Evaluating and Optimizing Transport Protocols for the Interplanetary Internet

Le descriptif de l’offre ci-dessous est en Anglais

Niveau de diplôme exigé: Bac + 4 ou équivalent

Fonction: Stagiaire de la recherche

Contexte et atouts du poste

This project seeks intern master students. Funds will be provided from the Space Terrestrial Integrated Internet of Things (STEREO) project, coordinated by J. Fraire (Inria). This internship will take place in the Inria Agora research group located in the La Doua Campus in Lyon. A certain level of remote working is allowed/expected.

Mission confiée

Overview

This project evaluates and optimizes transport protocols for the Interplanetary Internet (IPN) by comparing the Licklider Transmission Protocol (LTP) and the QUIC protocol. The assessment should include single-hop and multi-hop assessments under the Delay-Tolerant Bundle Protocol (BP) and Internet Protocol (IP) architectures. Using simulation tools and key performance metrics, the research will assess the protocols’ suitability for the unique challenges of space communication. The findings will inform potential improvements to these protocols and contribute to developing more efficient and reliable interplanetary communication systems.

Context, Challenges, and Objectives

Context

The concept of an Interplanetary Internet (IPN) has been a topic of significant interest in space communication. The IPN aims to establish a network facilitating communication between Earth and other planets, spacecraft, and satellites. This ambitious endeavor presents unique challenges due to interplanetary communication’s long delays and disruptions [1].

Researchers have proposed using Delay-Tolerant Networking (DTN) protocols to address these challenges. DTN protocols are designed to handle significant delays and disruptions, making them well-suited for interplanetary communication [2]. The DTN architecture uses a “store and forward” approach, storing data at each node until a connection can be established to the next node. This approach allows for communication even in the face of significant delays and intermittent connectivity.

One implementation of the DTN Bundle Protocol (BP) is the Interplanetary Overlay Network (ION). ION has been designed to facilitate communication in an IPN, providing a practical example of how DTN protocols can be applied to interplanetary communication [3].

The development and implementation of the IPN and associated networking protocols like DTN and ION are crucial for the future of space exploration and communication. They will enable more reliable and efficient communication between Earth and other celestial bodies, paving the way for more advanced space missions and scientific discoveries.

Challenges

The Interplanetary Internet (IPN) presents unique challenges for transport protocols designed to ensure
reliable, ordered delivery of data packets. Traditional protocols like TCP/IP, which work well on Earth, need to be better suited to the extreme conditions of space communication. The vast distances between planets result in high latency and long round-trip times, while celestial bodies and solar events can cause frequent and unpredictable link disruptions. Furthermore, the high cost of transmitting data in space necessitates highly efficient bandwidth use. These challenges require a new approach to transport protocols in the IPN.

**Licklider Transmission Protocol: A Solution for Today**

The Licklider Transmission Protocol (LTP) is a point-to-point protocol explicitly designed for the unique challenges of long-delay links in interplanetary communications. LTP operates in sessions, dividing data into segments for transmission. It uses a system of checkpoints and retransmissions to ensure data reliability, waiting for acknowledgment from the receiver before proceeding. If an acknowledgment isn't received within a specific timeframe, the sender retransmits the data starting from the last checkpoint. LTP also divides data into red and green parts, allowing for partial reliability where some data is more critical than others. This approach makes LTP well-suited to the high latency, frequent disruptions, and bandwidth constraints of space communication [4].

**QUIC: A Potential Future Solution**

Christian Huitema, in his blog post “QUIC to Mars,” explores the potential of using the QUIC protocol for interplanetary communication [5]. QUIC is a general-purpose transport layer protocol that provides security equivalent to TLS/SSL and reduces connection and transport latency. Huitema's simulations with Picoquic, an implementation of QUIC, revealed several adjustments necessary to accommodate the long delays of space communication, such as scaling various time-related constants in the protocol and adjusting the “handshake completion timer” and “idle timer.” The author also discusses using “chirping” to rapidly discover the path capacity and the need to consider flow control and timers. While there are challenges to using QUIC in space, the exercise helped identify and address issues, making the code more robust. In addition to Huitema's work, the paper "Performance Evaluation of QUIC with BBR in Satellite Internet" provides a preliminary evaluation of QUIC with the BBR (bottleneck bandwidth and round-trip propagation time) congestion control algorithm in the context of satellite internet [6]. The study confirms that QUIC with BBR improves compared to the classic CUBIC congestion control. This study thus suggests that QUIC with BBR could be a viable solution for interplanetary communication. Moreover, the recent publication “Revisiting the Use of the IP Protocol Stack in Deep Space: Assessment and Possible Solutions” [7] aims to leverage an adapted QUIC stack to address communications in deep space.

**BP and IP: Multi-Hop Considerations**

On the one hand, LTP is primarily designed for single-hop paths, particularly in environments with long-delay links, such as space communications. However, it can be and often is used in multi-hop scenarios in combination with BP. On the other hand, QUIC is an end-to-end transport layer protocol designed to operate over multi-hop paths. Nevertheless, these are assumed to be IP multi-hops, meaning no disruptions (e.g., topology partitions) are present. As temporary storage is needed to accommodate such partitions, [9] hints at temporary storage at the IP level and possible QUIC proxies in the transport layer. However, the concrete details of these solutions still need to be clarified at the time of writing.

**Assessment of Transport Protocols in the Interplanetary Internet**

An appropriate evaluation platform is crucial to effectively evaluate and contrast LTP and QUIC-based protocols within the context of single- and multi-hop Interplanetary Internet (IPN). Currently, three primary frameworks are recognized for this purpose.

1. **a) NS-3 DTN Module**: This module enhances the widely used NS-3 network simulator, incorporating a module specifically designed to simulate DTN. This module empowers researchers to create models and simulations that accurately reflect the unique challenges associated with space communication, such as extended delays and sporadic connectivity.

2. **b) OMNeT++ with INET**: OMNeT++ is a versatile network simulator that can be augmented with the INET Framework, with plenty of transport layer models. In addition, it supports DTN solutions like DtnSim [7], which was developed by one of the supervisors.

3. **c) Picoquic**: Picoquic is a minimalist implementation of the QUIC protocol, as defined by the IETF. The IETF spec started with the version of QUIC defined by Google and implemented in Chrome, but the IETF spec is independent of Chrome and does not attempt to be backward compatible. The first goal of this project was to provide feedback on developing a QUIC standard in the IETF QUIC WG.

However, it’s important to note that only some of these platforms support LTP or QUIC, indicating that creating new modules may be necessary. Furthermore, these simulators are protocol-specific and operate under the assumption that the topology and contact dynamics are pre-determined. To address this, the current research will leverage STK and a novel 3D Unity tool created by the Agora team to generate realistic topology and contact data [8].

**References**


Principales activités

Objectives

The primary objective of this research project is to evaluate and compare the performance of the LTP and the QUIC protocol in the context of single-hop and multi-hop IPN topologies. This will be achieved through activities designed to comprehensively understand these protocols and their potential improvements. The specific activities to be undertaken are as follows:

1. **Tool Analysis and Selection**: The first step in this project is to thoroughly understand the available platforms comprising NS-3, OMNeT++, Picoquic, and others. A qualitative comparison will be made to select the best way to compare LTP and QUIC, considering the feasibility of developing the missing elements.

2. **Tool Improvement and Implementation**: Once the tool is identified, the next step is to address potential enhancements, improvements, and fixes to enable an LTP or QUIC analysis. These improvements will then be implemented, ensuring the tool is optimized for extracting IPN contact and topology data.

3. **Simulation Campaign Execution**: With the simulator tool developed, a simulation campaign will be executed to compare the performance of LTP and QUIC in realistic topologies. This will provide valuable data on how these protocols perform under various conditions.

4. **Protocol Improvement Identification**: Based on the observations and data gathered from the simulation campaign, potential improvements for LTP and QUIC will be identified. These improvements will be proposed to enhance the performance of these protocols in the IPN context.

Through these activities, this project aims to contribute to developing and optimizing transport protocols for the Interplanetary Internet.

Compétences

Required Skills

We encourage applications from students pursuing a Computer Science or Computer Engineering degree. Practical proficiency with programming languages (C/C++ and Python) is desirable. A solid understanding of mathematics and networking is also preferred. Applicants must have fluency in English; proficiency in French is not a prerequisite but would be advantageous. We are seeking candidates who are empathetic, proactive, and self-motivated.

Avantages

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage under conditions

Rémunération

Gratification = 4,05€ gross / hour

Informations générales

- Thème/Domaine : Réseaux et télécommunications
- Système & réseaux (BAP E)
- Ville : Villeurbanne
- Centre Inria : Centre Inria de Lyon
- Date de prise de fonction souhaitée : 2024-01-01
- Durée de contrat : 6 mois
Date limite pour postuler : 2024-01-19

Contacts

- Équipe Inria : **AGORA**
- Recruteur : Fraire Juan Andres / juan.fraire@inria.fr

A propos d’Inria

Inria est l’institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 215 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3900 scientifiques pour relever les défis du numérique, souvent à l’interface d’autres disciplines. L’institut fait appel à de nombreux talents dans plus d’une quarantaine de métiers différents. 900 personnels d’appui à la recherche et à l’innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 200 start-up. L’institut s’efforce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l’économie.

L’essentiel pour réussir

There you can provide a "broad outline" of the collaborator you are looking for what you consider to be necessary and sufficient, and which may combine :

- tastes and appetencies,
- area of excellence,
- personality or character traits,
- cross-disciplinary knowledge and expertise...

This section enables the more formal list of skills to be completed and ‘lightened’ (reduced) :

- "Essential qualities in order to fulfill this assignment are feeling at ease in an environment of scientific dynamics and wanting to learn and listen."
- "Passionate about innovation, with expertise in Ruby on Rails development and strong influencing skills. A thesis in the field of **** is a real asset."

Attention : Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d’autres canaux n’est pas garanti.

Consignes pour postuler

Applications must be submitted online via the Inria website. Processing of applications submitted via other channels is not guaranteed.

Sécurité défense :
Ce poste est susceptible d’être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L’autorisation d’accès à une zone est délivrée par le chef d’établissement, après avis ministériel favorable, tel que défini dans l’arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l’annulation du recrutement.

Politique de recrutement :
Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.