Evaluation of SCTP as a Transport Mechanism for CORBA GIOP Messages

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Abstract – This paper reports work in progress on evaluating the Stream Control Transport Protocol (SCTP) as a reliable, high performance transport protocol for CORBA GIOP messages. The objective is to overcome limitations of the Internet Inter-ORB Protocol (IIOP) due to the use of TCP as the transport layer. Limitations of TCP are described. We review the CORBA Interoperability Architecture, and the SCTP standard. We then identify issues in mapping GIOP onto SCTP. Plans for further work are presented.

Keywords – DPE, SCTP, association, GIOP, SCIOP, SCIOR.

I. INTRODUCTION

Telecommunication networks are migrating from public circuit switched networks to a multi-service network based on packet switching, the so called Next Generation Network (NGN). We assume that the NGN will use a Distributed Processing Environment (DPE) as the basis for providing services and applications.

The Common Object Request Broker Architecture (CORBA) is a distributed object computer middleware standard defined by the Object Management Group (OMG) [1]. A CORBA-based DPE allows the development of services and applications to be reused and with flexibility to reconfigure. The NGN with a CORBA-based DPE allows creation of services independent of the platform, programming language, and locations [5].

The key component of CORBA architecture is the Object Request Broker (ORB) that enables transparent communication between application and service objects [1]. The CORBA standard defines an object invocation protocol for the communication between CORBA ORBs called the General Inter-ORB Protocol (GIOP). The GIOP protocol can operate on a range of transport protocols that meet the minimal assumptions reviewed in section II.B.3. In CORBA 2.0, GIOP is deployed in the TCP/IP environment. GIOP requires a mapping protocol, the Internet Inter-ORB Protocol (IIOP) to transfer its messages over TCP/IP.

The IIOP enables heterogeneous CORBA-compliant ORBs to interoperate over TCP/IP networks. TCP/IP delivers the GIOP messages with reliability in the TCP sense. TCP provides re-transmission of lost packets after a transmission delay or after expiration of timer, but these retransmissions may cause “head-of-line” blocking in the network [3]. TCP is inadequate in a high-performance signaling network. TCP/IP lacks inherent support for mobility and requires an additional protocol layer to provide reliability and mobility in wireless systems [11], [10]. The conventional IIOP implementation performs poorly in high performance network, due to the excessive marshaling and de-marshaling of overhead, data copying and high-levels of function call overhead [4].

Recently, the Internet Engineering Task Force (IETF) SIGTRAN Working Group published a standard for a transport protocol called Signalling Control Transmission Protocol (SCTP). SCTP is designed to provide reliable transport signalling messages between signalling endpoints in IP networks. The core features of SCTP are multi-streaming and multi-homing [3]. SCTP allows signalling messages to be independently ordered within multiple streams to ensure in-sequence delivery between associated endpoints. In SCTP it is less likely that the retransmission of a lost message will affect the timely delivery of other messages in unrelated sequences.

The 3rd Generation Partnership Project (3GPP), which defines the Universal Mobile Telephony System (UMTS), proposes using the SCTP as the transport protocol for the next generation mobile network. 3GPP implements CORBA as its management interface to provide services with SCTP running at the transport layer. The objective of this work is to investigate issues in using SCTP as a transport protocol for GIOP messages including the support for high reliability signaling architectures, mapping of GIOP onto SCTP and the relative performance of mapping SCTP and TCP under congested conditions.

This paper is structured as follows. Section 2 and 3 contain essential background on the GIOP message protocol and the SCTP respectively. Section 4 describes some of the configuration and settings of the mapping protocol and how to map the GIOP onto SCTP. Section 5 outline the design plans for the research.

II. CORBA INTEROPERABILITY ARCHITECTURE

The CORBA interoperability architecture defines how ORBs communicate with each other and the protocols used. This architecture allows ORB running at different network nodes to communicate.

A. CORBA Object Addressing

The ORB Interoperability Architecture provides a conceptual framework for defining the elements of interoperability and for identifying its compliance points. In general, the ORB is

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not required to be a single component; it is simply defined by its interfaces. To identify objects, CORBA defines a generic format called the Interoperable Object Reference (IOR).

An object reference identifies one instance of an object and associates one or more paths by which that object can be accessed. The same object may be located by different object references, for example if a server is re-started on a new port or migrated to another host. Multiple server location can be referenced by one IOR, for example, if a server has multiple network interfaces connecting to it to distinct networks, there may be multiple network addresses.

References to server location are called *profiles*. A profile provides an opaque, protocol-specific representation of an object location. Each profile supports one or more protocols and encapsulates all the basic information the protocol it supports needs to identify an object.

### B. CORBA Messaging Protocol - GIOP

The CORBA interoperability architecture defines the General Inter-ORB Protocol (GIOP) as the interoperability protocol for heterogeneous ORB communication. The GIOP protocol provides an abstract protocol specification that can be mapped onto conventional connection-oriented transport protocols [6]. The GIOP specification consists of the elements described in the following sections. Figure 1 illustrates elements referred to in the description.

#### 1. GIOP Common Data Representation

The CDR is the formal mapping of the data types to be used in a CORBA invocation. CDR is a transfer syntax that maps Interface Definition Language (IDL) types from their native host formats to a low-level bi-canonical representation [3]. CDR-encoded messages are used to transmit CORBA requests and server responses across a network.

#### 2. GIOP Messages

The GIOP specifies the format for messages that are exchanged between inter-operating ORBs. With eight messages, the GIOP supports full CORBA functionality between ORBs. GIOP messages provide support for object location services and dynamic migration, and efficient management of communication resources without requiring ORBs to implement any mechanisms when unnecessary or inappropriate to an ORB’s architecture [1]. GIOP is a client-server protocol. It has restriction on client and server roles with respect to initiating and receiving messages. GIOP incorporates eight message types: *Request*, *Reply*, *LocateRequest*, *LocateReply*, *CloseConnection*, *MessageError* and *Fragment*.

Clients send *Request* messages, which carry all the information necessary to invoke a remote object located on the Servers. *Reply* messages are sent in response to *Request* messages from the servers. Client and server roles are similarly assigned to the *LocateRequest* and *LocateReply* messages respectively. These two messages are used to query the current location of an object. It is permissible to have multiplex requests on connections. Therefore the client can issue new *Request* or *LocateRequest* messages on a given connection before replies to previously issued requests on the same connections have been received. *CancelRequest* is a client-side message; it is used to notify servers that a client is not expecting a reply for a specified pending *Request* or *LocateRequest* messages whose identifier is specified in the message. *CloseConnection* is a server-side message that is used to direct the client not to send further requests on the connection on which the *CloseConnection* message was received, because this connection is about to be closed. Both *MessageError* and *Fragment* messages can be send by either clients or servers.

The *MessageError* message is sent in response to any message with a bad header, and the *Fragment* message is used to support multi-fragment messages. *MessageError* message is sent in response to any GIOP message whose version number or message type is unknown to the recipient or any message received whose header is not properly formed. *Fragment* message follow an incomplete preceding message of type *Request*, *Reply*, *LocateRequest*, *LocateReply* or *Fragment*, which has its “following fragment” bit set. The last *Fragment* message in a multi-fragment message has its following fragment bit unset.

#### 3. GIOP Transport Adapter

The definition of these messages and the protocols governing their exchange are independent of the underlying message transport layer. However, GIOP requires the underlying transport protocol to be reliable. The GIOP specification is designed to operate over any connection-oriented transport protocol that meets a minimal set of assumptions listed below [1].

- The transport is connection-oriented.
- Connections are full duplex and symmetric.
- The transport is reliable; the transport guarantees that messages sent via a connection are delivered no more than once in the order in which they are sent. Positive acknowledgement of delivery is available.
- The transport can be view as a byte stream; no arbitrary message size limitations, fragmentation, or alignments are enforced.
- The transport provides reasonable notification of disorderly connection loss. If a network connection breaks down, both ends of the connection receive an error indication.

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**Fig 1. Elements in the CORBA Interoperability Architecture**
In addition, GIOP defines a connection management protocol and a set of constraints for GIOP messages ordering.

In the CORBA protocol Interoperability Architecture, OMG has defined GIOP to run on top of the most widely used communication transport protocol, TCP/IP. The concrete mapping of GIOP onto the TCP/IP transport protocol is known as the Internet Inter-ORB Protocol (IIOP).

III. LIMITATIONS IN THE EXIST ARCHITECTURE

This section discusses the limitations of TCP when used as the primary transport for carrying GIOP. And the motivations of developing the SCTP will be discussed.

A. TCP limitations

Transmission Control Protocol (TCP) is currently the primary means of reliable data transfer of GIOP messages in an IP-based network. A number of recent high performance and high-speed services applications have found TCP limiting, and have to integrate other protocols to provide reliable data transfer [7]. Some of the disadvantages of TCP are discussed as follows [3]:

1. TCP is byte-stream oriented. Applications are responsible for tracking messages boundaries and using the push facility to ensure that a complete message is transferred in reasonable time.
2. TCP preserves the order in which data are delivered. Services like data transfer needs reliable transfer without sequence maintenance, while others would be satisfied with partial ordering of data delivery. When the connection lost, message loss or sequence error occurs within the network, TCP needs to delay delivery of data until the correct sequencing is restored. The delay of delivery of data hold up other receiving data within the same connection, it known as “head of line” blocking problem in TCP.
3. TCP does not transparently support multihomed hosts.
4. TCP is vulnerable to denial of service attacks. Therefore TCP is a risky protocol to use in mission critical application.
5. TCP delivers the data in single stream. If connectivity is lost in a TCP connection, the connection will be aborted and must be reestablished. TCP provides no ability to migrate an established connection from one IP address to another and this reestablishing TCP connection causes delay for timing critical application.
6. TCP does not have inherent support for mobility. TCP requires the assistance of other protocols to provide reliable and efficient transport in the mobile system where IP address is continuously changing between two points.

With these limitations, TCP is not an adequate transport protocol to use in a time-critical telecoms signaling network.

B. Performance limits of IIOP

CORBA’s standard GIOP/IIOP protocols are well suited for conventional request/response application with best effort QoS Requirement [6]. The conventional ORBs perform poorly in the high performance real-time and /or embedded applications that cannot accept the message foot print size of GIOP or the latency, overhead, and jitter of the TCP/IP-based IIOP transport protocol.

IV. TRANSPORT PROTOCOL – SCTP

This section examines the key features of the Stream Control Transport Protocol relevant to high performance signaling networks. SCTP provides a concept of association and a number of features that consider critical for signalling transport, multistreaming and multihoming. Like TCP, SCTP offers a point-to-point, connection-oriented, reliable delivery transport services for application communicate over an IP network. SCPT uses the unordered delivery of data feature from UDP.

A. SCTP Association

The connection-oriented feature of SCTP allows a relationship is created between endpoints of SCTP session prior to data being transmitted, and this relationship is maintained until all the data transmission has been successfully completed. This relationship in SCTP terminology is called association.

A SCTP association is a broader concept than the TCP connection. One host address and one port are specified at a TCP endpoint. In SCTP, each endpoint consists of a list of host addresses, and a single port. An association setup happens between two SCTP endpoints. Each SCTP endpoint provides the other endpoint with a list of transport addresses through which that endpoint can be reached and from which it can be originate SCTP packets. This association represents an ongoing logical communication channel. Each streams in an association is identified by a unique STREAM_ID, shown in figure 2.

With the association feature offered in the SCTP, if connectivity is lost on the primary IP address used for the association, one SCTP endpoint will not lose its connectivity to the other. The SCTP association will seamlessly fail over to the next available IP address from a set of IP addresses received during association setup.

B. SCTP Multistreaming

SCTP supports the delivery of multiple independent user messages streams within a single SCTP association. This
feature allows data to be divided into multiple streams and delivered independently in an association. Any message lost in any of the streams does not influence deliveries in the other streams. This feature is useful for applications that need to exchange multiple, logically separate message streams between two endpoints.

With its unordered message transport feature, SCTP overcomes the head of line blocking problem found in TCP. For a number of applications, the strict sequence preservation may not truly necessary. For example, delivery of web page data, its goal is to have the reliable delivery of all the data, and the sequence at which data are received is not important.

C. SCTP Multihoming

With the SCTP concept of association and multistreaming, SCTP provides transport-layer support for multihoming. This multihoming support only deals with the communication between two endpoints of which one or two is assigned with multiple IP addresses. This feature can be used to build redundant communication path in application that seek transport level fault tolerance.

D. SCTP Mobility

The SCTP mobility feature uses the association concept to define sets of IP addresses between local and remote endpoints. With adding and deleting IP addresses from these sets, allow mobile system to hand-off connectivity between nodes smoothly and transparently. Each time a host moves into a new subnet, a new IP address is obtained and added with the deletion of the old one, and the connectivity between two endpoints remain connected, never gets interrupted.

V. GIOP SCTP MAPPING

The section presents the architectural framework for implementing the mapping between CORBA messages, GIOP and the transport protocol, SCTP. A mapping protocol called SCTP Inter-ORB Protocol (SCIOP) is the concrete mapping of GIOP over SCTP. SCTP fulfills all the assumptions made by GIOP about its underlying transport protocol. This section examines the Inter-ORB protocol used in the existing specification, IIOP, and then outline the issues to be considered in defining the SCIOP and describes how GIOP messages is used in association setup in SCTP.

A. Internet Inter-Orb Protocol (IIOP)

GOIP specifies most of the protocol details that are necessary for clients and servers to communicate. GIOP is independent of particular transport mechanisms and is therefore an abstract protocol. Internet Inter-ORB protocol (IIOP) specifies TCP/IP and is a concrete implementation and mapping of GIOP. In order to turn GIOP into a concrete protocol, IIOP needs to specify the encoding of IORs [12]. The IOR consists of three main components: the repository ID, the endpoint information and the object key. IIOP therefore specifies how an IOR encodes the TCP/IP addressing information inside an IOR, allowing a client to establish a list of connection to the server to send a request.

B. SCIOP

The mapping protocol, SCTP Inter-ORB protocol (SCIOP) uses the IIOP as the baseline protocol. To implement this mapping, the following issues are needed to look in detailed.

- CDR encoding
- Locate Object
- Additional GIOP header
- SCTP association

CDR-encoded messages are used to transmit CORBA requests and server responses across a network. The second, third and fourth issues are for study in this research.

1. SCIOR

The SCIOR is the SCIOP IOR profile. This SCIOR is an object reference profile analogous to the IIOP IOR profile. SCIOR identifies the host address(es) and the port on which target object resides through the SCTP Inter-ORB protocol [9]. SCIOR has the following form:

```c
module SCIOP{
    struct Version{
        octet major;
        octet minor;
    };
    struct ProfileBody{
        Version SCIOP_version;
        sequence<string> host_addresses;
        unsigned short port;
        unsigned short max_streams;
        sequence<octet> object_key;
        sequence<IOP::TaggedComponent> components;
    };
}
```

The members of SCIOP::ProfileBody are defined as follows: SCIOP_version describes the version of SCIOP that the agent at the specified address is prepared to received. When an agent generates SCIOP profiles specifying a particular version, it must be able to accept message complying with the specified version or any previous minor version.

- host_addresses identifies a list of Internet host addresses supported by the server’s association, to which a client will establish an SCTP association on which GIOP messages for the specified object may be sent.
- port contains the SCTP port number where the target agent is listening for association connection requests.
- max_streams contains the number of individual inbound and outbound data streams within the SCTP association for this port number.
- object_key is an opaque value supplied by the agent producing the IOR, this number will be used in request messages to identify the object to which the request is directed.
- components is a sequence of TaggedComponent, which contains additional information that may be used in making invocation on the object described by this profile.

2. Association Usage

This section discusses the roles of client and server which use SCTP as the transport protocol to establish the
association setup, then discuss how eight of GIOP messages effects the SCTP association.

Each SCTP endpoint specifies the maximum number of streams, which that endpoint accepts and uses (outbound streams and inbound streams). In the client and server scenario of association setup, the client initiates an association requests specifying the number of streams it would like to use and the server will send an association reply specified the number of streams it can be accepted for transmission. The lesser of the two values from the server-side inbound streams and the client-side outbound streams will be used.

In CORBA specification, an agent is used to represent the owner of the server side connection. Agents, which publish SCTP addresses in IORs, are capable of accepting object requests or providing locations for objects/servers. A SCTP address consists of a sequence of IP host addresses, and a SCTP port number. The server must listen for association requests. A client needing an object’s services must initiate an association with the SCTP endpoint specified in the IOR, with an association request. The listening server may accept or reject the connection request. If possible, servers should accept association connection requests, but ORBs are free to establish any desired policy for association connection acceptance. Once an association connection is accepted, all streams contained within that association are deemed to be connected and each stream represents an individual GIOP connection. [9]

In order to meet some of the connection management requirements of GIOP, the server receives a GIOP LocateRequest/Request messages on a particular inbound stream of an association, the GIOP LocateReply/Reply message must be returned on the outbound stream with the same identity (STREAM-ID).

VI. PLANNED WORK

The object for this research is to evaluate the performance of SCTP as a transport protocol for Inter-ORB messages in relation to TCP in a congested or overloaded network. The underlying network is an IP based network with QoS. In order to perform the evaluations, this research divides into three stages:

1. Design an experimental environment to illustrate the features offered in SCTP.
2. Implement SCTP in experimental IP network with QoS.
3. Develop the mapping between GIOP and SCTP.
4. Performance evaluation of SCTP with CORBA application.

Although SCTP transport protocol has been specified and defined by SIGTRAN, this protocol has not yet fully developed and implemented, it is still in an experimental stage. The SCTP protocol chosen for implementation in the research is called LKSCTP developed and specified by IBM Linux Technology Center. After successfully running the LKSCTP as the transport protocol in the SCTP-enable application over a network, then the research will move to the next stage to define and configure the mapping protocol for GIOP and SCTP mapping. Once CORBA applications can operate successfully using SCIOP to carry GIOP messages over SCTP, an evaluation-based network and tools will design to examine the performance of SCTP in transport GIOP messages in the CORBA-based network.

VII. CONCLUSION

This work in progress paper has shown advantages of SCTP over TCP. SCTP compensates the some problems found in the existing TCP/IP network, for example the head-of-line blocking. The concepts of association of SCTP, and the multistreaming and multihoming supports make it a high performance transport protocol to be used in the CORBA-based distributed environment. With this implementation allows the customer access those high performance and timing critical telecom services with reliability and mobility. In the security considering SCTP, SCTP has designed with the experiences made with TCP in mind. Therefore it makes hard for blind attacker to inject forged SCTP datagrams into existing association [7].

VIII. REFERENCE

Yuan-Wen Liang received his BSC in Electrical Engineering at the University of the Witwatersrand, Johannesburg in 2000. He is currently completing his MSc in Electrical Engineering at his alma mater. His research interests lie in evaluating the performance issues of CORBA’s transport mechanism.

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