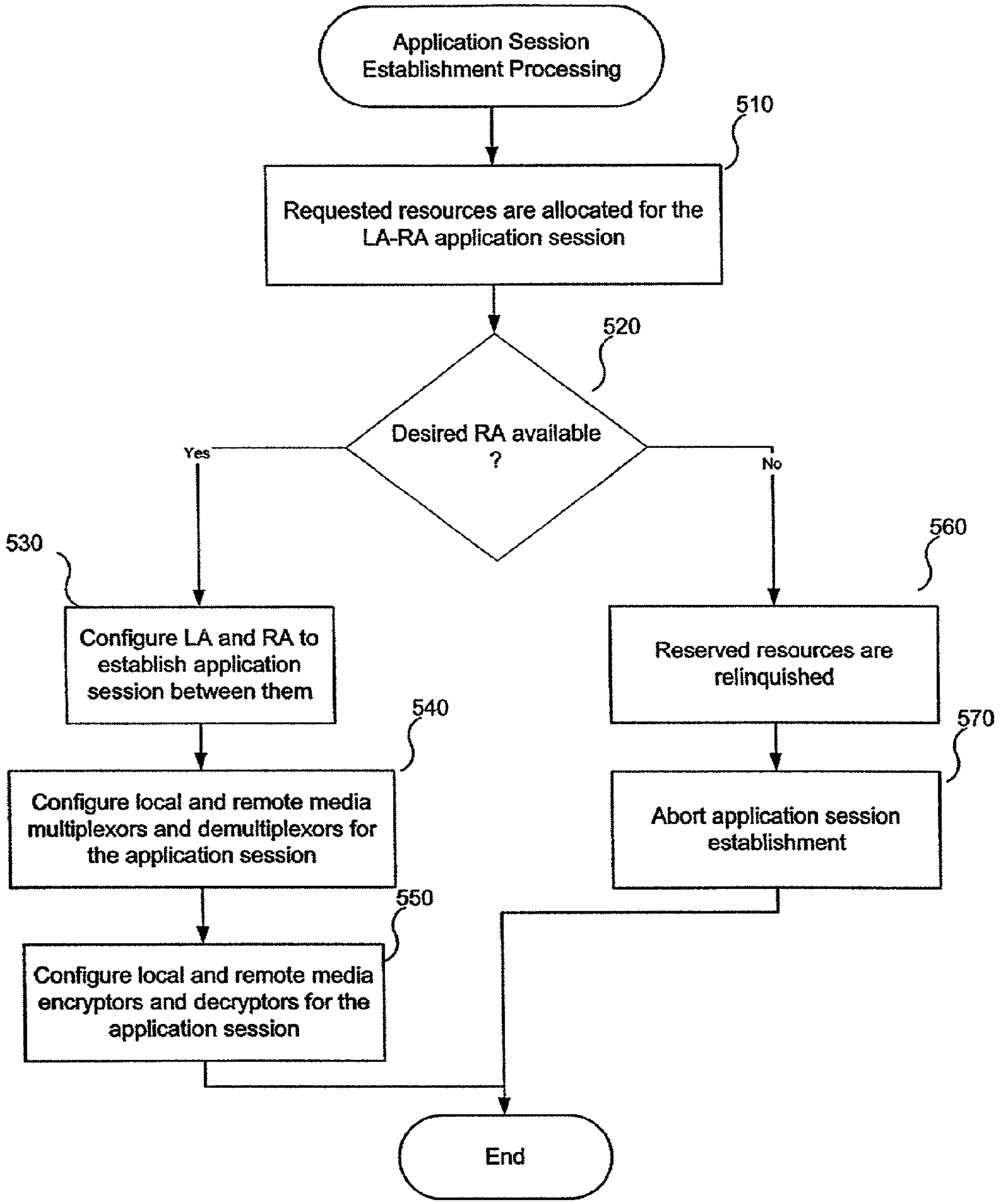

Application Session Establishment Processing
510
Requested resources are allocated for the LA-RA application session
520
Desired RA available ?
Yes
No
530
Configure LA and RA to establish application session between them
540
Configure local and remote media multiplexors and demultiplexors for the application session
550
Configure local and remote media encryptors and decryptors for the application session
560
Reserved resources are relinquished
570
Abort application session establishment
End

Figure 5

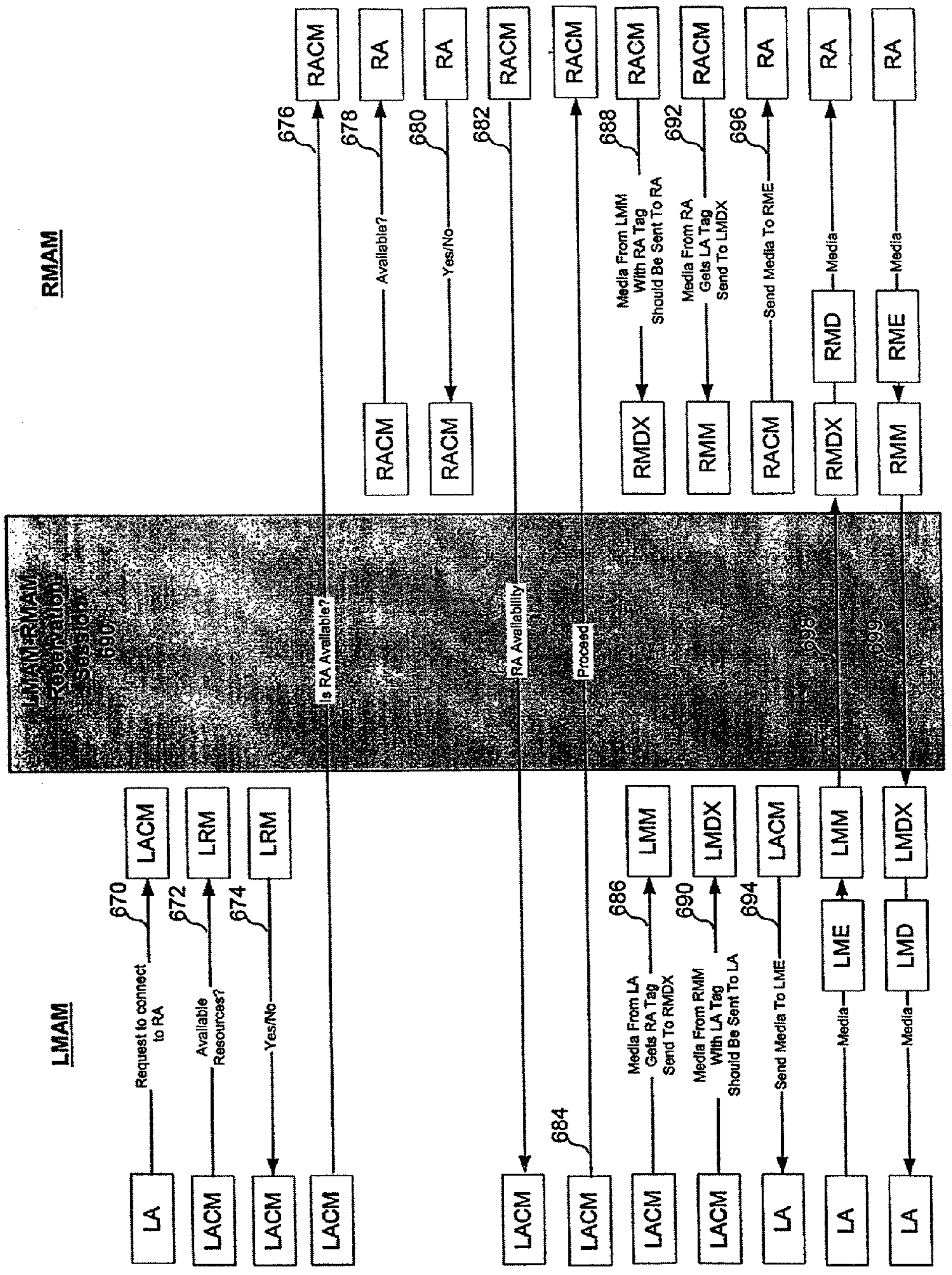

LMAM
RMAM
LMAM-RMAM Reservation Session
690
LA
Request to connect to RA
670
LACM
LACM
Available Resources?
672
LRM
LACM
Yes/No
674
LRM
LACM
Is RA Available?
676
RACM
RACM
Available?
678
RA
RACM
Yes/No
680
RA
LACM
RA Availability
682
RACM
LACM
684
Proceed
RACM
LACM
Media From LA Gets RA Tag Send To RMDX
686
LMM
RMDX
Media From LMM With RA Tag Should Be Sent To RA
688
RACM
LACM
Media From RMM With LA Tag Should Be Sent To LA
690
LMDX
RMM
Media From RA Gets LA Tag Send To LMDX
692
RACM
LA
Send Media To LME
694
LACM
RACM
Send Media To RME
696
RA
LA
Media
LME
LMM
698
RMDX
RMD
Media
RA
LA
Media
LMD
LMDX
699
RMM
RME
Media
RA

Figure 6

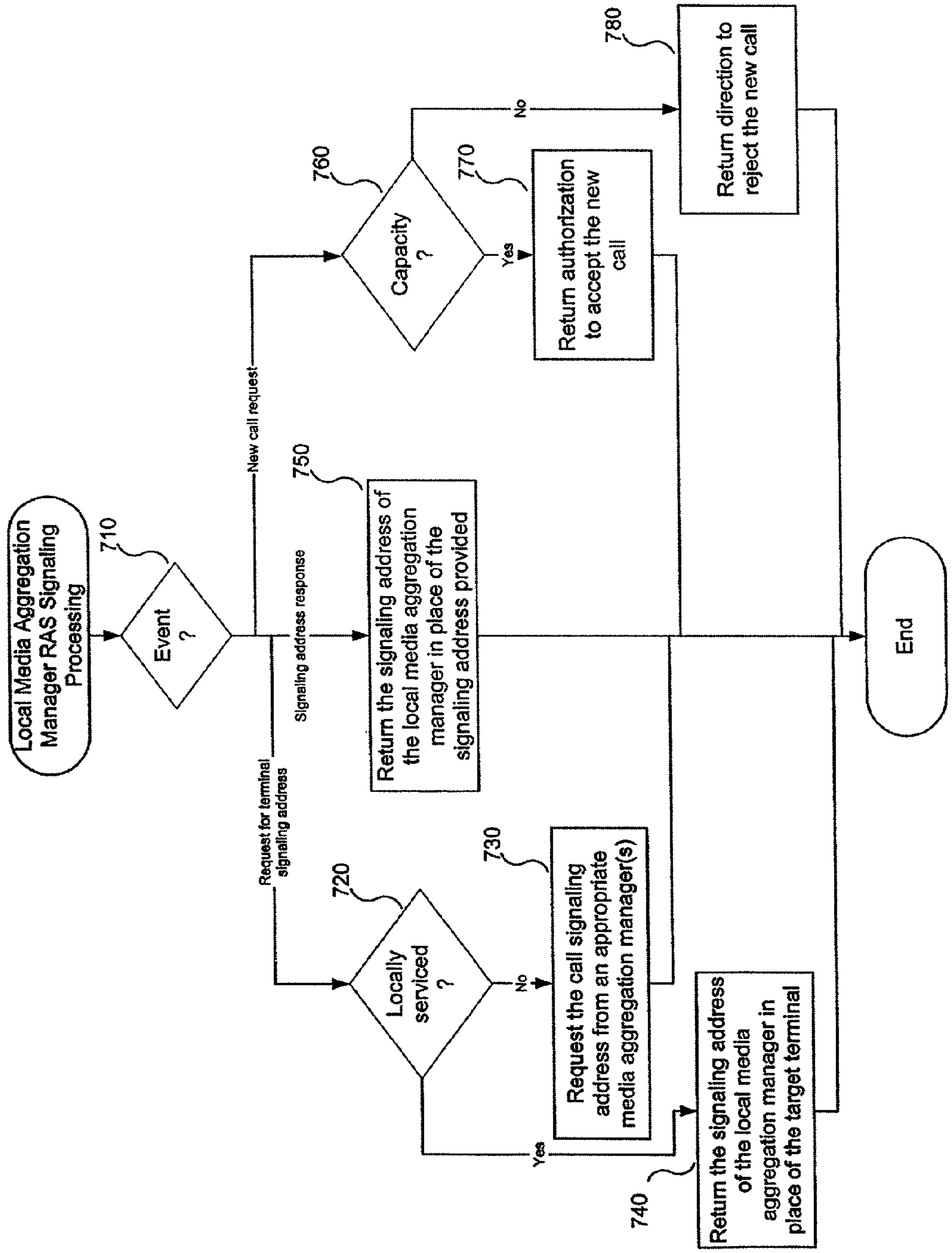

Local Media Aggregation Manager RAS Signaling Processing
710
Event ?
Request for terminal signaling address
Signaling address response
New call request
720
Locally serviced ?
No
Yes
730
Request the call signaling address from an appropriate media aggregation manager(s)
740
Return the signaling address of the local media aggregation manager in place of the target terminal
750
Return the signaling address of the local media aggregation manager in place of the signaling address provided
760
Capacity ?
Yes
No
770
Return authorization to accept the new call
780
Return direction to reject the new call
End

Figure 7

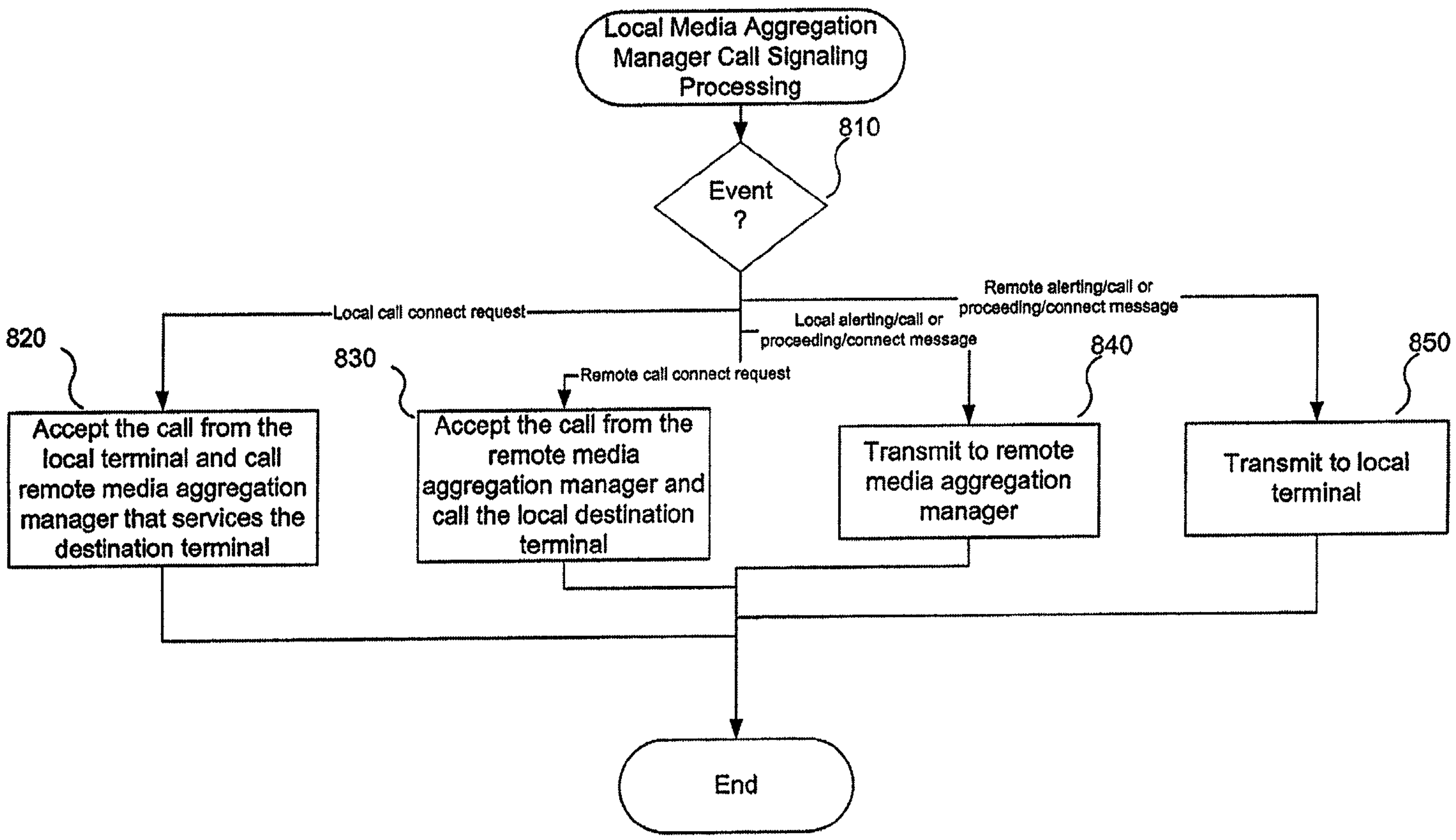

Local Media Aggregation Manager Call Signaling Processing
810
Event ?
Local call connect request
Remote call connect request
Local alerting/call or proceeding/connect message
Remote alerting/call or proceeding/connect message
820
Accept the call from the local terminal and call remote media aggregation manager that services the destination terminal
830
Accept the call from the remote media aggregation manager and call the local destination terminal
840
Transmit to remote media aggregation manager
850
Transmit to local terminal
End

Figure 8

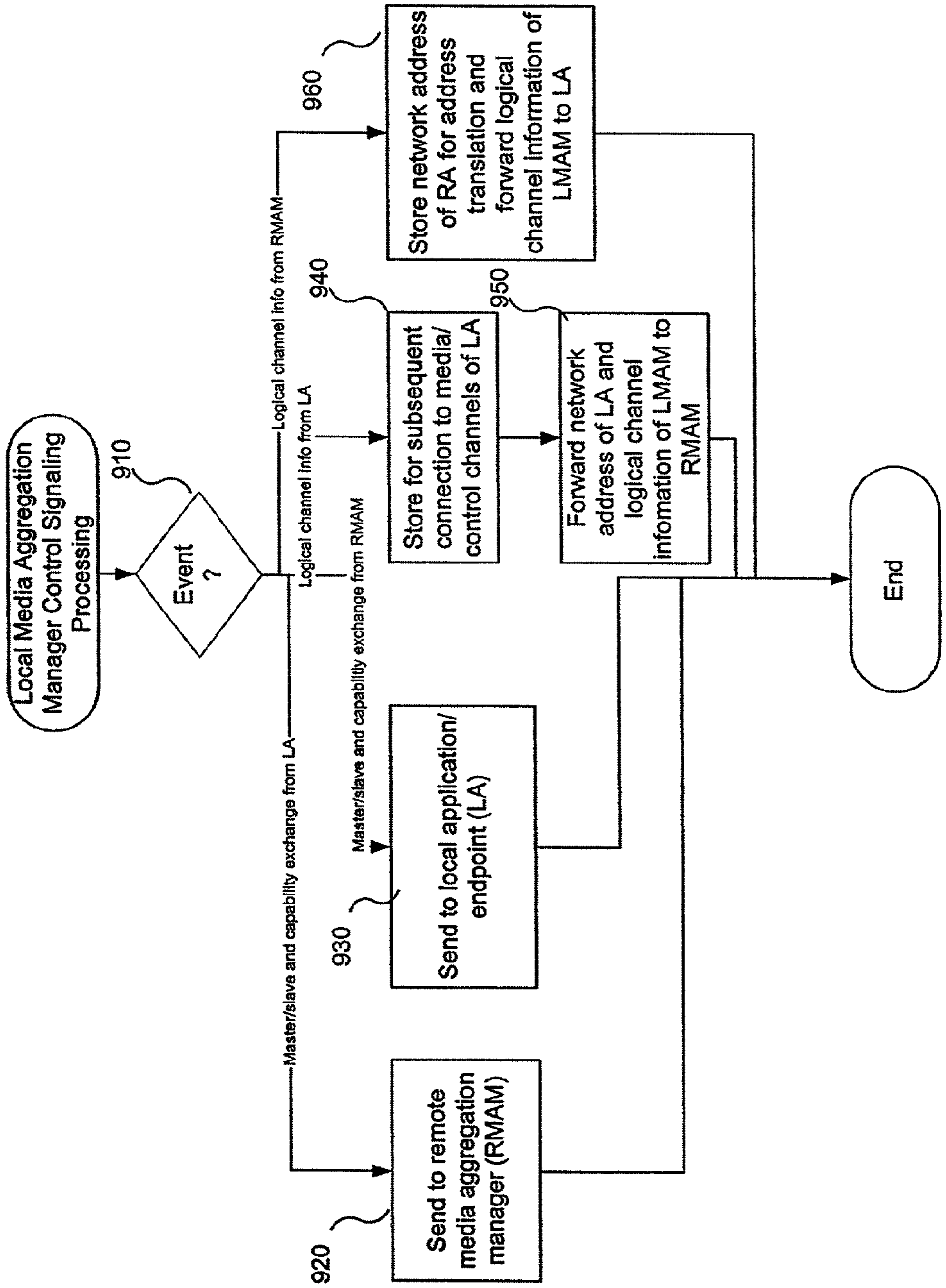

Local Media Aggregation Manager Control Signaling Processing
910
Event ?
Master/slave and capability exchange from LA
Master/slave and capability exchange from RMAM
Logical channel info from LA
Logical channel info from RMAM
920
Send to remote media aggregation manager (RMAM)
930
Send to local application/ endpoint (LA)
940
Store for subsequent connection to media/ control channels of LA
950
Forward network address of LA and logical channel infomation of LMAM to RMAM
960
Store network address of RA for address translation and forward logical channel information of LMAM to LA
End

Figure 9

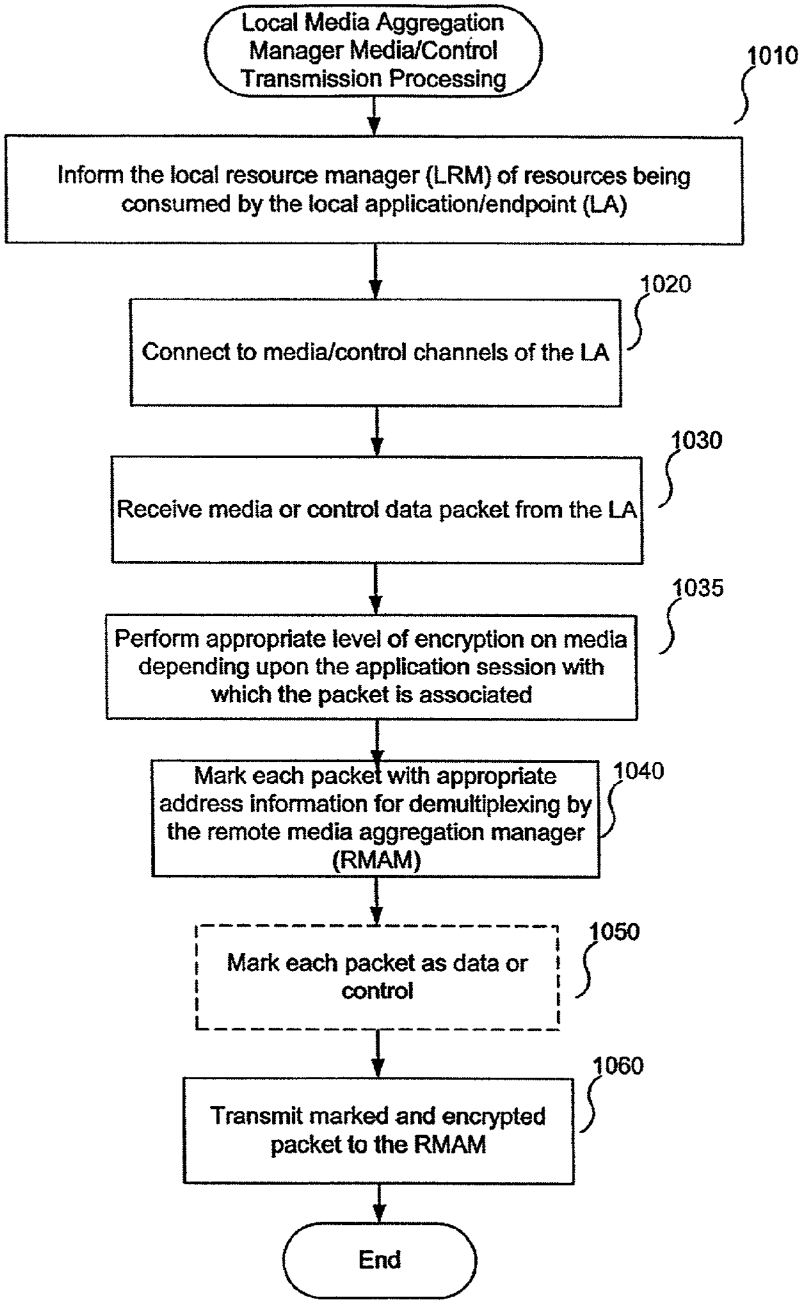

Local Media Aggregation Manager Media/Control Transmission Processing
1010
Inform the local resource manager (LRM) of resources being consumed by the local application/endpoint (LA)
1020
Connect to media/control channels of the LA
1030
Receive media or control data packet from the LA
1035
Perform appropriate level of encryption on media depending upon the application session with which the packet is associated
1040
Mark each packet with appropriate address information for demultiplexing by the remote media aggregation manager (RMAM)
1050
Mark each packet as data or control
1060
Transmit marked and encrypted packet to the RMAM
End

Figure 10

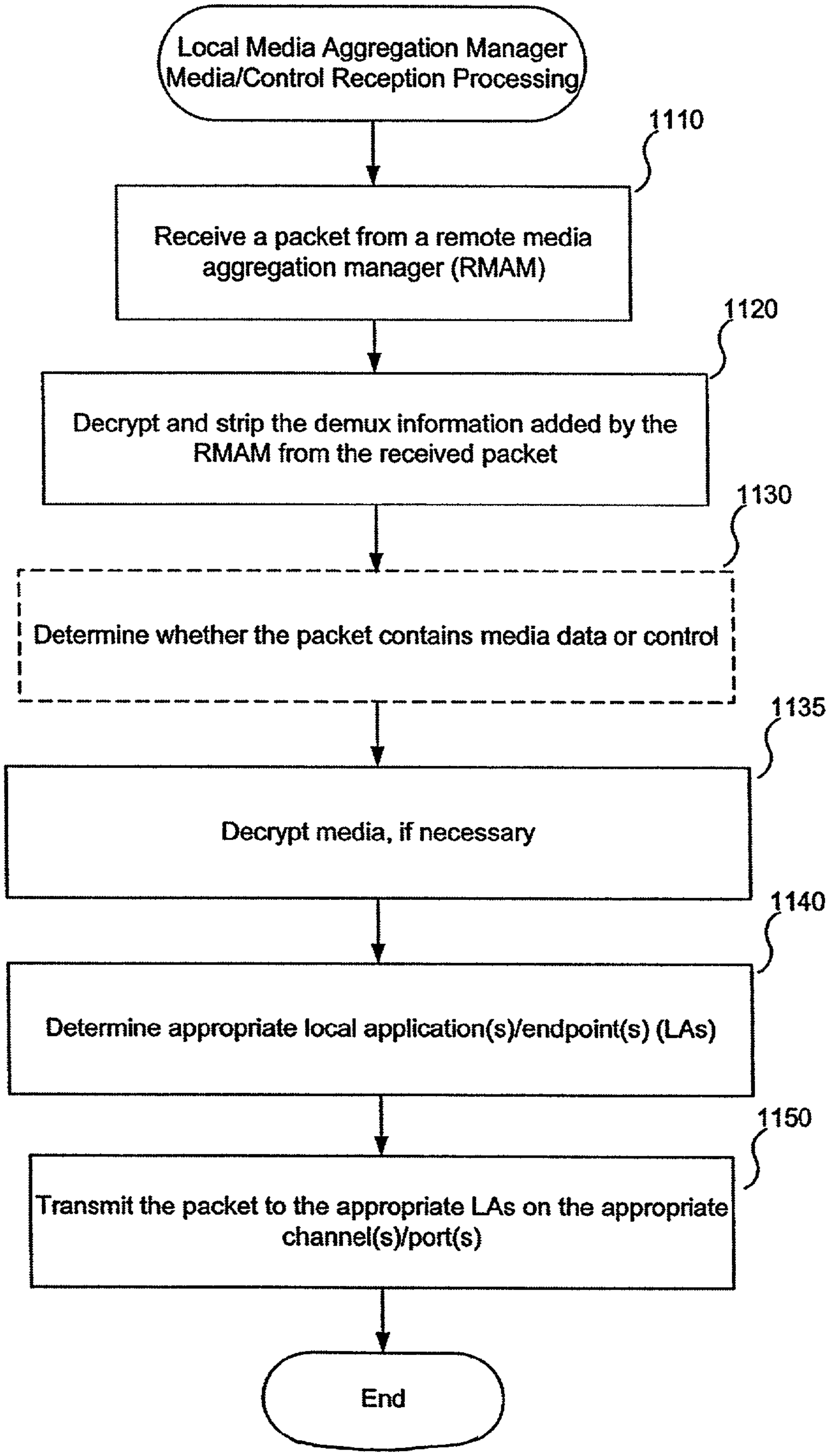

Local Media Aggregation Manager Media/Control Reception Processing
1110
Receive a packet from a remote media aggregation manager (RMAM)
1120
Decrypt and strip the demux information added by the RMAM from the received packet
1130
Determine whether the packet contains media data or control
1135
Decrypt media, if necessary
1140
Determine appropriate local application(s)/endpoint(s) (LAs)
1150
Transmit the packet to the appropriate LAs on the appropriate channel(s)/port(s)
End

Figure 11

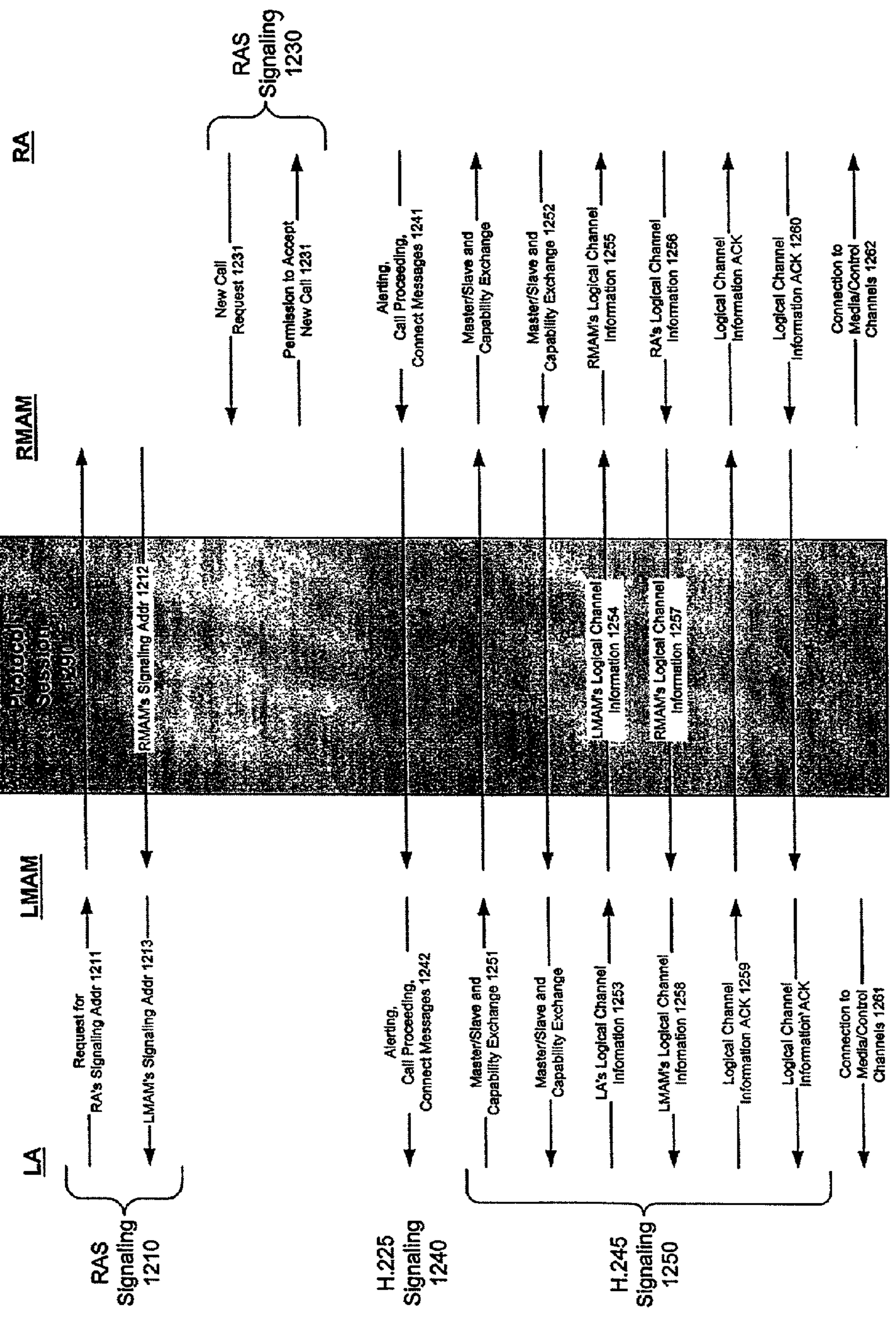

LA
LMAM
RMAM
RA
RAS Signaling 1210
Request for RA's Signaling Addr 1211
LMAM's Signaling Addr 1213
LMAM/RMAM Reservation Protocol Session 1290
RMAM's Signaling Addr 1212
RAS Signaling 1230
New Call Request 1231
Permission to Accept New Call 1231
H.225 Signaling 1240
Alerting, Call Proceeding, Connect Messages 1242
Alerting, Call Proceeding, Connect Messages 1241
H.245 Signaling 1250
Master/Slave and Capability Exchange 1251
Master/Slave and Capability Exchange
Master/Slave and Capability Exchange
Master/Slave and Capability Exchange 1252
LA's Logical Channel Information 1253
LMAM's Logical Channel Information 1254
RMAM's Logical Channel Information 1255
RA's Logical Channel Information 1256
RMAM's Logical Channel Information 1257
LMAM's Logical Channel Information 1258
Logical Channel Information ACK 1259
Logical Channel Information ACK
Logical Channel Information ACK 1260
Logical Channel Information ACK
Connection to Media/Control Channels 1261
Connection to Media/Control Channels 1262

Figure 12

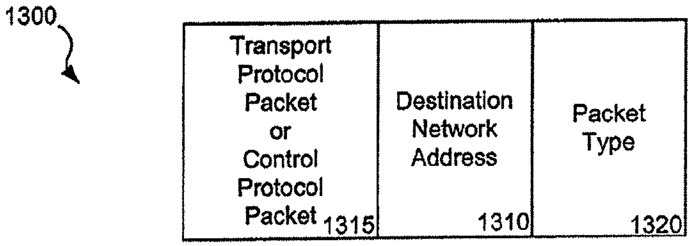

1300
Transport Protocol Packet or Control Protocol Packet
1315
Destination Network Address
1310
Packet Type
1320

Figure 13A

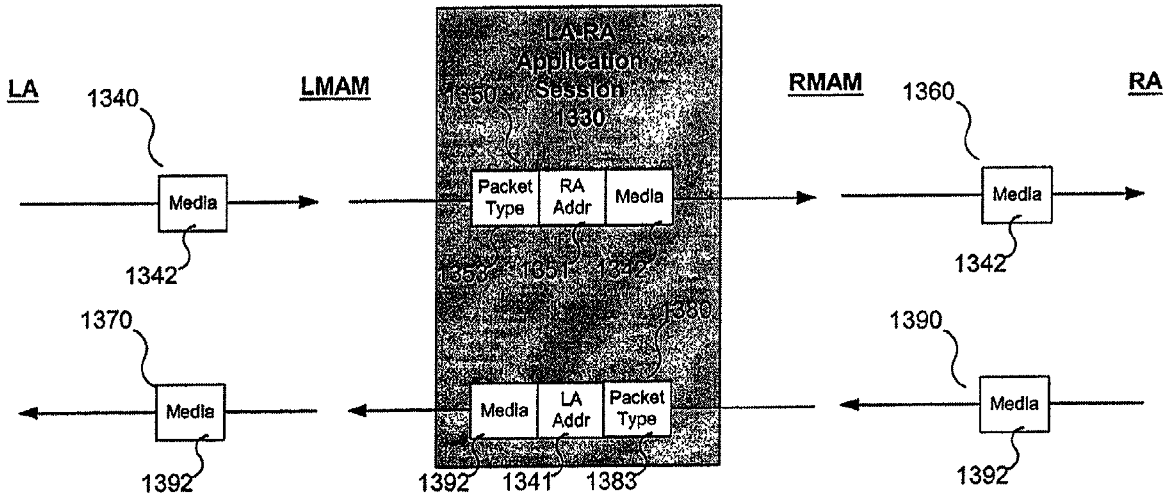


Figure 13B

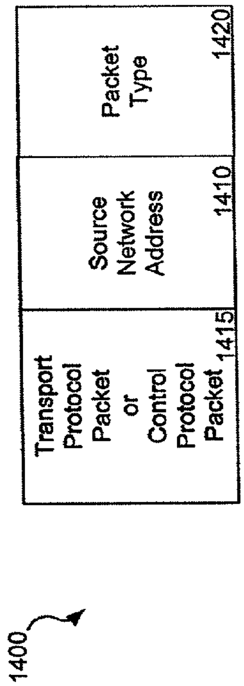


Figure 14A

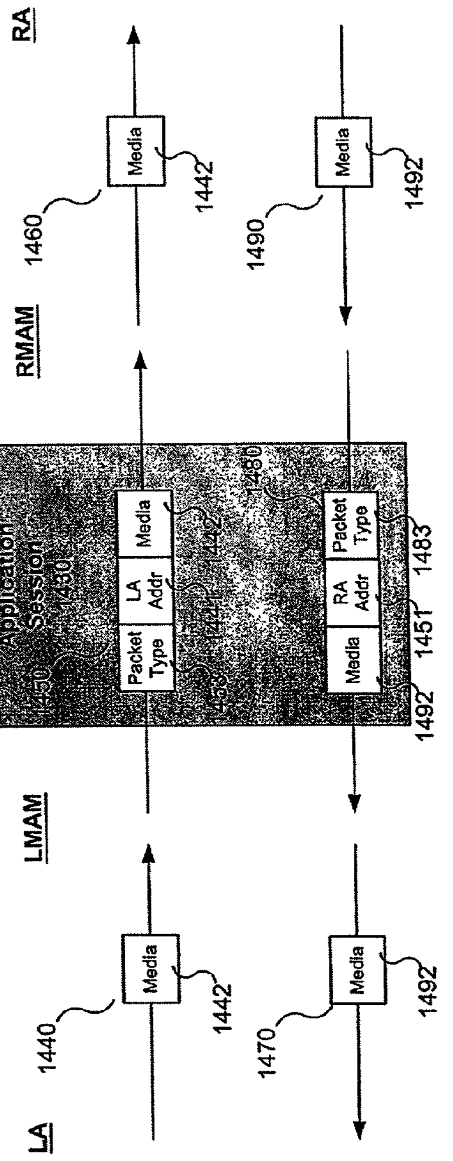


Figure 14B

SELECTIVE ENCRYPTION OF APPLICATION SESSION PACKETS

This application claims the benefit of U.S. Provisional Application No. 60/308,421, filed Jul. 27, 2001, entitled “Selective Encryption of Application Session Packets.”

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to managing flows for a reservation protocol and addressing security issues that exist in current Internet Protocol (IP) telephony products. More particularly, the invention relates to a technique for pre-allocating an aggregated reservation protocol session and thereafter sharing the reservation protocol session among multiple individual application sessions by multiplexing the multiple individual application flows thereon while additionally providing for selective end-to-end encryption.

2. Description of the Related Art

The consolidation and transfer of voice and voice-band data (e.g., fax and analog modems) with data services over public packet networks, such as the Internet, is rapidly gaining acceptance. However, significant work remains in the area of enhancing the quality and ensuring the security of such services. One potential technique for improving the quality of voice over Internet Protocol (VoIP) calls involves the use of a bandwidth reservation protocol to communicate per-flow requirements by signaling the network. Typically, however, bandwidth reservation protocols require per-flow state information to be maintained at each intermediate node between the initiator and the prospective recipient. As a result, in a VoIP network relying on such bandwidth reservation protocols, scalability becomes an issue since each VoIP call reservation requires a non-trivial amount of ongoing message exchange, computation, and memory resources in each intervening node to establish and maintain the reservation.

An example of a particular bandwidth reservation protocol that illustrates this scalability problem is the Resource Reservation Protocol (RSVP). RSVP is an Internet Protocol-(IP) based protocol that allows applications running on end-stations, such as desktop computers, to communicate per-flow requirements by signaling the network. Using RSVP, the initiator of a VoIP call transmits a Path message downstream to the prospective recipient. The Path message causes state information, such as information regarding the reverse path to the initiator, to be stored in each node along the way. Subsequently, the prospective recipient of the VoIP call initiates resource reservation setup by communicating its requirements to an adjacent router via an upstream Resv message. For example, the prospective recipient may communicate a desired quality of service (QoS), e.g., peak/average bandwidth and delay bounds, and a description of the data flow to all intervening routers between the call participants. Additionally, after the reservation has been established, participating routers must continue to exchange periodic status and control messages to maintain the reservation. Consequently, processing and storage overhead associated with reservation establishment and maintenance increases linearly as a function of the number of calls. For further background and information regarding RSVP see Braden, R., Zhang, L., Berson, S., Herzog, S. and Jamin, S., “Resource Reservation Protocol (RSVP) Version 1 Functional Specification,” RFC 2205, Proposed Standard, September 1997.

A proposed solution to RSVP’s scalability problems can be found in F. Baker et al., “Aggregation of RSVP for IPv4 and IPv6 Reservations,” Internet Draft, March 2000. However, the proposed solution requires a modification to RSVP, which would result in changes to router software. Additionally, the proposal does not use RSVP end-to-end, but rather uses Diff-Serv in the core. It may also require changes to other routing protocols like OSPF and IS-IS. Finally, it appears that there may also be additional burdens on network administrators to make the aggregation scheme work.

With regard to security, a technique for achieving router-to-router privacy is router-based encryption (RBE). However, this solution is neither scalable nor flexible as it encrypts every packet that is transmitted through the router and the router doesn’t have any information to map packets to a particular voice call to allow for selective encryption. In light of the foregoing, what is needed is a less invasive technique for managing application flows that require real-time response, such as flows associated with VoIP services, and addressing scalability and flexibility issues associated with bandwidth reservation protocols and RBE. It is also desirable to minimize changes to the particular bandwidth reservation protocol employed and existing router software.

BRIEF SUMMARY OF THE INVENTION

Apparatus and methods are described for multiplexing and selectively encrypting application flows over a pre-allocated bandwidth reservation protocol session. According to one embodiment, a pre-allocated reservation protocol session is shared by one or more individual application sessions. The reservation protocol session is pre-allocated over a path between a first network device associated with a first user community and a second network device associated with a second user community based upon an estimated usage of the path for individual application sessions between users of the first and second user communities. Subsequently, the one or more individual application sessions are dynamically aggregated by multiplexing application flows associated with the one or more individual application sessions onto the pre-allocated reservation protocol session at the first network device and demultiplexing at the second network device. Additionally, various levels of security may be selectively applied to the application sessions by performing encryption at the first network device and decryption at the second network device.

According to another embodiment, a network device enables multiple applications to share an aggregated reservation protocol session. The network device includes a storage device having stored therein one or more routines for establishing and managing the aggregated reservation protocol session and for establishing secure tunnels between end points. A processor coupled to the storage device executes the one or more routines to pre-allocate the aggregated reservation protocol session and thereafter share the aggregated reservation protocol session among multiple application sessions of individual application sessions. One or more secure tunnels may also be established within the aggregated reservation protocol session to provide one of multiple levels of security on an application session to application session basis. The aggregated reservation protocol session is pre-allocated based upon an estimate of the bandwidth requirements to accommodate the multiple application sessions. The aggregated reservation protocol session is shared by multiplexing, encrypting and transmitting, onto the aggregated reservation protocol session, outbound media packets originated by local application/endpoints associated with the application sessions, and decrypting, demultiplexing and receiving, from the aggregated reservation protocol session, inbound media packets originated by remote application/endpoints.

Other features of the present invention will be apparent from the accompanying drawings and from the detailed description that follows.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

FIG. **1** conceptually illustrates interactions between two media aggregation managers according to one embodiment of the present invention.

FIG. **2** is an example of a network device in which one embodiment of the present invention may be implemented.

FIG. **3** is a high-level block diagram of a media aggregation manager according to one embodiment of the present invention.

FIG. **4** is a simplified, high-level flow diagram illustrating application session processing according to one embodiment of the present invention.

FIG. **5** is a simplified, high-level flow diagram illustrating application session establishment processing according to one embodiment of the present invention.

FIG. **6** illustrates interactions among local and remote media aggregation manager functional units according to one embodiment of the present invention.

FIG. **7** is a flow diagram illustrating Registration, Admission, Status (RAS) signaling processing according to one embodiment of the present invention.

FIG. **8** is a flow diagram illustrating call signaling processing according to one embodiment of the present invention.

FIG. **9** is a flow diagram illustrating control signaling processing according to one embodiment of the present invention.

FIG. **10** is a flow diagram illustrating media/control transmission processing according to one embodiment of the present invention.

FIG. **11** is a flow diagram illustrating media/control reception processing according to one embodiment of the present invention.

FIG. **12** conceptually illustrates application session establishment in an H.323 environment according to one embodiment of the present invention.

FIG. **13**A illustrates the encapsulated ("MUX") packet format according to one embodiment of the present invention in which address replacement is performed by the LMAM.

FIG. **13**B illustrates media transmission in both directions according to the encapsulated packet format of FIG. **13**A.

FIG. **14**A illustrates the encapsulated ("MUX") packet format according to another embodiment of the present invention in which address replacement is performed by the RMAM.

FIG. **14**B illustrates media transmission in both directions according to the encapsulated packet format of FIG. **14**A.

DETAILED DESCRIPTION OF THE INVENTION

Apparatus and methods are described for multiplexing and selectively encrypting application flows over a pre-allocated bandwidth reservation protocol session. Broadly stated, embodiments of the present invention seek to provide a scalable and flexible architecture that enables efficient provisioning of reserved bandwidth for multiple application flows by multiplexing individual application flows over a pre-allocated reservation protocol session while providing configurable security on an application flow by application flow basis. The pre-allocated reservation protocol session preferably takes into consideration current network resources and estimated usage of network resources, such as bandwidth, based upon historical data. For example, the amount of pre-allocated resources may vary due to different loads being offered at different times of day and/or day of week. Additionally, the pre-allocated reservation protocol session may be dynamically adjusted to account for actual usage that surpasses the estimated usage or actual usage that falls below the estimated usage.

According to one embodiment, a more intelligent approach is employed in connection with initiation and maintenance of a large number of reservations. Rather than establishing and maintaining a reservation protocol session for each application flow that requires real-time response, which results in many independent reservation protocol sessions and high overhead, a single reservation protocol session may be pre-allocated and subsequently dynamically shared among the application flows by aggregating the associated media packets and transmitting them over a multiplexed media stream. Additionally, rather than indiscriminately encrypting every packet that is transmitted across the router, encryption may be selectively applied on a call-by-call basis at a Voice Service Unit (VSU) referred to herein as a media aggregation manager. For example, secure VoIP services may be provided between many different user communities using pre-allocated RSVP sessions between pairs of distributed media aggregation managers. The media aggregation managers multiplex and selectively encrypt outbound voice packets onto the pre-allocated RSVP session and decrypt and demultiplex inbound voice packet received over the pre-allocated RSVP session, thereby sharing a common RSVP session and reducing the computational resources required by the network to provide real-time response for multiple application flows. Advantageously, in this manner, it becomes feasible to use reservation protocols, such as RSVP, for large numbers of applications that require real-time performance, such as VoIP services.

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without some of these specific details. In other instances, well-known structures and devices are shown in block diagram form.

The present invention includes various steps, which will be described below. The steps of the present invention may be performed by hardware components or may be embodied in machine-executable instructions, which may be used to cause a general-purpose or special-purpose processor programmed with the instructions to perform the steps. Alternatively, the steps may be performed by a combination of hardware and software.

The present invention may be provided as a computer program product which may include a machine-readable medium having stored thereon instructions which may be used to program a computer (or other electronic devices) to perform a process according to the present invention. The machine-readable medium may include, but is not limited to, floppy diskettes, optical disks, CD-ROMs, and magneto-optical disks, ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, flash memory, or other type of media/machine-readable medium suitable for storing electronic instructions. Moreover, the present invention may also be downloaded as a computer program product, wherein the program may be transferred from a remote computer to a requesting computer by way of data signals embodied in a carrier wave or other propagation medium via a communication link (e.g., a modem or network connection).

While, for convenience, embodiments of the present invention are described with reference to particular existing signaling, control, and communications protocol standards, such as International Telecommunication Union Telecommunication Standardization Section (ITU-T) Recommendation H.225.0 entitled “Call Signalling Protocols and Media Stream Packetization for Packet-based Multimedia Communication Systems,” published February 1998 (hereinafter H.225.0); ITU-T Recommendation H.245 entitled “Control Protocol for Multimedia Communication,” published May 1999 (hereinafter H.245); ITU-T Recommendation H.323 entitled “Packet-based Multimedia Communications Systems,” published September 1999 (hereinafter H.323); and a particular bandwidth reservation protocol (i.e., RSVP), the present invention is equally applicable to various other signaling, control, communications and reservation protocols. For example, Session Initiation Protocol (SIP) may be employed to create, modify, and terminate application sessions with one or more participants. SIP is described in M. Handley et al., “SIP: Session Initiation Protocol,” RFC 2543, Network Working Group, March 1999, which is hereby incorporated by reference. Furthermore, it is contemplated that embodiments of the present invention will be applicable to various proprietary signaling and media transport protocols.

In addition, for sake of brevity, embodiments of the present invention are described with reference to a specific application (i.e., VoIP) in which individual flows may be multiplexed over a pre-allocated bandwidth reservation protocol session. Nevertheless, the present invention is equally applicable to various other network applications or services that are latency intensive (e.g., affected by jitter and/or transmission delays) and/or that require real-time performance, such as applications based on human interactions (e.g., collaborative software, online/Web collaboration, voice conferencing, and video conferencing), and real-time data communication and/or exchange, such as market data applications, financial transactions, and the like.

Terminology

Brief definitions of terms used throughout this application are given below.

In the context of the described embodiment, a “media aggregation manager” or a “Voice Service Unit (VSU)” may generally be thought of as a network device, such as an edge device at the ingress/egress edges of a user community, or a group of one or more software processes running on a network device that provides application/protocol specific multiplexing/demultiplexing of media traffic through one or more tunnels over a pre-allocated reservation protocol session.

A “reservation protocol” generally refers to a protocol that may be employed to communicate information regarding a desired level of service for a particular application flow. An example of an existing bandwidth reservation protocol is RSVP.

A “user community” generally refers to a group of users residing on a common network at a given location. For example, employees on an enterprise network at a given location or users of a particular Internet service provider (ISP) at a given location may represent a user community.

In the context of the described embodiment, a “reservation protocol session” generally refers to a set of reserved network resources established and maintained between two or more network devices that serve as proxies for application endpoints residing behind the proxies. An example, of a reservation protocol session is an RSVP session between two media aggregation managers.

In the context of the described embodiment, an “application session” generally refers to a session established and maintained between two or more terminals. According to embodiments of the present invention, one or more application sessions may be multiplexed onto a single reservation protocol session thereby reducing the overhead for establishing and maintaining multiple reservation protocol sessions.

A “terminal” generally refers to a LAN-based endpoint for media transmission, such as voice and/or voice-based data transmission. Terminals may be capable of executing one or more networked applications programs. An example of a terminal would be a computer system running an Internet telephony application, such as CoolTalk or NetMeeting.

A “tunnel” generally refers to a logical transmission medium through which packets of one protocol encapsulated or wrapped in a packet of another protocol are transmitted via the protocol of the wrapper. According to one embodiment, voice and/or voice-band data packets are encrypted proximate to the source for secure transmission over one or more public internetworks, such as the Internet, and then decrypted proximate to the destination.

An “application” or “endpoint” generally refers to a software program that is designed to assist in the performance of a specific task, such as Internet telephony, online collaboration, or video conferencing.

An “application flow” generally refers to the data associated with an application session. An example of an application flow is a media stream, such as a continuous sequence of packetized voice and/or voice-band data transmitted over a network.

A “tag,” in the context of the described embodiment, generally refers to information that is appended to application generated packets, such as Real-time Transport Protocol (RTP) packets or Real-time Transport Control Protocol (RTCP) packets, that allows the proxy endpoints of the reservation protocol session to transmit encapsulated packets to the appropriate remote application/endpoint (RA). According to one embodiment of the present invention, a tag includes address information, such as the destination network address of the terminal upon which the destination application/endpoint resides. When a media aggregation manager is employed in connection with a transport protocol and control protocol (such as RTP and RTCP) that use different channels or ports for control and data, control and data packets may be multiplexed onto the reservation protocol session as well by including protocol dependent control information. Then, the remote media aggregation manager may strip the tag from the encapsulated packet and determine the appropriate channel/port of the remote application/endpoint on which to forward the resulting packet based upon the additional protocol dependent control information within the tag. Advantageously, in this manner, two layers of multiplexing may be achieved, (1) a first layer that allows identification of the appropriate application at the remote media aggregation manager; and (2) a second layer that specifies a subclass/subprocess within an application.

Media Aggregation Overview

The architecture described herein seeks to resolve scalability problems observed in current reservation protocols. These scalability issues have slowed the adoption of reservation protocols in network environments where multiple applications must be provided with certainty regarding a minimum reserved bandwidth. The architecture described herein additionally seeks to address scalability problems associated with current security solutions for IP telephony product offerings.

FIG. **1** conceptually illustrates interactions between two media aggregation managers **110** and **120** according to one embodiment of the present invention. According to one embodiment, the media aggregation managers **110** and **120** act as reservation protocol proxies on behalf of the terminals **111**, **112**, **121**, and **122**. For example, the media aggregation managers **110** and **120** establish and maintain a reservation session, such as an RSVP session, between each other by exchanging reservation signaling messages **160**. Subsequently, rather than establishing additional reservation protocol sessions, the media aggregation managers **110** and **120** respond to reservation requests from the terminals **111**, **112**, **121**, and **122** by dynamically allocating the reserved resources, such as bandwidth, associated with the reservation protocol session to corresponding application sessions. In this manner, multiple application sessions may share the reservation session by multiplexing media packets onto the reservation session as described further below.

According to one embodiment, the media aggregation managers **110** and **120** may additionally act as tunnel endpoints through which encrypted voice and/or voice-band data and exchanged among the terminals **111**, **112**, **121**, and **122**. For example, one or more tunnels may be established between the media aggregation managers **110** and **120** through the pre-allocated reservation session by exchanging tunnel protocol signaling messages **165**.

In this example, a multiplexed and encrypted media/control stream **170** is established using admission control signaling messages **130**. The multiplexed and encrypted media/control stream **170** is carried over the pre-allocated reservation session between media aggregation manager **110** and media aggregation manager **120**. The multiplexed and encrypted media/control stream **170** represents one way to handle certain transport and control protocol combinations, such as RTP and RTCP, that use different channels or ports for control and data. In alternative embodiments, the reservation protocol session **160** may not need to distinguish between control and data.

While in the described embodiment, the media aggregation managers **110** and **120** are discussed as if they are autonomous network edge devices, it should be kept in mind that according to various embodiments of the present invention some or all of the functionality of a media aggregation manager might be integrated with existing network devices, such as bridges, routers, switches, and the like. Additionally, while only a single aggregated reservation protocol session between two media aggregation managers **110** and **120** is described in connection with the present example, it should be appreciated that each media aggregation manager **110** and **120** may support multiple, heterogeneous reservation protocol sessions capable of providing heterogeneous application flows among multiple user communities. Importantly, according to embodiments of the present invention, regardless of the number of terminals or application/endpoints, application flows may be provided with reserved bandwidth between any and all pairs of terminals of N user communities by establishing and sharing no more than N^2 reservation protocol sessions.

Network Device Overview

An exemplary machine in the form of a network device **200**, representing an exemplary media aggregation manager **110**, in which features of the present invention may be implemented will now be described with reference to FIG. **2**. In this simplified example, the network device **200** comprises a bus or other communication means **201** for communicating information, and a processing means such as one or more processors **202** coupled with bus **201** for processing information. Networking device **200** further comprises a random access memory (RAM) or other dynamic storage device **204** (referred to as main memory), coupled to bus **201** for storing information and instructions to be executed by processor(s) **202**. Main memory **204** also may be used for storing temporary variables or other intermediate information during execution of instructions by processor(s) **202**. Network device **200** also comprises a read only memory (ROM) and/or other static storage device **206** coupled to bus **201** for storing static information and instructions for processor **202**. Optionally, a data storage device (not shown), such as a magnetic disk or optical disc and its corresponding drive, may also be coupled to bus **201** for storing information and instructions.

One or more communication ports **225** may also be coupled to bus **201** for allowing various local terminals, remote terminals and/or other network devices to exchange information with the network device **200** by way of a Local Area Network (LAN), Wide Area Network (WAN), Metropolitan Area Network (MAN), the Internet, or the public switched telephone network (PSTN), for example. The communication ports **225** may include various combinations of well-known interfaces, such as one or more modems to provide dial up capability, one or more 10/100 Ethernet ports, one or more Gigabit Ethernet ports (fiber and/or copper), or other well-known interfaces, such as Asynchronous Transfer Mode (ATM) ports and other interfaces commonly used in existing LAN, WAN, MAN network environments. In any event, in this manner, the network device **200** may be coupled to a number of other network devices, clients and/or servers via a conventional network infrastructure, such as a company's Intranet and/or the Internet, for example.

Media Aggregation Manager

FIG. **3** is a high-level block diagram of a media aggregation manager according to one embodiment of the present invention. By interconnecting a plurality of distributed media aggregation managers, such as media aggregation manger **300**, an architecture is provided for selectively encrypting and multiplexing several application flows (e.g., VoIP calls) over a pre-allocated reservation protocol session, such as a pre-allocated RSVP pipe. Advantageously, the multiplexing of application flows reduces the computational resources required by the network to provide reserved bandwidth, e.g., guaranteed bandwidth, for multiple application flows. Additionally, the selective encryption at the media aggregation manager **300** is more elegant and scalable than RBE solutions due in part to the ability of the media aggregation manager's ability to maintain state on a packets-to-call mapping basis. Furthermore, in a VoIP environment, the logical positioning of the media aggregation managers **300** relative to the terminals enables encryption to be performed only on voice related packets rather than every packet that hits the router as would be the case in a RBE solution.

In the example depicted, the source media aggregation manager receives media packets from its local terminals and transmits encrypted multiplexed media to the destination aggregation manager. The destination aggregation manager receives the encrypted multiplexed media and routes media packets to the appropriate terminal(s) of its local terminals by performing demultiplexing and decryption.

In this example, the media aggregation manger **300** includes an application/protocol specific media multiplexor **350**, an application/protocol specific media demultiplexor **360**, a media encryptor **355**, a media decryptor **365**, an admission control manager **315**, a tunneling control manager **320**, a generic resource manager **340**, and a resource pool **345**. In a software implementation, instances of the media multiplexor **350**, media demultiplexor **360**, and admission control manager **315** may be created for each particular application/protocol needed to allow communications between terminals of the geographically diverse user communities. Importantly, it should be appreciated that the particular partitioning of functionality described with reference to this example is merely illustrative of one or many possible allocations of functionality.

According to the embodiment depicted, the resource manager **340** establishes and maintains one or more pre-allocated reservation protocol sessions between the local media aggregation manager and one or more remote media aggregation managers. The resource manager **340** optionally interfaces with a centralized entity (not shown) that provides information relating to the characteristics and estimated amount of resources for the pre-allocated reservation protocol sessions. Alternatively, a network administrator may provide information to the resource manager **340** relating to desired characteristics of the pre-allocated reservation protocol sessions. The resource manager **340** also tracks active application sessions for each reservation protocol session and the current availability of resources for each reservation protocol session in the resource pool **345**.

The tunneling control manager **320** interfaces with the media encryptor **350** and one or more other remote tunneling control managers (RTCMs) associated with other user communities to agree upon encryption, such as Message Digest 5 (MD5), RSA Data Encryption Standard (DES) or other encryption standard, key management, and/or a tunneling protocol to be employed for a particular application session, such as existing or future versions of the IP Security (IPSec) Protocol, generic routing encapsulation (GRE), Layer 2 Forwarding (L2F), Layer 2 Tunneling Protocol (L2TP), or the Point-to-Point Tunneling Protocol (PPTP).

The media encryptor **355** receives media packets from the local terminals (not shown) and selectively encrypts the media packets for exchange with the media decryptor **365** of the remote media aggregation manger as previously agreed upon by the participating tunneling control managers based upon the application session with which the media packets are associated. In this manner, security may be configured on an application session basis (e.g., a call-by-call basis).

The admission control manager **315** interfaces with local terminals (not shown) associated with a particular user community, the media multiplexor **350**, the resource manager **340**, and one or more other remote media aggregation managers associated with other user communities. Importantly, in one embodiment, the media multiplexor **350** hides the details of how reserved resources are internally allocated and managed, thereby allowing the local terminals to use existing reservation protocols, such as RSVP, without change.

The media multiplexor **350** receives selectively encrypted media packets from the media encryptor **355** and appropriately translates/encapsulates the packets for communication with the media demultiplexor **360** of the remote media aggregation manger in accordance with the aggregation technique described further below. When application flows are established and terminated, the admission control manager **315** interfaces with the resource manager **340** to allocate and deallocate resources, respectively.

The media demultiplexor **360** interfaces with the media decryptor **365** to supply the media decryptor **365** with the selectively encrypted media packets by demultiplexing the respective application flows from the pre-allocated reservation protocol session. The media decryptor **365** then decrypts the media packets, if necessary, and forwards them to the appropriate local terminals (not shown).

The admission control manager **315** exchanges admission control signaling messages with remote admission control managers and configures the local application/endpoint (LA) to send media to transmitted to the local media aggregation manager after an application session has been established with a remote media aggregation manager. For VoIP using the H.323 protocol, the admission control manager **315** may include RAS, call control, and call signaling processing.

When application flows are established and terminated, the admission control manager **315** interfaces with the resource manager **340** to allocate and deallocate resources, respectively.

In operation, two resource managers cooperate to establish a pre-allocated reservation protocol session between a local media aggregation manager (LMAM) and a remote media aggregation manager (RMAM). The resource managers make a reservation that is large enough to accommodate the anticipated load offered by applications that need to communicate over the reservation protocol session. Subsequently, a local media encryptor (LME) associated with the LMAM provides admission control for application flows between one or more terminals of the LMAM and the RMAM with the assistance of the local and remote admission control managers and the local and remote resource managers. If sufficient resources, such as bandwidth, are available over the pre-allocated reservation protocol session, then the LME selectively encrypts the application flows and the local media multiplexor (LMM) multiplexes the application flows for transmission over the pre-allocated reservation protocol session. On the receiving end, the remote media demultiplexor (RMDX) demultiplexes the application flows and sends them to their intended destinations through the remote media decryptor (RMD) which performs any necessary decryption. The typical admission control manager **315** will be a player in the path of the application protocol for setting up the connection between two or more application endpoints; hence, it may be instrumented to modify the path of the media packets to flow through the LME, LMM, the remote media encryptor (RME), and the remote media multiplexor (RMM).

In brief, after an application session has been associated with the pre-allocated reservation protocol session, the application/endpoints may use a transport protocol and/or a control protocol, such as RTP and/or RTCP to exchange encrypted media packets between them. The media packets may carry various types of real-time data, such as voice, voice-band data, video, multi-media, or other data for human interactions or collaboration. Media packets from a data source are optionally encrypted by the local media encryptor **355**, tagged by the local media multiplexor **350**, and sent over the reserved path to one or more media demultiplexors **360** corresponding to the data destination. As illustrated below, the media demultiplexor **360** strips the tag before the media packets are forwarded, the media decryptor **360** performs decryption processing, and then the tag information is used to determine the ultimate destination of the data packet.

From the perspective of the local terminals, they are establishing and using reservation protocol sessions for each application flow and communicating in the clear. However, in reality, the media aggregation manger **300** shares the pre-allocated reservation protocol session among multiple application flows and transparently performs encryption and/or decryption as necessary.

As will be described further below, a specific example of the use of this architecture is in connection with the use of the H.323 protocol for VoIP calls. Typically, an H.323 Gatekeeper is used by endpoints to help in address resolution, admission control etc. So, for the H.323 protocol, the gatekeeper is a convenient place for the media multiplexor **350** and/or media encryptor **355** to reside.

Note that in this description, in order to facilitate explanation, the media aggregation manager **300** is generally discussed as if it is a single, independent network device or part of single network device. However, it is contemplated that the media aggregation manager **300** may actually comprise multiple physical and/or logical devices connected in a distributed architecture; and the various functions performed may actually be distributed among multiple network devices. Additionally, in alternative embodiments, the functions performed by the media aggregation manager **300** may be consolidated and/or distributed differently than as described. For example, any function can be implemented on any number of machines or on a single machine. Also, any process may be divided across multiple machines. Specifically, the media multiplexor **350** and the media encryptor **355** may be combined as a single functional unit or the multiplexing and encrypting processing may be performed in the opposite order than described above. Similarly, the media demultiplexor **360** and the media decryptor **365** may be combined as a single functional unit or the demultiplexing and decrypting processing may be performed in the opposite order than described above, e.g., encryption may be performed before or after multiplexing. Finally, encryption may be performed at various levels of the application flow. For example, encryption may be performed on the media and/or control information directly, the media and/or control packets, or on multiplexed media and/or control packets.

Sharing a Pre-Allocated Reservation Protocol Session

FIG. **4** is a simplified, high-level flow diagram illustrating application session processing according to one embodiment of the present invention. In one embodiment, the processing blocks described below may be performed under the control of a programmed processor, such as processor **202**. However, in alternative embodiments, the processing blocks may be fully or partially implemented by any programmable or hard-coded logic, such as Field Programmable Gate Arrays (FPGAs), TTL logic, or Application Specific Integrated Circuits (ASICs), for example.

In this example, it is assumed that a reservation protocol session has been previously established. The pre-allocated reservation protocol session preferably takes into consideration current network resources and estimated usage of network resources, such as bandwidth, based upon historical data. For example, the amount of pre-allocated resources may vary due to different loads being offered at different times of day and/or day of week.

At any rate, at decision block **410**, the media aggregation manager **300** determines the type of event that has occurred. If the event represents the receipt of an application session establishment request from a local terminal, then processing proceeds to decision block **420**. If the event represents the receipt of media packets from a local application/endpoint, then processing continues with decision block **450**. If the event represents the receipt of a media packet from a remote application/endpoint, then control passes to processing block **460**. If the event represents the receipt of an application session termination request, then processing continues with processing block **470**. At decision block **420**, a determination is made whether resources are available to meet the needs identified in the application session establishment request. For example, the resource manager **340** may determine if sufficient bandwidth is available on an appropriate pre-allocated reservation protocol session by comparing a minimum bandwidth specified in the application session establishment request to a bandwidth availability indication provided by the resource pool **345**.

If adequate resources are available to provide the requester with the minimum resources requested, processing continues with processing block **430** where application session establishment processing is performed. Application session establishment processing is described below with reference to FIG. **5**. Otherwise, if there are insufficient resources to accommodate the application session establishment request, processing branches to processing block **440**. At processing block **440**, the media aggregation manager **300** may reject the application session establishment request. Alternatively, the media aggregation manager **300** may continue the application session establishment process and provide a best effort service for the request (without the use of pre-allocated resources).

At processing block **450**, media packets received from a local application/endpoint are selectively encrypted depending upon the application session with which they are associated, tagged, and sent over the network to the destination using the previously reserved resources (e.g., the pre-allocated reservation protocol session). The tagging and multiplexing of media packets onto the pre-allocated reservation protocol session will be discussed in detail below.

At processing block **460**, potentially encrypted and multiplexed media packets received from a remote application/endpoint are decrypted, if necessary, and forwarded to the appropriate local application/endpoint. For example, the packets may be sent to the appropriate local application/endpoint based upon an examination of the tag information added by the remote media aggregation manager.

At processing block **470**, in response to an application session termination request, resources allocated to this application session are relinquished and made available for other application sessions. For example, the resource manager **340** may update an indication of available resources in the resource pool **345** for the pre-allocated reservation protocol session associated with the terminated application session.

FIG. **5** is a simplified, high-level flow diagram illustrating application session establishment processing according to one embodiment of the present invention. In the present example, application session establishment processing begins with processing block **510**. At processing block **510**, the requested resources are allocated to the application session. According to one embodiment, the local resource manager **340** creates a new application session entry, in the resource pool **345**, containing an indication of the resources granted to the application session.

At decision block **520**, a determination is made whether the desired remote application/endpoint is available to participate in the application session. If so, processing proceeds to processing block **530**; otherwise, processing branches to processing block **560**.

Assuming the desired remote application/endpoint is available to participate in the application session, then at processing block **530**, the local application/endpoint and the remote application/endpoint are configured to send media packets associated with the application session to the local and remote media multiplexors, respectively.

At processing block **540**, the local and remote media multiplexors and demultiplexors are configured in accordance with the application session. For example, as described further below, a lookup table may be maintained by the media multiplexor **350** or media demultiplexor **360** to translate the source network address of the local application/endpoint to the destination network address of the remote application/endpoint.

Finally, at processing block **550**, the local and remote media encryptors **355** and decryptors **365** are configured in accordance with the desired level of security for the application session. Exemplary standards-based encryption options include Message Digest 5 (MD5), RSA Data Encryption Standard (DES), and Triple DES encryption. Exemplary tunneling options include the IP Security (IPSec) Protocol, generic routing encapsulation (GRE), Layer 2 Forwarding (L2F), Layer 2 Tunneling Protocol (L2TP), or the Point-to-Point Tunneling Protocol (PPTP).

FIG. **6** illustrates interactions among local and remote media aggregation manager functional units according to one embodiment of the present invention. In general, the media aggregation managers abstract the true application session endpoints from each other and serve as proxies for their respective local applications/endpoints. The media aggregation managers accomplish this by intercepting messages originating from their respective local applications/endpoints and modifying the messages to make themselves appear as the actual application flow originators/recipients.

In this example, for simplicity, it is assumed that a single local application/endpoint (LA) is establishing an application session with a single remote application/endpoint (RA) over a pre-allocated reservation protocol session **690** between a local media aggregation manager (LMAM) geographically proximate to the LA and a remote media aggregation manager (RMAM) geographically proximate to the RA.

The LA transmits a request to connect to the RA to the LMAM (**670**). The LACM inquires of the local resource manager (LRM) whether sufficient resources are currently available to accommodate the LA's request (**672**). The LRM indicates the availability or in availability of available resources to the LACM (**674**).

Assuming, sufficient resources are available to provide the reserved resources the LA needs for the requested connection to the RA, then the LACM asks the RACM if the RA is available (**676**). In response to the LACM's request, the RACM queries the RA to determine its present availability (**678**). The RA indicates whether or not it is currently available to participate in an application session (**680**).

Assuming, the RA indicates that it is available, then the RACM communicates the RA's availability to the LACM (**682**). In response to the availability of the RA, the LACM directs the RACM to proceed with establishment of a connection between the LA and RA.

Having determined that a connection is feasible, the LACM and RACM proceed to configure their media multiplexors and media demultiplexors for the LA-RA connection. The LACM configures the local media multiplexor (LMM) to tag media originated from the LA for routing to the RA and to send the resulting encapsulated media packets to the remote media demultiplexor (RMDX) (**686**). The LACM further configures the local media demultiplexor (LMDX) to forward media packets that are received from the RMM and tagged as being associated with the LA-RA connection to the LA (**690**).

Similarly, the RACM configures the remote media demultiplexor (RMDX) to forward media packets that are received from the LMM and tagged as being associated with the LA-RA connection to the RA (**688**). The RACM also configures the remote media multiplexor (RMM) to tag media originated from the RA for routing to the LA and to send the resulting encapsulated media packets to the local media demultiplexor (LMDX) (**692**).

Once the media multiplexors and media demultiplexors have been appropriately configured for the LA-RA connection, the LACM and the RACM inform their application/endpoints to commence transmission of media to the LME and the RME, respectively **694** and **696**. Thus, the media aggregation managers appear to their respective application/endpoints as the actual application flow originators/recipients and subsequently serve as proxies for their respective application/endpoints.

During media transmission between the LA and the RA **698** and **699**, media packets originated by the LA are sent to the LME for optional encryption, then to the LMM, which encapsulates the media packets by appending a tag appropriate for the LA-RA connection and forwards the encapsulated packets over the pre-allocated reservation protocol session **690** to the RMDX. The RMDX determines the RA is the intended destination based upon the tag, removes the tag, and forwards the media packet to the RA via the RMD. Media packets originated by the RA are sent to the RME which performs encryption then to the RMM which encapsulates the media packets by appending a tag appropriate for the LA-RA connection and forwards the encapsulated packets over the pre-allocated reservation protocol session **690** to the LMDX. The LMDX determines the LA is the intended destination based upon the tag, removes the tag, and forwards the media packet to the LA via the local media decryptor (LMD).

An Exemplary H.323 VoIP Implementation

H.323 is basically an umbrella that covers several existing protocols, including but not limited to H.225.0, and H.245. The later two protocols are used to establish call connection, and capability information between two endpoints. Once this information is exchanged, the endpoints may use RTP and RTCP to exchange voice, voice-band data, and multimedia information between them.

H.323 suggests that RTP/RTCP should be established between two endpoints (caller/receiver) for each call. Consequently, in order to provide Quality Of Service (QoS) for each call using a protocol like RSVP would mean that every endpoint pair (caller/receiver) for every H.323 call would need to establish RSVP between one another. This would create a huge amount of overhead on the endpoint and adversely affect network resources as RSVP "soft states" must be maintained for the life of the call. This quickly becomes a tremendous scalability issue, since as number of simultaneous calls increase, so do the RSVP "soft state" maintenance messages between endpoints, and every router involved in the transmitting RTP/RTCP data stream.

The media aggregation manager **300** described herein seeks to provide a clean, and scalable solution for this problem, while providing the same QoS as if two individual endpoints had used a reservation protocol session, such as RSVP, between them. Briefly, according to the described H.323 VoIP embodiment, the H.323 endpoints (callers/receivers) need not have knowledge of how to establish and maintain RSVP sessions. Instead, the media aggregation managers establish one or more RSVP "pipes" between them that can accommodate several (expected) voice calls. These RSVP pipes are created as the media aggregation managers are started and the RSVP pipes are maintained between them. This immediately reduces the amount of RSVP state processing in the network. The RSVP pipes between media aggregation managers may be created based upon an educated estimate of the number of calls that are expected between user communities being managed by these media aggregation managers. Since RSVP by nature is established between a specific IP address/port pair and since the pipes are pre-created between media aggregation managers, all voice traffic (RTP/RTCP) originates and terminates between media aggregation managers at the media multiplexor **350** and the media demultiplexor **360**, respectively.

In this manner, according to one embodiment, the "local" media aggregation manager appears to an H.323 voice application caller as its intended receiver. The H.323 endpoints make calls to the local media aggregation managers without realizing the local media aggregation managers are not really the final destination. The local media aggregation manager calls the remote media aggregation manager and passes the RTP/RTCP voice data to it. The remote media aggregation manager receives the voice data and sends it the "real" receiver while hiding all multiplexing details from both the caller and the receiver. However, as the voice data is actually exchanged between media aggregation managers over the network it gets RSVP treatment, reserved bandwidth, and QoS. Advantageously, this solution serves as a surrogate to route calls over the pre-created RSVP pipes eliminating QoS processing by endpoints, without any deviations from each involved standard protocol.

Referring now to FIG. **7**, a flow diagram illustrating exemplary Registration, Admission, Status (RAS) signaling processing will now be described. At decision block **710**, the appropriate processing path is determined based upon the triggering event. If the event is a request for a terminal's signaling address then processing proceeds to decision block **720**. If the event represents a signaling address response, then control flow branches to processing block **750**. However, if the event is a new call request, then processing continues with decision block **760**.

At decision block **720**, in response to a request for a terminal signaling address, a determination is made whether or not the terminal is locally serviced. If it is determined that the terminal is not serviced by the media aggregation manager **300**, then processing continues with processing block **730**; otherwise processing proceeds to processing block **740**.

At processing block **730**, the media aggregation manager **300** requests the call signaling address from an appropriate remote media aggregation manager. For example, the local media aggregation manager may transmit a multicast message or a directed broadcast to locate the appropriate remote media aggregation manager that services the desired terminal.

At processing block **740**, the media aggregation manager **300** returns its own signaling address rather than the signaling address of the locally serviced terminal. In this manner, subsequent call signaling and control signaling is routed through the local media aggregation manager rather than letting the locally service terminal handle this signaling directly.

At processing block **750**, in response to a signaling address response, the media aggregation manager **300**, as above, returns its signaling address in place of the signaling address of the locally serviced terminal to abstract call and control signaling from the locally serviced terminal.

At decision block **760**, in response to a new call request on the RAS channel of the media aggregation manager **300**, a determination is made whether there is capacity for the new call. For example, the local resource manager verifies whether the reservation protocol session over which the new call will be multiplexed can accommodate the additional bandwidth requirements of the new call. At any rate, if the local resource manager determines that the reservation protocol session has adequate resource or the new call, then processing continues to processing block **770**. Otherwise, control flows to processing block **780**.

At processing block **770**, the media aggregation manager **300** returns an indication that the new call can be accepted. At processing block **780**, the media aggregation manager **300** returns direction to reject the new call.

Advantageously, since the terminals/phones register with the media aggregation manager **300**, additional authentication processing can be performed in addition to optional encryption, thereby also serving as a checkpoint for only accepting packets from those entities/end points/phones that have previously registered.

FIG. **8** is a flow diagram illustrating call signaling processing according to one embodiment of the present invention. At decision block **810**, the appropriate processing path is determined based upon the event that has triggered the call signaling processing tread. If the event is a local call connect request, the processing proceeds to processing block **820**. If the event represents a remote call connect request, then control flow branches to processing block **830**. If the event is a local alerting/call or proceeding/connect message, then processing continues with processing block **840**. However, if the event is a remote alerting/call or proceeding/connect message, the processing proceeds with processing block **850**.

At processing block **820**, in response to a local call connect request, the media aggregation manager **300** accepts the call from the local terminal and calls the remote media aggregation manager that services the destination terminal. In this manner, the local media aggregation manager poses as the intended receiver to its local terminals that are callers.

At processing block **830**, in response to a remote call connect request, the media aggregation manager **300** accepts the call from the remote media aggregation manager and calls the intended recipient, e.g., on of the terminals serviced by the local media aggregation manager. In this manner, the local media aggregation manager poses a caller to its local terminals that are receivers.

At processing block **840**, in response to a local alerting/call or proceeding/connect message, the local media aggregation manager relays the message to the appropriate remote media aggregation manager(s).

At processing block **850**, in response to a remote alerting/call or proceeding/connect message, the local media aggregation manager relays the message to the appropriate local terminal(s). After processing block **850**, call signaling is complete and control protocol signaling (e.g., H.245) can begin.

FIG. **9** is a flow diagram illustrating control signaling processing according to one embodiment of the present invention. At decision block **910**, the appropriate processing path is determined based upon the event that has triggered the control signaling processing tread. If the event is receipt of a master/slave and capability exchange from a local application/endpoint, the processing proceeds to processing block **920**. If the event represents receipt of a master/slave and capability exchange from a remote media aggregation manager, then control flow branches to processing block **930**. If the event is receipt of logical channel information from a local application/endpoint, then processing continues with processing block **940**. However, if the event is reception of logical channel information from a remote media aggregation manager, the processing proceeds with processing block **950**.

At processing block **920**, the master/slave and capability exchange is transmitted to the remote media aggregation manager.

At processing block **930**, the master/slave and capability exchange is transmitted to the local application/endpoint.

At processing block **940**, the logical channel information from the local application/endpoint is stored in anticipation of making a connection with the media and/or control channels of the local application/endpoint. At processing block **950**, the LMAM forwards its own logical channel information to the RMAM. Additionally, the network address of the LA is sent to the RMAM.

At processing block **960**, the network address of the RA is stored in a lookup table for address translation and the logical channel information of the LMAM is forwarded to the LA.

FIG. **10** is a flow diagram illustrating media/control transmission processing according to one embodiment of the present invention. At processing block **1010**, the local media multiplexor reports the resources being consumed by the local application/endpoint to the local resource manager.

At processing block **1020**, the media aggregation manager **300** connects to the media and/or control channels of the local application/endpoint.

At processing block **1030**, media and control packets generated by the local application/endpoint are received by the local media encryptor (LME). Depending upon the application session with which the media packets are associated the appropriate form of encryption is applied to the media packets at processing block **1035**.

According to this example, at processing block **1040**, after optional encryption is performed, the media multiplexor **350** marks the outbound packets with appropriate address information (referred to as a "tag") for demultiplexing at the remote media aggregation manager. The tag is typically appended to transport protocol packets, such as TCP or RTP packets, to allow the media multiplexor **350** to direct packets to the appropriate remote application/endpoint. According to one embodiment, the tag includes address information, such as the destination network address associated with the remote application/endpoint. The destination network address may be determined with reference to a lookup table that allows translation between the source network address associated with the local application/endpoint and the destination network address associated with the remote application/endpoint. Alternatively, a lookup table may be maintained on the media demultiplexor **360** and the tag would include the source network address associated with the local application/endpoint. Then, the source network address would be used by the remote media demultiplexor to determine how to route the inbound packet to the appropriate remote application/endpoint.

When different channels or ports are used for transport and control protocols (such as RTP and RTCP), then the tag may also include additional protocol dependent control information to allow multiplexing of data and control packets onto the reservation protocol session. Therefore, at optional processing block **1050**, each outbound packet may additionally be marked as control or data to allow the remote media aggregation manager to determine the appropriate channel/port of the remote application/endpoint on which to forward the packet.

Finally, at processing block **1060**, the marked packet is transmitted to the appropriate remote media aggregation manager(s).

FIG. **11** is a flow diagram illustrating media/control reception processing according to one embodiment of the present invention. At processing block **1110**, a packet is received from a remote media aggregation manager. The demultiplexing information (e.g., the tag) added by the remote media multiplexor is stripped from the packet and examined at processing block **1120**. Optionally, at processing block **1130**, if control and data packets are being multiplexed onto the reservation protocol session, a determination is made whether the packet is a media packet or a control packet based upon the tag. Encrypted media packets are decrypted at processing block **1135** using the appropriate form of decryption for the associated application session. At processing block **1140**, the appropriate local application(s)/endpoint(s) to which the packet is destined is/are determined. As described above, the media multiplexor **350** may perform address translation from a source network address to a destination network address. In this case, the appropriate local application(s)/endpoint(s) that are to receive the packet is/are determined by examining the address portion of the tag. Alternatively, if the media multiplexor **350** leaves the source network address in the address portion of the tag, then the appropriate local application(s)/endpoint(s) is/are determined by first translating the address portion using a local lookup table, for example.

In any event, finally, at processing block **1150**, the packet is transmitted to those of the local application(s)/endpoint(s) identified in processing block **1140**. If, according to the particular transport and/or control protocols employed, the application(s)/endpoint(s) receive media packets and control packets on different channels/ports, then the packet is forwarded onto the appropriate channel/port of the local application(s)/endpoints(s) based on the packet classification performed at processing block **1130**.

FIG. **12** conceptually illustrates application session establishment in an H.323 environment according to one embodiment of the present invention. In general, the media aggregation managers abstract the true application session endpoints from each other and serve as proxies for their respective local applications/endpoints. As explained above, the media aggregation managers accomplish this by intercepting signaling messages originating from their respective local applications/endpoints and modifying the signaling messages to make themselves appear as the actual callers/recipients.

In this illustration, for simplicity, it is assumed that a single local application/endpoint (LA) is establishing an application session with a single remote application/endpoint (RA) over a pre-allocated reservation protocol session **1290** between a local media aggregation manager (LMAM) geographically proximate to the LA and a remote media aggregation manager (RMAM) geographically proximate to the RA.

According to this example, application session establishment involves RAS signaling **1210** and **1230**, H.225 signaling **1240**, and H.245 signaling **1250**. RAS signaling **1210** begins with a request for the RA signaling address **1211** by the LA to the LMAM. The LMAM transmits the request **1211** via the reservation protocol session **1290** to the RMAM. In response to the request **1211**, the RMAM decides it wants to route H.225/H.245 signaling through it instead of letting the RA do it directly. Therefore, the RMAM replies with a packet **1212** containing RMAM's signaling address. Similarly, the LMAM decides it wants to route H.225/H.245 signaling through it instead of letting the LA do it directly. Therefore, the LMAM substitutes its signaling address for that of the RMAM and forwards packet **1213** to the LA.

RAS signaling continues with the RA asking the RMAM (on its RAS channel) if it is okay to accept a new call by sending the RMAM a new call request **1231**. The RMAM authorizes the new call by responding with a packet **1231** giving the RA permission to accept the new call.

H.225 signaling comprises the RA sending H.225 alerting/call proceeding/connect messages **1241** to the RMAM. The RMAM sends the same to the LMAM; and the LMAM sends the same to the LA. At this point, the LA determines that H.225 call signaling is complete and starts H.245 signaling.

H.245 signaling begins with the LA sending master/slave and capability exchange messages **1251** to the LMAM, which are relayed to the RMAM and from the RMAM to the RA. Then, the RA sends master/slave and capability exchange messages **1252** to the RMAM. The RMAM transmits these messages to the LMAM; and the LMAM forwards them to the LA.

Subsequently, the LA initiates an exchange of logical channel information by sending logical channel information packets **1253** to the LMAM. The logical channel information identifies the network address (e.g., IP address) and port numbers where RTP/RTCP connections will be accepted. The LMAM stores the LA's logical channel information and passes its own connection information **1254** to the RMAM. Additionally, the LMAM provides the network address of the LA to the RMAM for later use in address translation lookups. As mentioned above, the network address of the LA may be used by the RMM or the RMDX depending upon where the address translation lookup is performed. The RMAM remembers the information provided by the LMAM and generates its own RTP/RTCP information **1255** and passes it to the RA.

After receiving logical channel information thought to be associated with the LA, the RA sends its logical channel information **1256** to the RMAM (thinking it is being directed to the LA). The RMAM stores the RA's logical channel information and passes its own connection information **1257** to the LMAM. Additionally, the RMAM provides the network address of the RA to the LMAM. The LMAM remembers the logical channel information provided by the RMAM and generates its own RTP/RTCP information **1258** and passes it to the LA.

The LA sends an ACK message **1259** to the LMAM to acknowledge receipt of what it thinks to be the RA's logical channel information. The acknowledgement is relayed to the RA by the LMAM and the RMAM. The RA also sends an ACK message **1260** to the RMAM to acknowledge receipt of what it thinks to be the LA's logical channel information. The acknowledgement is related to the LA by the RMAM and the LMAM. Finally, the LMAM and the RMAM each use the logical channel information intercepted from the LA and the RA, respectively, to connect to the media and/or control channels of the LA and RA.

Exemplary Encapsulated Packet Formats

FIG. **13**A illustrates the encapsulated ("MUX") packet format **1300** according to one embodiment of the present invention in which address replacement is performed by the LMAM. The payload of the encapsulated packet **1300** includes a destination network address field **1310**, a variable length transport or control protocol packet portion **1315**, and a packet type indication **1320**. The destination network address **1310** is typically the IP address of the true recipient (e.g., the application/endpoint to which the packet is destined). In environments where multiplexing of control and data is employed, the variable length portion **1315** may include either a transport protocol packet (e.g., a RTP packet) or a control protocol packet (e.g., a RTCP packet) as indicated by the packet type indication **1320**. In alternative embodiments, where multiplexing of control and data is not employed, then the variable length portion **1315** would still include either control or data, but the packet type indication **1320** would no longer be necessary.

FIG. 13B illustrates media transmission in both directions according to the encapsulated packet format of FIG. **13**A. When the LA originates a media packet, it generates a packet **1340** including media **1342**. The LMAM optionally encrypts the media **1342** and encapsulates the media **1342** in the encapsulated packet format **1300** by generating an encapsulated packet **1350** that includes the RA's network address **1351**, the media **1342**, and a packet type indicator **1353**. For example, upon receipt of packet **1340**, the LMAM may append the network address of the RA and a packet type indicator **1353** based upon the channel/port upon which the packet **1340** was received. When the encapsulated packet **1350** is received by the RMAM, it strips the information added by the LMAM, decrypts the media **1342**, if necessary, and forwards a packet **1360** comprising the media **1342** to the RA.

When the RA originates a media packet, it generates a packet **1390** including media **1392**. The RMAM optionally encrypts the media **1392** and encapsulates the media **1392** in the encapsulated packet format **1300** by generating an encapsulated packet **1380** that includes the LA's network address **1341**, the media **1392**, and a packet type indicator **1383**. For example, upon receipt of packet **1390**, the RMAM may append the network address of the LA and a packet type indicator **1383** based upon the channel/port upon which the packet **1390** was received. When the encapsulated packet **1380** is received by the LMAM, it strips the information added by the RMAM, decrypts the media **1392**, if necessary, and forwards a packet **1370** comprising the media **1392** to the LA.

FIG. **14**A illustrates the encapsulated ("MUX") packet format according to another embodiment of the present invention in which address replacement is performed by the RMAM. The payload of the encapsulated packet **1400** includes a source network address field **1410**, a variable length transport or control protocol packet portion **1415**, and a packet type indication **1420**. The source network address **1410** is typically the IP address of the true caller (e.g., the application/endpoint from which the packet is originated). In environments where multiplexing of control and data is employed, the variable length portion **1415** may include either a transport protocol packet (e.g., a RTP packet) or a control protocol packet (e.g., a RTCP packet) as indicated by the packet type indication **1420**. In alternative embodiments, where multiplexing of control and data is not employed, then the variable length portion **1415** would still include either control or data, but the packet type indication **1420** would no longer be necessary.

FIG. **14**B illustrates media transmission in both directions according to the encapsulated packet format of FIG. **14**A. When the LA originates a media packet, it generates a packet **1440** including media **1442**. The LMAM optionally encrypts the media **1442** and encapsulates the media **1442** in the encapsulated packet format **1400** by generating an encapsulated packet **1450** that includes the LA's network address **1441**, the media **1442**, and a packet type indicator **1453**. For example, upon receipt of packet **1440**, the LMAM may append the network address of the LA and a packet type indicator **1453** based upon the channel/port upon which the packet **1440** was received. When the encapsulated packet **1450** is received by the RMAM, it strips the information added by the LMAM, decrypts the media **1442**, if necessary, and forwards a packet **1460** comprising the media **1442** to the RA by looking up the network address of the RA based upon the LA's network address **1441**.

When the RA originates a media packet, it generates a packet **1490** including media **1492**. The RMAM optionally encrypts the media **1492** and encapsulates the media **1492** in the encapsulated packet format **1400** by generating an encapsulated packet **1480** that includes the RA's network address **1451**, the media **1492**, and a packet type indicator **1483**. For example, upon receipt of packet **1480**, the RMAM may append the network address of the RA and a packet type indicator **1483** based upon the channel/port upon which the packet **1480** was received. When the encapsulated packet **1480** is received by the LMAM, it strips the information added by the RMAM, decrypts the media **1492**, if necessary, and forwards a packet **1470** comprising the media **1492** to the RA by looking up to network address of the LA based upon the RA's network address **1451**.

In the foregoing specification, the invention has been described with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A method comprising:

providing a first media at an edge of a first local area network on which a first set of terminals of a first user community of an enterprise reside, the first set of terminals running a first set of local applications on behalf of which the first media aggregation manager is configured to act as a signaling and control proxy;

providing a second media aggregation manager at an edge of a second local area network on which a second set of terminals of a second user community of the enterprise reside, the second set of terminals running a second set of local applications on behalf of which the second media aggregation manager is configured to act as a signaling and control proxy;

reserving a predetermined portion of available bandwidth as a real-time bandwidth pool over a path through an enterprise network between the first media aggregation manager and the second media aggregation manager for real-time communication sessions between the first set of local applications and the second set of local applications

sharing the real-time bandwidth pool among a plurality of real-time communication sessions by selectively admitting application sessions based upon currently available resources in real-time bandwidth pool; and

securely communicating between the first user community and the second user community by selectively encrypting information associated with the plurality of real-time communication sessions.

2. The method of claim **1**, wherein said reserving a predetermined portion of available bandwidth between the first media aggregation manager and the second media aggregation manager includes pre-allocating a reservation protocol session over a path between the first media aggregation manager and the second media aggregation manager based upon an estimated usage of the path for individual application sessions between users of the first user community and the second user community.

3. The method of claim **2**, wherein said sharing the real-time bandwidth pool among a plurality of real-time communication sessions includes dynamically aggregating one or more individual application sessions by multiplexing application flows associated with plurality of real-time communication sessions onto the pre-allocated reservation protocol session at the first media aggregation manager.

4. The method of claim **3**, wherein the reservation protocol session comprises a Resource Reservation Protocol (RSVP) session.

5. The method of claim **4**, wherein at least one of the real-time communication session includes H.323 session and as a real-time Transport Protocol (RTP) session.

6. The method of claim **3**, further comprising:

forming an encapsulated packet by appending a tag to a media packet received at the first media aggregation manager from a source local application/endpoint associated with the first user community, the tag including information to allow the second media aggregation manager to determine a destination local application/endpoint associated with the second user community, and

removing the tag at the second media aggregation manager prior to forwarding the media packet to the destination local application/endpoint.

7. The method of claim **6**, wherein the tag includes a network address associated with the source local application/endpoint.

8. The method of claim **6**, wherein the tag includes a network address associated with the destination local application/endpoint.

9. The method of claim **6**, wherein the tag includes a packet type indication that specifies how to further identify a subprocess within the destination local application/endpoint.

10. A method comprising:

establishing an aggregated reservation protocol session over a path between a first edge device and a second edge device based upon an estimate of a number of individual application sessions needed for the path during a predetermined window of time; and

securely communicating and sharing the aggregated reservation protocol session among a plurality of individual application sessions tagging packets associated with corresponding application flows and selectively encrypting application flows for transmission between the first edge device and the second edge device, the tagged packets being multiplexed onto the aggregated reservation protocol session by the first edge device or the second edge device and demultiplexed by the other including removal of the tags from the media packets.

11. A method comprising:

establishing a Resource Reservation Protocol (RSVP) session between a first network device and a second network device that are part of an Internet Protocol (IP) network;

receiving, at the first network device from a first local terminal, a request to initiate a first real-time communication session with a first remote terminal associated with the second network device;

allocating a portion of pre-allocated resources associated with the RSVP session to the first real-time communication session between the first local terminal and the first remote terminal;

receiving, at the first network device from a second local terminal, a request to initiate a second real-time communication session with a second remote terminal associated with the second network device;

allocating portion of the pre-allocated resources associated with the RSVP session to the second real-time communication session between the second local terminal and the second remote terminal; and

securely communicating over the RSVP session and sharing the RSVP session between the first real-time communication session and the second real time communication session by encrypting and multiplexing voice packets associated with the first and second real-time communication sessions onto the RSVP session.

12. The method of claim **11**, further comprising:

transmitting voice packets from the first local terminal and first remote terminal by forming an encapsulated packet at the first network device that includes tag information to allow the second network device to determine the voice packets are intended for the first remote terminal; and

removing the tag information at the second network device prior to forwarding the voice packets to the first remote terminal.

13. The method of claim **12**, wherein the tag information includes the IP address of the first local terminal.

14. The method of claim **12**, wherein the tag information includes the IP address of the first remote terminal.

15. The method of claim **12**, wherein the tag information includes a packet type indicator that specifies how to further identify a subprocess within the first remote terminal.

16. A method comprising:

establishing a Resource Reservation Protocol (RSVP) session between a first network device and a second network device that are part of an Internet Protocol (IP) network;

the first network device presenting itself as a recipient of a first call originated by a first local terminal associated with the first network device by providing its logical channel information to the first local terminal rather than providing logical channel information associated with the intended recipient of the first call;

the first network device presenting itself as a recipient of a second call originated by a second local terminal associated with the first network device by providing its logical channel information to the second local terminal rather than providing logical channel information associated with the intended recipient of the second call; and

the first network device selectively and securely transmitting voice packets from the first local terminal to an intended recipient of the first call and from the second local terminal to the intended recipient of the second call by encrypting and multiplexing the voice packets onto the RSVP session.

17. The method of claim **16**, further comprising the first network device presenting itself as the originator of a third call to the second network device by providing its logical channel information to the second network device rather than providing logical channel information associated with a third local terminal associated with the first network device that truly originated the third call.

18. A media aggression manager comprising:

a resource manager to establish a reservation protocol session with one or more other media aggression managers prior to establishment of any application sessions that share resources associated with the reservation protocol and to subsequently allocate and deallocate the resources in response to anticipated use of application session establishment requests and application session termination requests, respectively;

an admission control manager coupled to the resource manager, the admission control manager to provide admission control for application flows based upon availability of the resources as indicated by the resource manager;

a media multiplexor coupled to the admission control manager, the media multiplexor to tag media packets received from local application/endpoints that are associated with admitted application flows and to transmit the tagged media packets over the reservation protocol session;

a media demultiplexor to forward media packets received from remote application/endpoints to the local application/endpoints based upon tags appended by a media multiplexor of the one or more other media aggregation managers;

a media encryptor coupled to the media multiplexor to selectively encrypt media packet received from local application/endpoints that are associated with secure application flows; and

a media decryptor coupled to the media demultiplexor to decrypt encrypted media packets received from the remote application/endpoints.

19. A network device comprising:

a storage device having stored therein one or more routines for establishing and managing an aggregated reservation protocol session;

a processor coupled to the storage device for executing the one or more routines to pre-allocate the aggregated reservation protocol session and thereafter share the aggregated reservation session among a plurality of individual application sessions, where:

the aggregated reservation protocol session is pre-allocated based upon an estimate of the bandwidth requirements to accommodate the plurality of individual application sessions, the plurality of individual application sessions are established between a plurality of local application/endpoints and a plurality of remote application/endpoints;

the aggregated reservation protocol session is securely shared by selectively encrypting and multiplexing outbound media packets originated by a local application/endpoint of plurality of local application/endpoints onto the aggregated reservation protocol session, and decrypting and demultiplexing inbound media packets originated by a remote application/endpoint of the plurality of remote application/endpoints from the aggregated reservation protocol session.

20. A system for secure real-time communications comprising:

a first edge device coupled to a first plurality of terminals, the first edge device including a resource manager to reserve a predetermined portion of available bandwidth by establishing a reservation protocol session with one or more other media aggression managers prior to establishment of any application sessions that share resources associated with the reservation protocol;

an admission control manager to provide admission control for real-time communication application sessions based upon remaining resources associated with a real-time bandwidth pool,

a tunneling control manager that specifies an encryption program and a tunneling protocol; and,

a media encryptor to selectively encrypt information associated with secure application flows based on said encryption program specified by said tunneling control manager;

and a second edge device coupled to a second plurality of terminals, the second edge device including a decryptor to decrypt information associated with secure application flows for use by the appropriate terminal of the second plurality of terminals.

21. A machine-readable medium having stored thereon data representing instructions which, when executed by a processor, cause the processor to:

providing a first media at an edge of a first local area network on which a first set of terminals of a first user community of an enterprise reside, the first set of terminals running a first set of local applications on behalf of which the first media aggregation manager is configured to act as a signaling and control proxy;

providing a second media aggregation manager at an edge of a second local area network on which a second set of terminals of a second user community of the enterprise reside, the second set of terminals running a second set of local applications on behalf of which the second media aggregation manager is configured to act as a signaling and control proxy;

reserving a predetermined portion of available bandwidth as a real-time bandwidth pool over a path through an enterprise network between the first media aggregation manager and the second media aggregation manager for real-time communication sessions between the first set of local applications and the second set of local applications;

share the real-time bandwidth pool among a plurality of real-time communication session by selectively admitting application sessions based upon currently available resources to the real-time bandwidth pool; and

securely communicate between the first user community and the second user community by selectively encrypting information associated with the plurality of real-time communication sessions.

22. The machine-readable medium of claim **21**, wherein the predetermined portion of available bandwidth between the first media aggregation manager and the second media aggregation manager is reserved by pre-allocating a reservation protocol session over a path between the first media aggregation manager and the second media aggregation manager based upon an estimated usage of the path for individual application sessions between users of the first user community and the second user community.

23. The machine-readable medium of claim **22**, wherein the real-time bandwidth pool is shared among the plurality of real-time communication sessions by multiplexing application flows associated with plurality of real-time communication sessions onto the pre-allocated reservation protocol session at the first media aggregation manager.

24. The machine-readable medium of claim **23**, wherein the reservation protocol session comprises a Resource Reservation Protocol (RSVP) session.

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