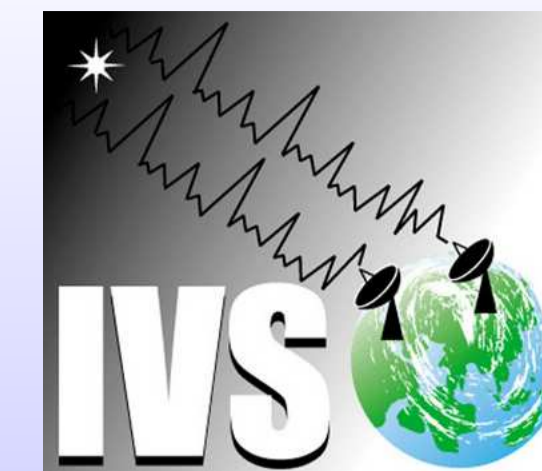




# eVLBI Development in TIGO

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## Introduction

The Geodetic Observatory TIGO in Chile is one of the few VLBI network stations in the southern hemisphere. Concerning the growing eVLBI community TIGO, due to its remote location, has access to a very limited bandwidth of the transcontinental communication networks. Recent data transmission speed tests have been executed between TIGO and some correlator locations showing a maximum speed of 5 Mbps.

There are two approaches under research in order to increase the transmitted data per time unit:

1. The Multipath Routing where the bandwidth is maximized by using different paths simultaneously.
2. The EXPReS project aiming for better connectivity to radiotelescope sites by identifying and removing bottlenecks along one transmission line.

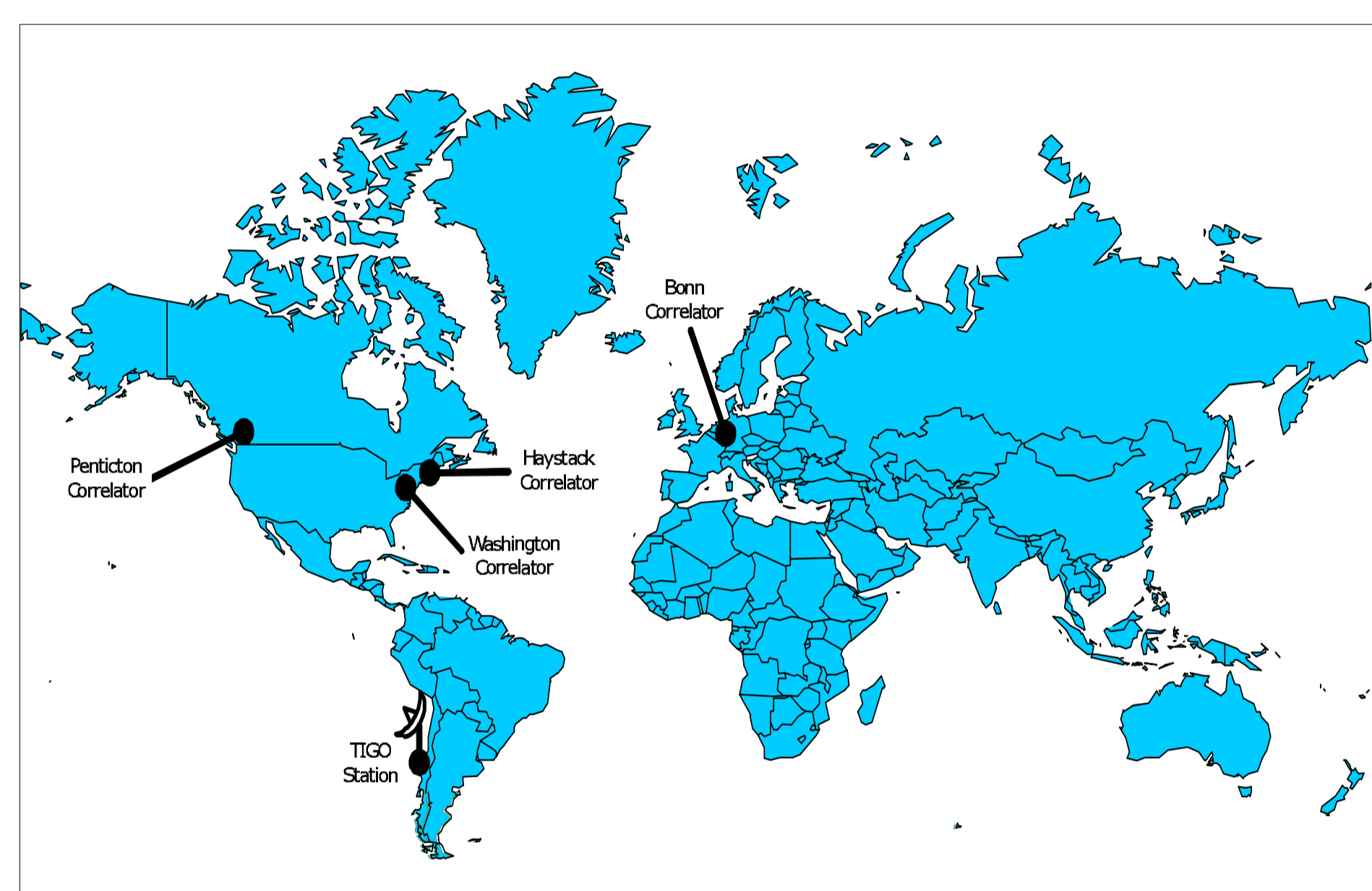


Figure 1: TIGO Station producing VLBI data and VLBI correlators processing it. The distance allows more than one route to its destination.

## Current Status

The international Internet connection of TIGO can be divided in 3 sections as is shown in Figure 2:

- The path from TIGO facility to the University backbone.
- The link between the University and REUNA (Red Universitaria Nacional) Academic Chilean Network.
- The REUNA International link.

The current configuration has a total speed of 5Mbps. In the last mile connection from TIGO to the University there is an optical path with a monomode optical fiber with a speed of 100Mbps. The connection between the University and REUNA has a speed limited to 15 Mbps for national traffic with a capacity of 155 Mbps. The international link of REUNA has a capacity of 96 Mbps, but the University has a contract for 5 Mbps only.

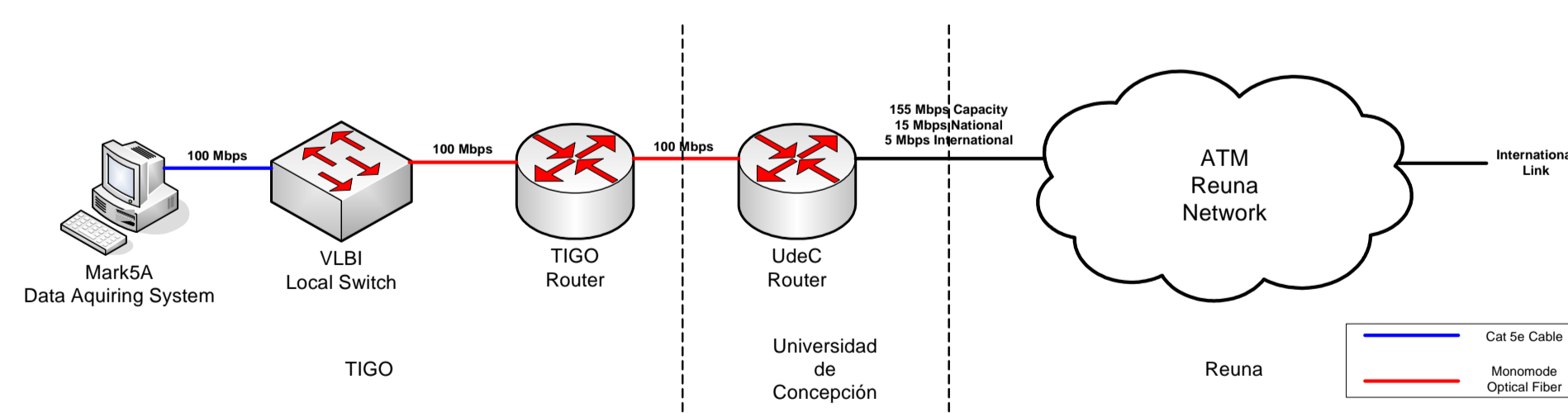


Figure 2: Current status of TIGO connection.

A test of the real speed connection from Concepción to United States and Germany is shown in Figure 3. This tests were conducted during working and non-working hours sending a 4 MB file to show the influence of the Universidad de Concepción traffics. The results show a clear influence of the difference between working and non-working hours and the destination. The transmission to United States is slower due to high demand of commercial sites over there. The average speed obtained for a transfer to Boston during working and non-working hours was 21.8 and 38.8 KBps respectively. For a transmission to Bonn the speed was 58.9 and 73.5 Kbps for working and non-working hours, respectively.

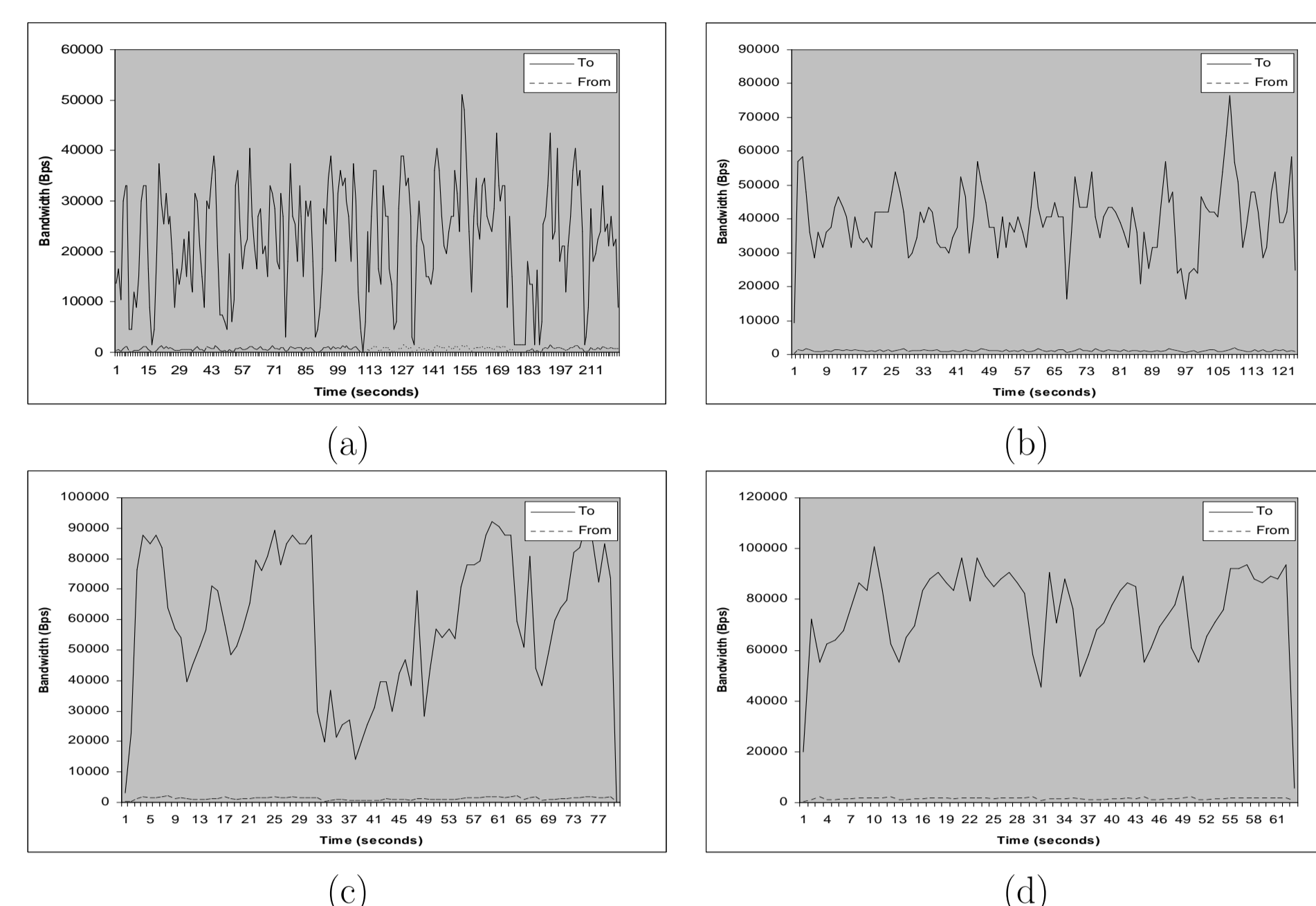


Figure 3: a) Speed results of transferring from Concepción to Boston during working hours. b) Speed results of transferring from Concepción to Boston during non-working hours. c) Speed results of transferring from Concepción to Bonn during working hours. d) Speed results of transferring from Concepción to Bonn during non-working hours

## Multipath Routing Approach

VLBI has special requirements since it needs a fix point to point path between the VLBI station and the correlation facilities. It has been proved that the use of multiple streams can increase the final speed of a connection since it's possible to bypass bottlenecks using alternative routes.

A closer look of the REUNA network shows that while the infrastructure can support higher speeds, the final speed of every connected university is limited due the inherent sharing feature of REUNA. Besides the speed achieved for international connections is limited by contract for each university. This scenario gives the opportunity to apply the Multipath Routing as a plausible solution for eVLBI transmissions at high speeds.

In Figure 4 a Multipath Routing scheme is presented. The main route path is obtained when a connection is done using default routing algorithms, like OSPF or BGP limited by the constraints described before. The alternative routes can be used to send data as parallel streams to the destination. In the REUNA particular case, Universidad de Concepción has a bandwidth of 15 Mbps for national traffic but the international traffic is limited to 5 Mbps, with the installation of custom eVLBI data routers in other universities it is possible to bypass the international speed restriction of Universidad de Concepción *masquerading* the data to the correlators as national traffic increasing the total speed.

The expected result is a theoretically raise of the transmission speed from 5 Mbps to 15 Mbps. However, the imminent upgrade of REUNA network to 1 Gbps will allow higher speeds.

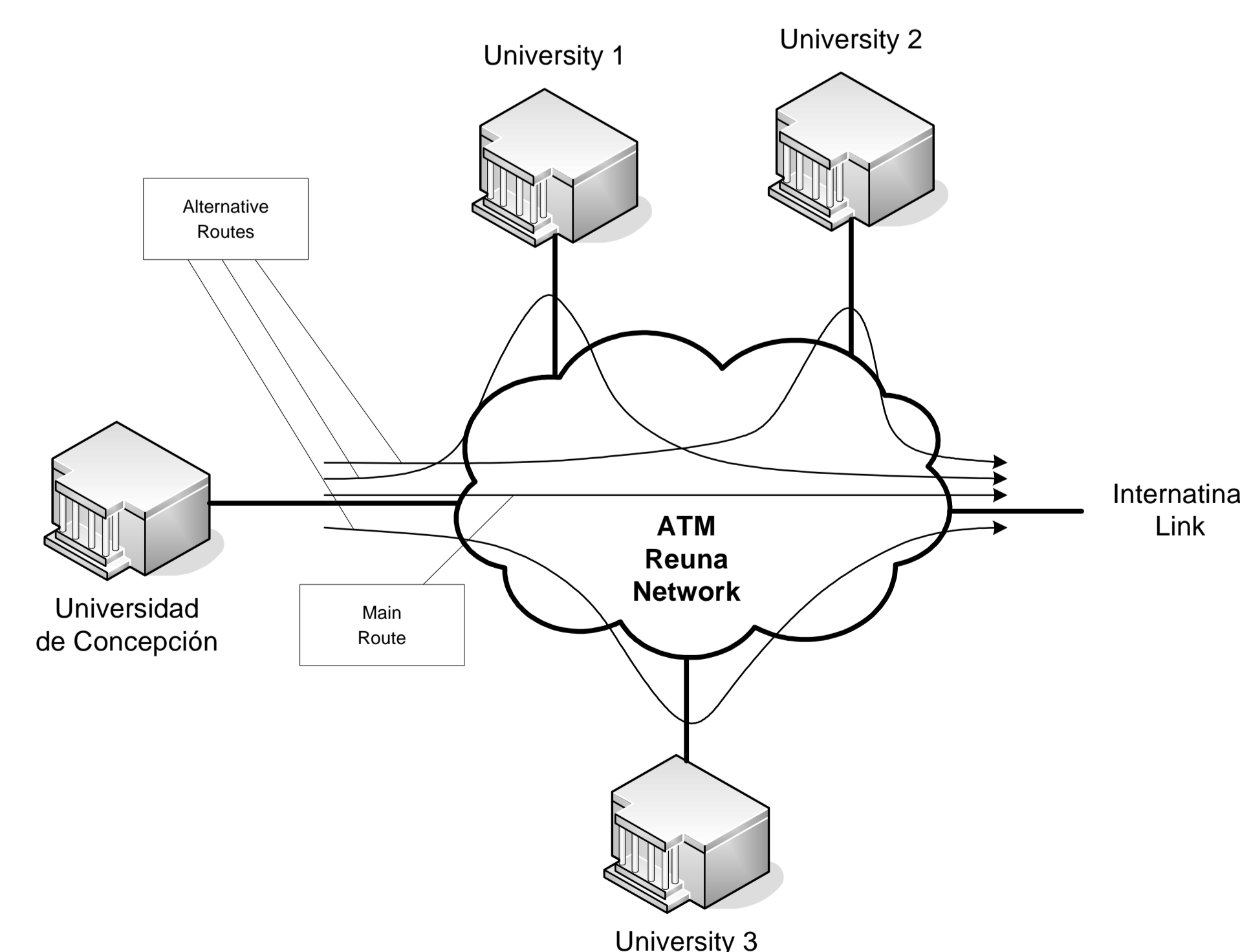


Figure 4: Multipath Routing in REUNA Network.

## EXPReS Project Approach

The EXPReS project aims to identify the bottlenecks of the route from the TIGO VLBI station to a correlator in Europe and to expand the bandwidth in order to join the European VLBI network as an eVLBI station. The lowest speed of the path from TIGO to Europe is limited by a contract bandwidth of 5 Mbps provided by REUNA. This speed can be increased buying more bandwidth up to 64 Mbps (96 Mbps are available but ~ 32 Mbps are in use as normal traffic). Furthermore, in order to achieve this maximum speed it's necessary to release the 15 Mbps constraint of Universidad de Concepción, which can be selectively made by REUNA for the TIGO traffic only. The path from TIGO to Universidad de Concepción has a total speed of 100 Mbps and there are plans to upgrade this path to 1 Gbps. Therefore, 64 Mbps can be expected as total speed for the EXPReS project unless further improvements are made in the REUNA network.

The first step is to find the bottlenecks along the path in order to identify a needed upgrade of the equipments/links involved. A closer look of the route from TIGO to JIVE is shown in Figure 5.

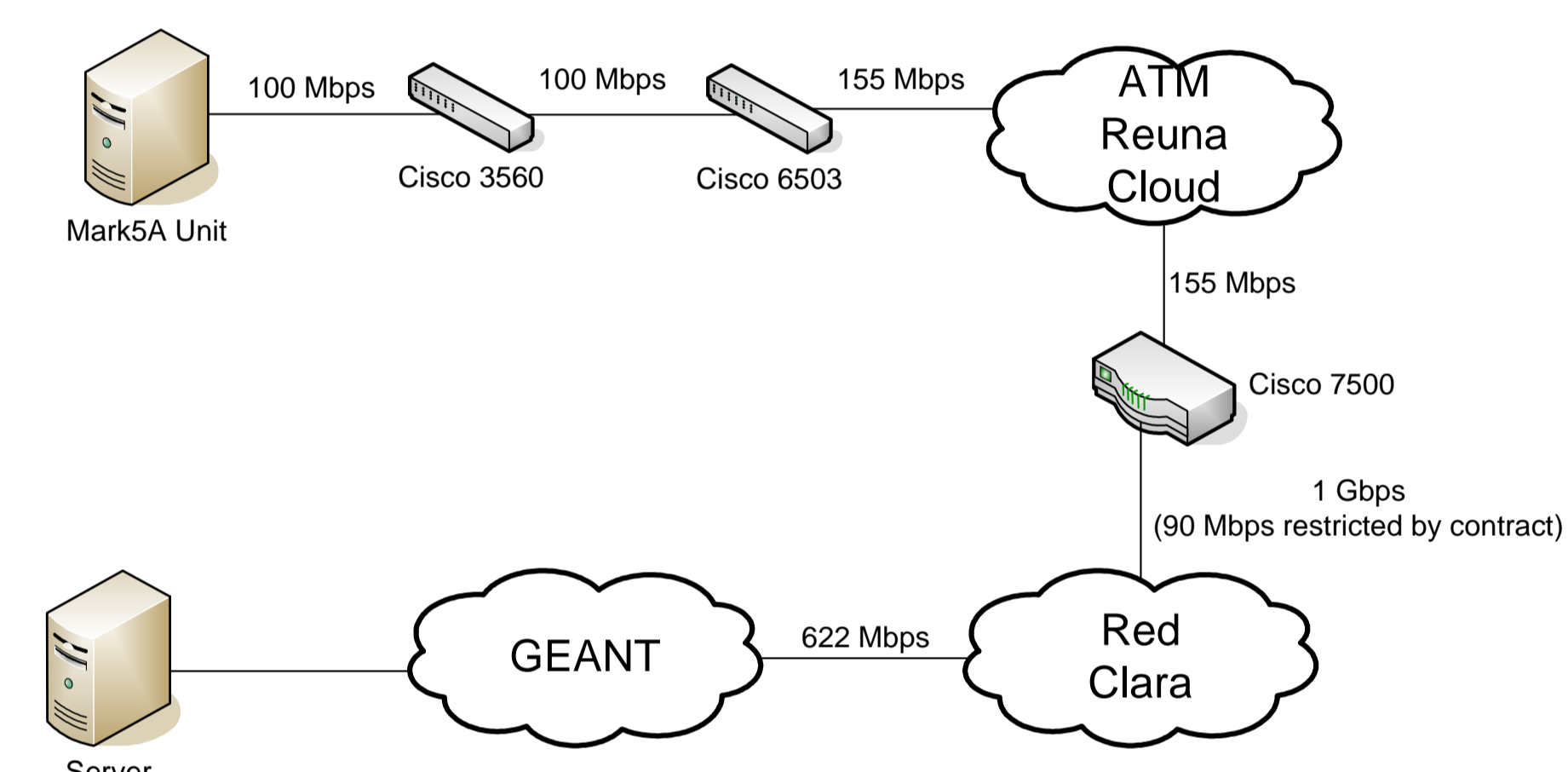


Figure 5: Route detail from TIGO to JIVE Correlator.

According to this, REUNA opened their restrictions with interesting results. Two test were conducted to JIVE VLBI correlator in Netherlands which are shown in Figure 6. The first test was made using two parallel streams with a per flow restriction applied in the REUNA border router linked to Concepción. The first streams was started with an upload speed of ~ 200 KBps, at 68 and 98 minutes of transmission a second stream was started with a resulting total upload speed of ~ 400 KBps. The second test was made without any restriction in TIGO, Universidad de Concepción, REUNA or JIVE VLBI correlator networks with a theoretical upload speed of 64Mbps. Both ends had the TCP stack tuned. The average upload speed obtained was 1.29 MBps and the peak was 6.2 MBps.

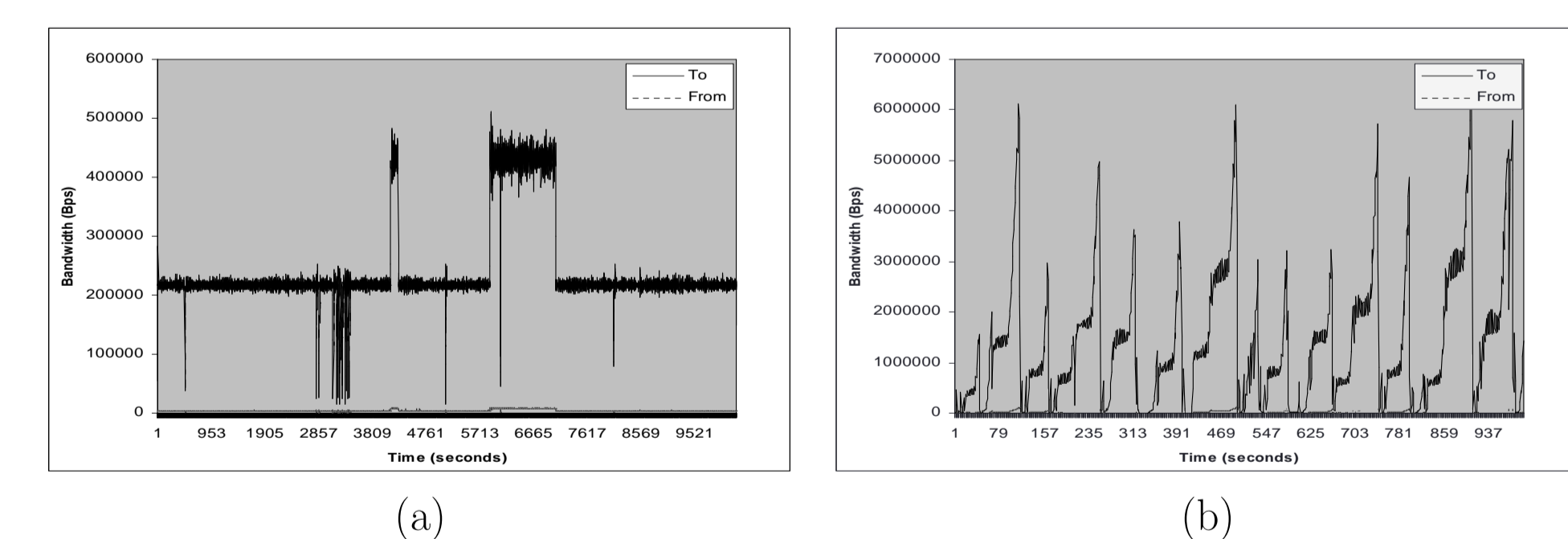


Figure 6: a) Speed results of transferring from Concepción to Netherlands when REUNA restrictions applied. b) Speed results of transferring from Concepción to Netherlands with REUNA restrictions lifted.

## Conclusions

Both approaches will be further investigated. The MPR scheme needs the definition of a protocol and the development of the software, while the solution framed by the EXPReS project needs to investigate the discrepancy between the theoretical 96 Mbps and the average 15 Mbps obtained.