                  A Framework for Telephony Routing over IP

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Abstract

   This document serves as a framework for Telephony Routing over IP
   (TRIP), which supports the discovery and exchange of IP telephony
   gateway routing tables between providers. The document defines the
   problem of telephony routing exchange, and motivates the need for the
   protocol. It presents an architectural framework for TRIP, defines
   terminology, specifies the various protocol elements and their
   functions, overviews the services provided by the protocol, and
   discusses how it fits into the broader context of Internet telephony.

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1 Introduction

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   (TRIP), which supports the discovery and exchange of IP telephony
   gateway routing tables between providers. The document defines the
   problem of telephony routing exchange, and motivates the need for the
   protocol. It presents an architectural framework for TRIP, defines
   terminology, specifies the various protocol elements and their
   functions, overviews the services provided by the protocol, and
   discusses how it fits into the broader context of Internet telephony.

2 Terminology

   We define the following terms. Note that there are other definitions
   for these terms, outside of the context of gateway location. Our
   definitions aren't general, but refer to the specific meaning here:

     Gateway: A device with some sort of circuit switched network
        connectivity and IP connectivity, capable of initiating and
        terminating IP telephony signaling protocols, and capable of
        initiating and terminating telephone network signaling
        protocols.

     End User: The end user is usually (but not necessarily) a human
        being, and is the party who is the ultimate initiator or
        recipient of calls.

     Calling Device: The calling device is a physical entity which has
        IP connectivity. It is under the direction of an end user who
        wishes to place a call. The end user may or may not be directly
        controlling the calling device. If the calling device is a PC,

the end user is directly controlling it. If, however, the
calling device is a telephony gateway, the end user may be
accessing it through a telephone.

Gatekeeper: The H.323 gatekeeper element, defined in [1].

SIP Server: The Session Initiation Protocol proxy or redirect
server defined in [2].

Call Agent: The MGCP call agent, defined in [3].

GSTN: The Global Switched Telephone Network, which is the worldwide
circuit switched network.

Signaling Server: A signaling server is an entity which is capable
of receiving and sending signaling messages for some IP
telephony signaling protocol, such as H.323 or SIP. Generally
speaking, a signaling server is a gatekeeper, SIP server, or
call agent.

Location Server (LS): A logical entity with IP connectivity which
has knowledge of gateways that can be used to terminate calls
towards the GSTN. The LS is the main entity that participates in
Telephony Routing over IP. The LS is generally a point of
contact for end users for completing calls to the telephony
network. An LS may also be responsible for propagation of
gateway information to other LS's. An LS may be coresident with
an H.323 gatekeeper or SIP server, but this is not required.

Internet Telephony Administrative Domain (ITAD): The set of
resources (gateways and Location Servers) under the control of a
single administrative authority. End users are customers of an
ITAD.

Provider: The administrator of an ITAD.

Location Server Policy: The set of rules which dictate how a
location server processes information it sends and receives via
TRIP. This includes rules for aggregating, propagating,
generating, and accepting information.

End User Policy: Preferences that an end user has about how a call
towards the GSTN should be routed.

Peers: Two LS's are peers when they have a persistent association
between them over which gateway information is exchanged.

   Internal peers: Peers that both reside within the same ITAD.

   External peers: Peers that reside within different ITADs.

   Originating Location Server: A Location Server which first
      generates a route to a gateway in its ITAD.

   Telephony Routing Information Base (TRIB): The database of gateways
      an LS builds up as a result of participation in TRIP.

3 Motivation and Problem Definition

  As IP telephony gateways grow in terms of numbers and usage, managing
  their operation will become increasingly complex. One of the
  difficult tasks is that of gateway location, also known as gateway
  selection, path selection, gateway discovery, and gateway routing.
  The problem occurs when a calling device (such as a telephony gateway
  or a PC with IP telephony software) on an IP network needs to
  complete a call to a phone number that represents a terminal on a
  circuit switched telephone network. Since the intended target of the
  call resides in a circuit switched network, and the caller is
  initiating the call from an IP host, a telephony gateway must be
  used. The gateway functions as a conversion point for media and
  signaling, converting between the protocols used on the IP network,
  and those used in the circuit switched network.

  The gateway is, in essence, a relaying point for an application layer
  signaling protocol. There may be many gateways which could possibly
  complete the call from the calling device on the IP network to the
  called party on the circuit switched network. Choosing such a gateway
  is a non-trivial process. It is complicated because of the following
  issues:

    Number of Candidate Gateways: It is anticipated that as IP
       telephony becomes widely deployed, the number of telephony
       gateways connecting the Internet to the GSTN will become large.
       Attachment to the GSTN means that the gateway will have
       connectivity to the nearly one billion terminals reachable on
       this network. This means that every gateway could theoretically
       complete a call to any terminal on the GSTN. As such, the
       number of candidate gateways for completing a call may be very
       large.

    Business Relationships: In reality, the owner of a gateway is
       unlikely to make the gateway available to any user who wishes to
       connect to it. The gateway provides a useful service, and incurs
       cost when completing calls towards the circuit switched network.
       As a result, providers of gateways will, in many cases, wish to

charge for use of these gateways. This may restrict usage of the
gateway to those users who have, in some fashion, an established
relationship with the gateway provider.

Provider Policy: In all likelihood, an end user who wishes to make
use of a gateway service will not compensate the gateway
provider directly. The end user may have a relationship with an
IP telephony service provider which acts as an intermediary to
providers of gateways. The IP telephony service provider may
have gateways of its own as well. In this case, the IP telephony
service provider may have policies regarding the usage of
various gateways from other providers by its customers. These
policies must figure into the selection process.

End User Policy: In some cases, the end user may have specific
requirements regarding the gateway selection. The end user may
need a specific feature, or have a preference for a certain
provider. These need to be taken into account as well.

Capacity: All gateways are not created equal. Some are large,
capable of supporting hundreds or even thousands of simultaneous
calls. Others, such as residential gateways, may only support
one or two calls. The process for selecting gateways should
allow gateway capacity to play a role. It is particularly
desirable to support some form of load balancing across gateways
based on their capacities.

Protocol and Feature Compatibilities: The calling party may be
using a specific signaling or media protocol that is not
supported by all gateways.

From these issues, it becomes evident that the selection of a gateway
is driven in large part by the policies of various parties, and by
the relationships established between these parties. As such, there
cannot be a global "directory of gateways" in which users look up
phone numbers. Rather, information on availability of gateways must
be exchanged by providers, and subject to policy, made available
locally and then propagated to other providers. This would allow each
provider to build up its own local database of available gateways -
such a database being very different for each provider depending on
policy.

From this, we can conclude that a protocol is needed between
administrative domains for exchange of gateway routing information.
The protocol that provides these functions is Telephony Routing over
IP (TRIP). TRIP provides a specific set of functions:

   o Establishment and maintenance of peering relationships between
     providers;

   o Exchange and synchronization of telephony gateway routing
     information between providers;

   o Prevention of stable routing loops for IP telephony signaling
     protocols;

   o Propagation of learned gateway routing information to other
     providers in a timely and scalable fashion;

   o Definition of the syntax and semantics of the data which
     describe telephony gateway routes.

   TRIP can be generally summarized as an inter-domain IP telephony
   gateway routing protocol.

4 Related Problems

   At a high level, the problem TRIP solves appears to be a mapping
   problem: given an input telephone number, determine, based on some
   criteria, the address of a telephony gateway. For this reason, the
   gateway location problem is often called a "phone number to IP
   address translation problem". This is an over-simplification,
   however. There are at least three separate problems, all of which can
   be classified as a "phone number to IP address translation problem",
   and only one of which is addressed by TRIP:

   o Given a phone number that corresponds to a terminal on a
     circuit switched network, determine the IP address of a
     gateway capable of completing a call to that phone number.

   o Given a phone number that corresponds to a specific host on
     the Internet (this host may have a phone number in order to
     facilitate calls to it from the circuit switched network),
     determine the IP address of this host.

   o Given a phone number that corresponds to a user of a terminal
     on a circuit switched network, determine the IP address of an
     IP terminal which is owned by the same user.

   The last of these three mapping functions is useful for services
   where the PC serves as an interface for the phone. One such service
   is the delivery of an instant message to a PC when the user's phone
   rings. To deliver this service, a switch in the GSTN is routing a
   call towards a phone number. It wishes to send an Instant Message to
   the PC for this user. This switch must somehow have access to the IP

network, in order to determine the IP address of the PC corresponding
to the user with the given phone number. The mapping function is a
name to address translation problem, where the name happens to be
represented by a string of digits. Such a translation function is
best supported by directory protocols. This problem is not addressed
by TRIP.

The second of these mappings is needed to facilitate calls from
traditional phones to IP terminals. When a user on the GSTN wishes to
call a user with a terminal on the IP network, they need to dial a
number identifying that terminal. This number could be an IP address.
However, IP addresses are often ephemeral, assigned on demand by DHCP
[4] or by dialup network access servers using PPP [5]. The number
could be a hostname, obtained through some translation of groups of
numbers to letters. However, this is cumbersome. It has been proposed
instead to assign phone numbers to IP telephony terminals. A caller
on the GSTN would then dial this number as they would any other. This
number serves as an alternate name for the IP terminal, in much the
same way its hostname serves as a name. A switch in the GSTN must
then access the IP network, and obtain the mapping from this number
to an IP address for the PC. Like the previous case, this problem is
a name to address translation problem, and is best handled by a
directory protocol. It is not addressed by TRIP.

The first mapping function, however, is fundamentally an address to
route translation problem. It is this problem which is considered by
TRIP. As discussed in Section 3, this mapping depends on local
factors such as policies and provider relationships. As a result, the
database of available gateways is substantially different for each
provider, and needs to be built up through specific inter-provider
relationships. It is for this reason that a directory protocol is not
appropriate for TRIP, whereas it is appropriate for the others.

5 Relationship with BGP

TRIP can be classified as a close cousin of inter-domain IP routing
protocols, such as BGP [6]. However, there are important differences
between BGP and TRIP:

    o TRIP runs at the application layer, not the network layer,
      where BGP resides.

    o TRIP runs between servers which may be separated by many
      intermediate networks and IP service providers. BGP runs
      between routers that are usually adjacent.

o The information exchanged between TRIP peers describes routes
  to application layer devices, not IP routers, as is done with
  BGP.

o TRIP assumes the existence of an underlying IP transport
  network. This means that servers which exchange TRIP routing
  information need not act as forwarders of signaling messages
  that are routed based on this information. This is not true in
  BGP, where the peers must also act as forwarding points (or
  name an adjacent forwarding hop) for IP packets.

o The purpose of TRIP is not to establish global connectivity
  across all ITADs. It is perfectly reasonable for there to be
  many small islands of TRIP connectivity. Each island
  represents a closed set of administrative relationships.
  Furthermore, each island can still have complete connectivity
  to the entire GSTN. This is in sharp contrast to BGP, where
  the goal is complete connectivity across the Internet. If a
  set of AS's are isolated from some other set because of a BGP
  disconnect, no IP network connectivity exists between them.

o Gateway routes are far more complex than IP routes (since they
  reside at the application, not the network layer), with many
  more parameters which may describe them.

o BGP exchanges prefixes which represent a portion of the IP
  name space. TRIP exchanges phone number ranges, representing a
  portion of the GSTN numbering space. The organization and
  hierarchies in these two namespaces are different.

These differences means that TRIP borrows many of the concepts from
BGP, but that it is still a different protocol with its own specific
set of functions.

6 Example Applications of TRIP

TRIP is a general purpose tool for exchanging IP telephony routes
between providers. TRIP does not, in any way, dictate the structure
or nature of the relationships between those providers. As a result,
TRIP has applications for a number of common cases for IP telephony.

6.1 Clearinghouses

A clearinghouse is a provider that serves as an exchange point
between a number of other providers, called the members of the
clearinghouse. Each member signs on with the clearinghouse. As part
of the agreement, the member makes their gateways available to the
other members of the clearinghouse. In exchange, the members have

access to the gateways owned by the other members of the
clearinghouse. When a gateway belonging to one member makes a call,
the clearinghouse plays a key role in determining which member
terminates the call.

TRIP can be applied here as the tool for exchanging routes between
the members and the clearinghouse. This is shown in Figure 1.

There are 6 member companies, M1 through M6. Each uses TRIP to send
and receive gateway routes with the clearinghouse provider.

6.2 Confederations

We refer to a confederation as a group of providers which all agree
to share gateways with each other in a full mesh, without using a
central clearinghouse. Such a configuration is shown in Figure 2.
TRIP would run between each pair of providers.

6.3 Gateway Wholesalers

```
    ------                              ------
   |      |                            |      |
   | M1   |     TRIP          TRIP     | M2   |
   |      |\      |            |      /|      |
    ------  \     |            |     / ------
            \ \ /  -------------- \ / /
    ------   \----|            |----/  ------
   |      |       |            |      |      |
   | M3   |-------| Clearinghouse|--------| M4   |
   |      |       |            |      |      |
    ------   /----|            |----\  ------
          /        --------------     \
    ------ /                           \  ------
   |      |/                           \|      |
   | M5   |                            | M6   |
   |      |                            |      |
    ------                              ------
```
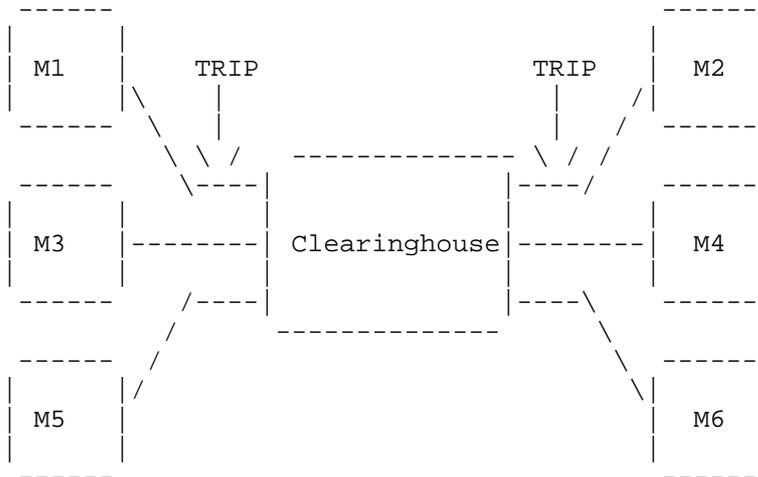
        Figure 1: TRIP in the Clearinghouse Application

```
        ------      ------
        |    |------|    |
        | M1 |      | M2 |
        |    |\    /|    |
        ------ \  / ------
          |     \/    |
          |     /\    |<-----TRIP
        ------ /  \ ------
        |    |/    \|    |
        | M3 |      | M4 |
        |    |------|    |
        ------      ------
```
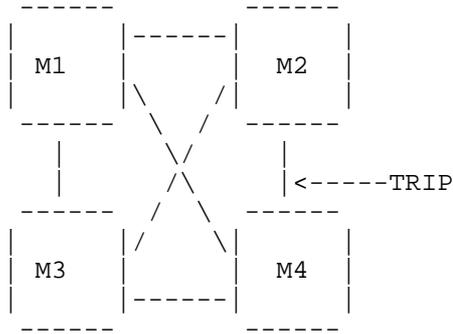
                 Figure 2: TRIP for Confederations

   In this application, there are a number of large providers of
   telephony gateways. Each of these resells its gateway services to
   medium sized providers. These, in turn, resell to local providers who
   sell directly to consumers. This is effectively a pyramidal
   relationship, as shown in Figure 3.

```
                      ------
                      |    |
                      | M1 |
                      |    |
                      ------
                    /        \ <------- TRIP
               ------          ------
               |    |          |    |
               | M2 |          | M3 |
               |    |          |    |
               ------          ------
              /      \        /      \
         ------      ------      ------
         |    |      |    |      |    |
         | M4 |      | M5 |      | M6 |
         |    |      |    |      |    |
         ------      ------      ------
```
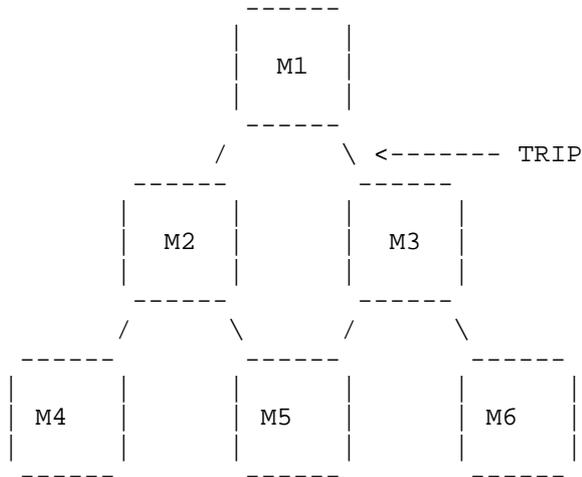
                  Figure 3: TRIP for Wholesalers

   Note that in this example, provider M5 resells gateways from both M2
   and M3.

7 Architecture

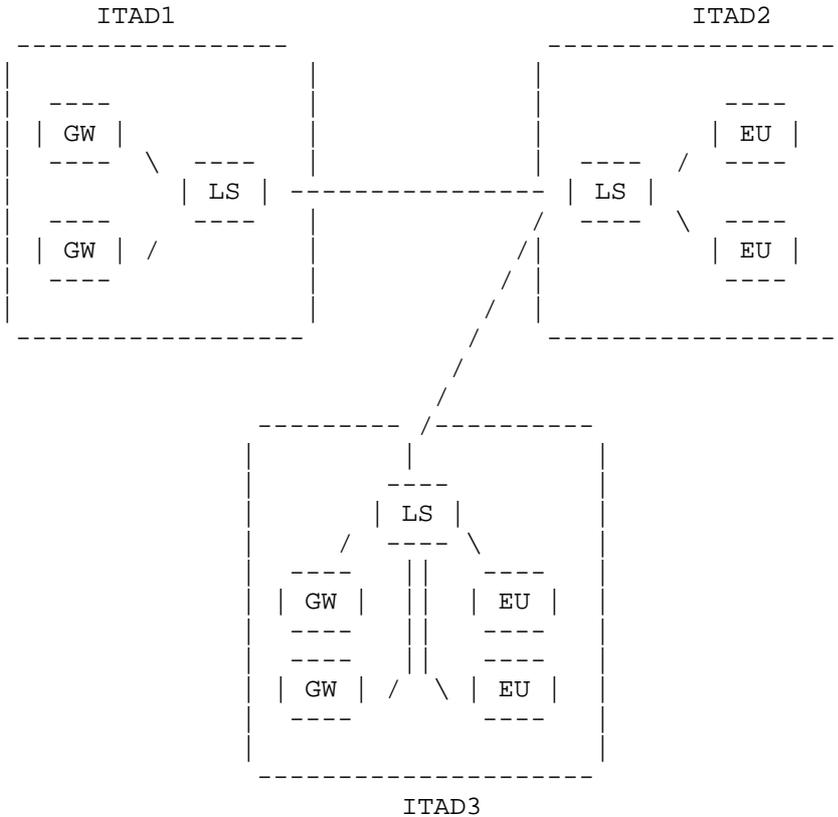   Figure 4 gives the overall architecture of TRIP.

```
          ITAD1                        ITAD2
     ----------------          ------------------
     |              |          |                |
     | ----        |          |            ---- |
     | | GW |        |          |            | EU | |
     | ----   \  ----  |          |  ----   /  ---- |
     |        | LS | --------------- | LS | \        |
     | ----      ----  |          |  / ----   \  ---- |
     | | GW | /    ----  |          | /|        | EU | |
     | ----        |          | / |          ---- |
     |              |          |  / |              |
     ----------------          / ------------------
                              /
                             /
             --------- /---------
             |        |         |
             |      ----        |
             |      | LS |        |
             |    /  ---- \      |
             | ----   ||   ----  |
             | | GW | ||  | EU | |
             | ----   ||   ----  |
             | ----   ||   ----  |
             | | GW | / \ | EU | |
             | ----        ----  |
             |                  |
             --------------------
                    ITAD3
```

                  Figure 4: TRIP Architecture

   There are a number of Internet Telephony administrative domains
   (ITAD's), each of which has at least one Location Server (LS). The
   LS's, through an out-of-band means, called the intra-domain protocol,
   learn about the gateways in their domain. The intra-domain protocol
   is represented by the lines between the GW and LS elements in ITAD1
   in the Figure. The LS's have associations with other LS's, over which
   they exchange gateway information. These associations are established
   administratively, and are set up when the IT administrative domains
   have some kind of agreements in place regarding exchange of gateway
   information. In the figure, the LS in ITAD1 is connected to the LS in
   ITAD2, which is in turn connected to the LS in ITAD3. Through
   Telephony Routing over IP (TRIP), the LS in ITAD2 learns about the
   two gateways in ITAD1. This information is accessed by end users

(EUs) in ITAD2 through the front-end. The front-end is a non-TRIP
protocol or mechanism by which the LS databases are accessed. In
ITAD3, there are both EUs and gateways. The LS in ITAD3 learns about
the gateways in ITAD1 through a potentially aggregated advertisement
from the LS in ITAD2.

8 Elements

The architecture in Figure 4 consists of a number of elements. These
include the IT administrative domain, end user, gateway, and location
server.

8.1 IT Administrative Domain

An IT administrative domain consists of zero or more gateways, at
least one Location Server, and zero or more end users. The gateways
and LS's are those which are under the administrative control of a
single authority. This means that there is one authority responsible
for dictating the policies and configuration of the gateways and
LS's.

An IT administrative domain need not be the same as an autonomous
system. While an AS represents a set of physically connected
networks, an IT administrative domain may consist of elements on
disparate networks, and even within disparate autonomous systems.

The end users within an IT administrative domain are effectively the
customers of that IT administrative domain. They are interested in
completing calls towards the telephone network, and thus need access
to gateways. An end user may be a customer of one IT administrative
domain for one call, and then a customer of a different one for the
next call.

An IT administrative domain need not have any gateways. In this case,
its LS learns about gateways in other domains, and makes these
available to the end users within its domain. In this case, the IT
administrative domain is effectively a virtual IP telephony gateway
provider. This is because it provides gateway service, but may not
actually own or administer any gateways.

An IT administrative domain need not have any end users. In this
case, it provides "wholesale" gateway service, making its gateways
available to customers in other IT administrative domains.

An IT administrative domain need not have gateways nor end users. In
this case, the ITAD only has LS's. The ITAD acts as a reseller,
learning about other gateways, and then aggregating and propagating
this information to other ITAD's which do have customers.

8.2 Gateway

   A gateway is a logical device which has both IP connectivity and
   connectivity to some other network, usually a public or private
   telephone network. The function of the gateway is to translate the
   media and signaling protocols from one network technology to the
   other, achieving a transparent connection for the users of the
   system.

   A gateway has a number of attributes which characterize the service
   it provides. Most fundamental among these are the range of phone
   numbers to which it is willing to provide service. This range may be
   broken into subranges, and associated with each, some cost metric or
   cost token. This token indicates some notion of cost or preference
   for completing calls for this part of the telephone number range.

   A gateway has attributes which characterize the volume of service
   which it can provide. These include the number of ports it has (i.e.,
   the number of simultaneous phone calls it can support), and the
   access link speed. These two together represent some notion of the
   capacity of the gateway. The metric is useful for allowing Location
   Servers to decide to route calls to gateways in proportion to the
   value of the metric, thus achieving a simple form of load balancing.

   A gateway also has attributes which characterize the type of service
   it provides. This includes, but is not limited to, signaling
   protocols supported, telephony features provided, speech codecs
   understood, and encryption algorithms which are implemented. These
   attributes may be important in selecting a gateway. In the absence of
   baseline required features across all gateways (an admirable, but
   difficult goal), such a set of attributes is required in order to
   select a gateway with which communications can be established. End
   users which have specific requirements for the call (such as a user
   requesting a business class call, in which case certain call features
   may need to be supported) may wish to make use of such information as
   well.

   Some of these attributes are transported in TRIP to describe
   gateways, and others are not. This depends on whether the metric can
   be reasonably aggregated, and whether it is something which must be
   conveyed in TRIP before the call is set up (as opposed to negotiated
   or exchanged by the signaling protocols themselves). The philosophy
   of TRIP is to keep it simple, and to favor scalability above
   abundance of information. TRIP's attribute set is readily extensible.
   Flags provide information that allow unknown attributes to be
   reasonably processed by an LS.

8.3 End Users

   An end user is an entity (usually a human being) which wishes to
   complete a call through a gateway from an IP network to a terminal on
   a telephone network. An end user may be a user logged on at a PC with
   some Internet telephony software. The end user may also be connected
   to the IP network through an ingress telephone gateway, which the
   user accessed from telephone handset. This is the case for what is
   referred to as "phone to phone" service with the IP network used for
   interexchange transport.

   End users may, or may not be aware that there is a telephony routing
   service running when they complete a call towards the telephone
   network. In cases where they are aware, end users may have
   preferences for how a call is completed. These preferences might
   include call features which must be supported, quality metrics, owner
   or administrator, and cost preferences.

   TRIP does not dictate how these preferences are combined with those
   of the provider to yield the final gateway selection. Nor does TRIP
   support the transport of these preferences to the LS. This transport
   can be accomplished using the front end, or by some non-protocol
   means.

8.4 Location Server

   The Location Server (LS) is the main functional entity of TRIP. It
   is a logical device which has access to a database of gateways,
   called the Telephony Routing Information Base (TRIB). This database
   of gateways is constructed by combining the set of locally available
   gateways and the set of remote gateways (learned through TRIP) based
   on policy. The LS also exports a set of gateways to its peer LS's in
   other ITAD's. The set of exported gateways is constructed from the set
   of local gateways and the set of remote gateways (learned through
   TRIP) based on policy. As such, policy plays a central role in the LS
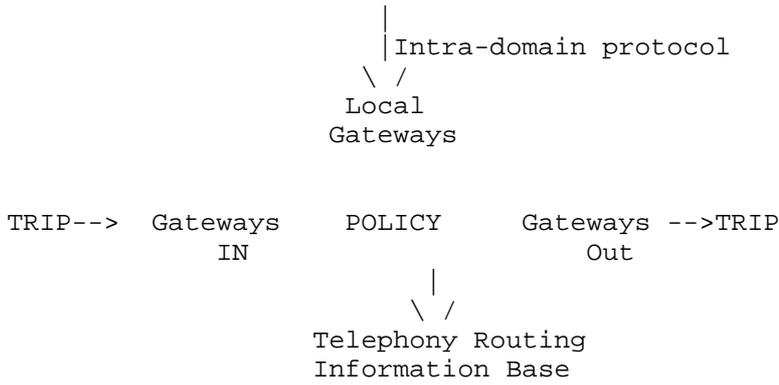   operation. This flow of information is shown in Figure 5.

```
                    |
                    |Intra-domain protocol
                  \ /
                 Local
                Gateways


  TRIP-->  Gateways     POLICY      Gateways -->TRIP
           IN                          Out
                         |
                        \ /
                 Telephony Routing
                 Information Base
```

          Figure 5: Flow of Information in TRIP

The TRIB built up in the LS allows it to make decisions about IP
telephony call routing. When a signaling message arrives at a
signaling server, destined for a telephone network address, the LS's
database can provide information which is useful for determining a
gateway or an additional signaling server to forward the signaling
message to. For this reason, an LS may be coresident with a signaling
server. When they are not coresident, some means of communication
between the LS and the signaling server is needed. This communication
is not specifically addressed by TRIP, although it is possible that
TRIP might meet the needs of such a protocol.

An ITAD must have at least one LS in order to participate in TRIP.
An ITAD may have more than one LS, for purposes of load balancing,
ease of management, or any other reason. In that case, communications
between these LS's may need to take place in order to synchronize
databases and share information learned from external peers. This is
often referred to as the interior component of an inter-domain
protocol. TRIP includes such a function.

Figure 5 shows an LS learning about gateways within the ITAD by means
of an intra-domain protocol. There need not be an intra-domain
protocol. An LS may operate without knowledge of any locally run
gateways. Or, it may know of locally run gateways, but through static
configuration. An LS may also be co-resident with a gateway, in which
case it would know about the gateway that it is co-resident with.

9 Element Interactions

9.1 Gateways and Location Servers

   Gateways must somehow propagate information about their
   characteristics to an LS within the same ITAD. This LS may, in turn,
   further propagate this information outside of the ITAD by means of
   TRIP. This LS is called an originating LS for that gateway. When an
   LS nis not coresident with the gateway, the means by which the
   information gets propagated is not within the scope of TRIP. The
   protocol used to accomplish this is generally called an intra-domain
   protocol.

   One way in which the information can be propagated is with the
   Service Location Protocol (SLP) [7]. The gateway can contain a
   Service Agent (SA), and the LS can act as a Directory Agent (DA). SLP
   defines procedures by which service information is automatically
   propagated to DA's from SA's. In this fashion, an LS can learn about
   gateways in the ITAD.

   An alternate mechanism for the intra-domain protocol is via the
   registration procedures of SIP or H.323. The registration procedures
   provide a means by which users inform a gatekeeper or SIP server
   about their address. Such a registration procedure could be extended
   to allow a gateway to effectively register as well.

   LDAP [8] might also be used for the intra-domain protocol. A gateway
   can use LDAP to add an entry for itself into the database. If the LS
   also plays the role of the LDAP server, it will be able to learn
   about all those gateways in its ITAD.

   The intra-domain protocol which is used may be different from IT
   administrative domain to IT administrative domain, and is a matter of
   local configuration. There may also be more than one intra-domain
   protocol in a particular ITAD. An LS can also function without an
   intra-domain protocol. It may learn about gateways through static
   configuration, or may not know of any local gateways.

9.2 Location Server to Location Server

   The interaction between LS's is what is defined by TRIP. LS's within
   the same ITAD use TRIP to synchronize information amongst themselves.
   LS's within different ITADs use TRIP to exchange gateway information
   according to policy. In the former case the LS's are referred to as
   internal peers, and in the latter case, external peers.

LS's communicate with each other through persistent associations. An
LS may be connected to one or more other LS's. LS's need not be
physically adjacent or part of the same autonomous system. The
association between a pair of LS's is normally set up
administratively. Two LS's are configured to communicate with each
other when their administrators have an agreement in place to
exchange gateway information. While TRIP does not provide an
autodiscovery procedure for peer LS's to discover each other, one
could possibly be used. Such a procedure might be useful for finding
a backup peer LS when a crash occurs. Alternatively, in an
environment where the business relationships between peers become
more standardized, peers might be allowed to discover each other
through protocols like the Service Location Protocol (SLP) [9].
Determination about whether autodiscovery should or should not be
used is at the discretion of the administrator.

The syntax and semantics of the messages exchanged over the
association between LS's are dictated by TRIP. The protocol does not
dictate the nature of the agreements which must be in place. TRIP
merely provides a transport means to exchange whatever gateway
routing information is deemed appropriate by the administrators of
the system. Details are provided in the TRIP protocol specification
itself.

The rules which govern which gateway information is generated,
propagated, and accepted by a gateway is called a location server
policy. TRIP does not dictate or mandate any specific policy.

9.2.1 Nature of Exchanged Information

The information exchanged by the LS's is a set of routing objects.
Each routing object minimally consists of a range of telephone
numbers which are reachable, and an IP address or host name which is
the application-layer "next hop" towards a gateway which can reach
that range. Routing objects are learned from the intra-domain
protocol, static configuration, or from LS's in remote ITAD's. An LS
may aggregate these routing objects together (merging ranges of
telephone numbers, and replacing the IP address with its own IP
address, or with the IP address of a signaling server with which the
LS is communicating) and then propagate them to another LS. The
decision about which objects to aggregate and propagate is known as a
route selection operation. The administrator has great latitude in
selecting which objects to aggregate and propagate, so long as they
are within the bounds of correct protocol operation (i.e., no loops
are formed). The selection can be made based on information learned
through TRIP, or through any out of band means.

A routing object may have additional information which characterizes
the service at the gateway. These attributes include things like
protocols, features supported, and capacity. Greater numbers of
attributes can provide useful information, however, they come at a
cost. Aggregation becomes difficult with more and more information,
impacting the scalability of the protocol.

Aggregation plays a central role in TRIP. In order to facilitate
scalability, routing objects can be combined into larger aggregates
before being propagated. The mechanisms by which this is done are
specified in TRIP. Aggregation of application layer routes to
gateways is a non-trivial problem. There is a fundamental tradeoff
between aggregatability and verbosity. The more information that is
present in a TRIP routing object, the more difficult it is to
aggregate.

Consider a simple example of two gateways, A and B, capable of
reaching some set of telephone numbers, X and Y, respectively. C is
an LS for the ITAD in which A and B are resident. C learns of A and B
through some other means. As it turns out, X and Y can be combined
into a single address range, Z. C has several options. It can
propagate just the advertisement for A, just the advertisement for B,
propagate both, or combine them and propagate the aggregate
advertisement. In this case C chooses the latter approach, and sends
a single routing object to one of its peers, D, containing address
range Z and its own address, since it is also a signaling server. D
is also a signaling server.

Some calling device, E, wishes to place a phone call to telephone
number T, which happens to be in the address range X. E is configured
to use D as its default H.323 gatekeeper. So, E sends a call setup
message to D, containing destination address T. D determines that the
address T is within the range Z. As D had received a routing object
from C containing address range Z, it forwards the call setup message
to C. C, in turn, sees that T is within range X, and so it forwards
the call setup to A, which terminates the call signaling and
initiates a call towards the telephone network.

9.2.2 Quality of Service

One of the factors which is useful to consider when selecting a
gateway is "QoS" - will a call through this gateway suffer
sufficiently low loss, delay, and jitter? The quality of a call
depends on two components - the QoS on the path between the caller
and gateway, and the capacity of the gateway itself (measured in
terms of number of circuits available, link capacity, DSP resources,
etc.). Determination of the latter requires intricate knowledge of

underlying network topologies, and of where the caller is located.
This is something handled by QoS routing protocols, and is outside
the scope of TRIP.

However, gateway capacity is not dependent on the caller location or
path characteristics. For this reason, a capacity metric of some form
is supported by TRIP. This metric represents the static capacity of
the gateway, not the dynamic available capacity which varies
continuously during the gateways operation. LS's can use this metric
as a means of load balancing of calls among gateways. It can also be
used as an input to any other policy decision.

9.2.3 Cost Information

Another useful attribute to propagate is a pricing metric. This might
represent the amount a particular gateway might charge for a call.
The metric can be an index into a table that defines a pricing
structure according to a pre-existing business arrangement, or it can
contain a representation of the price itself. TRIP itself does not
define a pricing metric, but one can and should be defined as an
extension. Using an extension for pricing means more than one such
metric can be defined.

10 The Front End

As a result of TRIP, the LS builds up a database (the TRIB) of
gateway routes. This information is made available to various
entities within the ITAD. The way in which this information is made
available is called the front end. It is the visible means by which
TRIP services are exposed outside of the protocol.

10.1 Front End Customers

There are several entities which might use the front end to access
the TRIB. These include, but are not limited to:

   Signaling Servers: Signaling servers receive signaling messages
      (such as H.323 or SIP messages) whose purpose is the initiation
      of IP telephony calls. The destination address of these calls
      may be a phone number corresponding to a terminal on the GSTN.
      In order to route these calls to an appropriate gateway, the
      signaling server will need access to the database built up in
      the LS.

   End Users: End users can directly query the LS to get routing
      information. This allows them to provide detailed information on
      their requirements. They can then go and contact the next hop
      signaling server or gateway towards that phone number.

   Administrators: Administrators may need to access the TRIB for
      maintenance and management functions.

When a signaling server contacts the LS to route a phone number, it
is usually doing so because a calling device (on behalf of an end
user) has attempted to set up a call. As a result, signaling servers
effectively act as proxies for end users when accessing the LS
database. The communication between the calling devices and their
proxies (the signaling servers) is through the signaling protocol.

The advantage of this proxy approach is that the actual LS
interaction is hidden from the calling device. Therefore, whether the
call is to a phone number or IP address is irrelevant. The routing in
the case of phone numbers takes place transparently. Proxy mode is
also advantageous for thin clients (such as standalone IP telephones)
which do not have the interfaces or processing power for a direct
query of the LS.

The disadvantage of the proxy approach is the same as its advantage -
the LS interaction is hidden from the calling device (and thus the
end user). In some cases, the end user may have requirements as to
how they would like the call to be routed. These include preferences
about cost, quality, administrator, or call services and protocols.
These requirements are called the end user policy. In the proxy
approach, the user effectively accesses the service through the
signaling protocol. The signaling protocol is not likely to be able
to support expression of complex call routing preferences from end
users (note however, that SIP does support some forms of caller
preferences for call routing [10]). Therefore, direct access from the
end user to the LS can provide much richer call routing services.

When the end user policy is presented to the LS (either directly or
through the signaling protocol), it is at the discretion of the LS
how to make use of it. The location server may have its own policies
regarding how end user preferences are handled.

10.2 Front End Protocols

   There are numerous protocols that can be used in the front end to
   access the LS database. TRIP does not specify or restrict the
   possibilities for the front end. It is not clear that it is necessary
   or even desirable for there to be a single standard for the front
   end. The various protocols have their strengths and weaknesses. One
   may be the right solution in some cases, and another in different
   cases.

Some of the possible protocols for the front end are:

Service Location Protocol (SLP): SLP has been designed to fit
    exactly this kind of function. SLP is ideal for locating servers
    described by a set of attributes. In this case, the server is a
    gateway (or next hop towards the gateway), and the attributes
    are the end user policy. The end user is an SLP UA, and the LS
    is an SLP DA. The Service Query is used to ask for a gateway
    with a particular set of attributes.

Open Settlements Protocol (OSP): OSP [11] is a client server
    protocol. It allows the client to query a server with a phone
    number, and get back the address of a next hop, along with
    authorization tokens to use for the call. In this case, the
    server can be an LS. The routing table it uses to respond to OSP
    queries is the one built up using TRIP.

Lightweight Directory Access Protocol (LDAP): LDAP is used for
    accessing distributed databases. Since the LS server contains a
    database, LDAP could be used to query it.

Web Page: The LS could have a web front end. Users could enter
    queries into a form, and the matching gateways returned in the
    response. This access mechanism is more appropriate for human
    access, however. A signaling server would not likely access the
    front end through a web page.

TRIP: The protocols discussed above are all of the query-response
    type. There is no reason why the LS access must be of this form.
    It is perfectly acceptable for the access to be through complete
    database synchronization, so that the entity accessing the LS
    database effectively has a full copy of it. If this approach
    were desired, TRIP itself is an appropriate mechanism. This
    approach has obvious drawbacks, but nothing precludes it from
    being done.

11 Number Translations

   The model for TRIP is that of many gateways, each of which is willing
   to terminate calls towards some set of phone numbers. Often, this set
   will be based on the set of telephone numbers which are in close
   geographic proximity to the gateway. For example, a gateway in New
   York might be willing to terminate calls to the 212 and 718 area
   codes. Of course, it is up to the administrator to decide on what
   phone numbers the gateway is willing to call.

However, certain phone numbers don't represent GSTN terminals at all,
but rather they represent services or virtual addresses. An example
of such numbers are freephone and LNP numbers. In the telephone
network, these are actually mapped to routable telephone numbers,
often based on complex formulae. A classic example is time-of-day-
based translation.

While nothing prevents a gateway from advertising reachability to
these kinds of numbers, this usage is highly discouraged. Since TRIP
is a routing protocol, the routes it propagates should be to routable
numbers, not to names which are eventually translated to routable
numbers. Numerous problems arise when TRIP is used to propagate
routes to these numbers:

   o Often, these numbers have only local significance. Calls to a
     freephone number made from New York might terminate in a New
     York office of a company, while calls made from California
     will terminate in a California branch. If this freephone
     number is injected into TRIP by a gateway in New York, it
     could be propagated to other LS's with end users in
     California. If this route is used, calls may be not be routed
     as intended.

   o The call signaling paths might be very suboptimal. Consider a
     gateway in New York that advertises a ported number that maps
     to a phone in California. This number is propagated by TRIP,
     eventually being learned by an LS with end users in
     California. When one of them dials this number, the call is
     routed over the IP network towards New York, where it hits the
     gateway, and then is routed over the GSTN back to California.
     This is a waste of resources. Had the ported number been
     translated before the gateway routing function was invoked, a
     California gateway could have been accessed directly.

As a result, it is more efficient to perform translations of these
special numbers before the LS routing databases are accessed. How
this translation is done is outside the scope of TRIP. It can be
accomplished by the calling device before making the call, or by a
signaling server before it accesses the LS database.

12 Security Considerations

Security is an important component in TRIP. The TRIP model assumes a
level of trust between peer LS's that exchange information. This
information is used to propagate information which determines where
calls will be routed. If this information were incorrect, it could
cause complete misrouting of calls. This enables a significant denial
of service attack. The information might also be propagated to other

ITADs, causing the problem to potentially spread. As a result, mutual
authentication of peer LS's is critical. Furthermore, message
integrity is required.

TRIP messages may contain potentially sensitive information. They
represent the routing capabilities of an ITAD. Such information might
be used by corporate competitors to determine the network topology
and capacity of the ITAD. As a result, encryption of messages is also
supported in TRIP.

As routing objects can be passed via one LS to another, there is a
need for some sort of end to end authentication as well. However,
aggregation will cause the routing objects to be modified, and
therefore authentication can only take place from the point of last
aggregation to the receiving LS's.

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