Final Task

Simulation of
Communication Networks

Institute of Communication Networks, TUHH

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1 Introduction

Humans set foot on the Moon in 1969 during NASA's Apollo 11 mission, with the last crewed landing being in 1972 [1]. The interest in going to the Moon seemed to be lost, until now. Space agencies from all over the world have set their eye on the lunar surface again, and astronauts are expected to set foot on the Moon in the next few years [2].

One of the most interesting areas of study is the South Pole of the Moon, since the shadowed places could contain ice and minerals [3], and the mountain peaks are illuminated for large periods of time [4], making it an ideal landing site for future missions [5]. An example of this is NASA's Artemis III, which aims to send two astronauts on a week-long mission near the South Pole of the Moon in 2026 or 2027 [6]. Moreover, in the future there will be permanently crewed bases in the Moon, such as the Moon Village planned by the European Space Agency (ESA) [7].

The project you will be working on is the **Lunar Camp**, which consists of two Moon bases - a control station outside one of the craters on the lunar South Pole, and a science station, located inside the crater. The control station has access to the lunar internet, whereas the science station does not have direct access because of its location. The bases are connected with a point-to-point radio link.

Both bases have a crew of astronauts living inside, and are in constant communication with one another via a bidirectional video link. The Quality of Service (QoS) of this video stream must be maintained at all times. Other than that, the astronauts can access the lunar web to download material such as the solar weather forecast or the latest scientific discoveries via Hypertext Transfer Protocol (HTTP). When they are the ones doing a scientific discovery, the crew uploads the results of their experiments with a computer located inside one of their laboratories using File Transfer Protocol (FTP). Since some experiments are very dangerous, a CCTV camera streams video of the high risk laboratory at the science station for safety reasons. The camera is connected via Ethernet. The same Wireless Local Area Network (WLAN) is used for HTTP lunar web browsing, FTP file uploads and video conferencing. To evaluate the capabilities of the experimental Moon Village, you, as consultants, are requested to simulate the whole network and determine the key characteristics of this setup.

2 Problem Description

Figure 1 shows the network topology. All wireless users are uniformly distributed in a $20\,\text{m} \times 20\,\text{m}$ area around the access point. The astronauts' computers are not mobile, so they are to be considered stationary. The WLAN is based on IEEE 802.11g with 54 Mbit/s and the access point is connected via Fast Ethernet IEEE 802.3, 100 Mbit/s to the science station router. The CCTV camera is connected to the same router using Fast Ethernet as well.

The science station router is connected to the control station router via a point-to-point radio link. The CCTV monitoring station at the control station is connected to the control station router. A Very High Speed Digital Subscriber Line (VDSL) connection with a data rate of 100 Mbit/s connects the control station router to the lunar internet, where HTTP and FTP servers are located. This VDSL connection exhibits a propagation delay, which is exponentially distributed with a mean of 30 ms. The video conference room at the control station has a 5 ms propagation delay to the respective router. The point-to-point radio link can be modeled as a PPP connection with the parameters given in Figure 1.

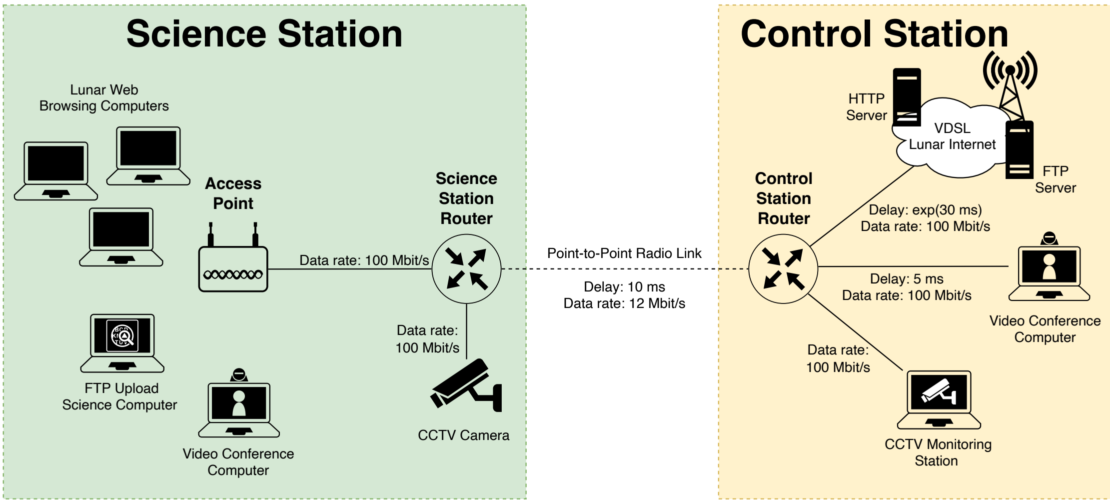

Figure 1: Scenario overview

To analyze the scenario, the computer center captured statistics about the lunar web browsing behavior. The traffic caused by the astronauts can be modeled as one HTTP request and response followed by a randomly distributed reading time before the next request is issued. The requested size (in Bytes) and the response length are given (see common .ini file). The reading times are recorded in a trace file. You as consultants need to identify the statistical behavior of the HTTP reading times by analyzing the recorded traces. Assumptions on the statistical distribution should be validated by evaluating the goodness of fit. The CCTV camera is constantly streaming a high quality video to the CCTV monitoring station at the control station. The stream is modeled as a constant User Datagram Protocol (UDP) stream containing packets of size 30 kB every 40 ms. The video conference rooms also transmit with a constant data rate of one packet every 40 ms.

A video packet consists of 1388 B of payload plus protocol headers. The video call application uses the Real-Time Transport Protocol (RTP) over UDP over Internet Protocol version 4 (IPv4). For a good QoS of the video connection, the maximum acceptable end-to-end delay is 100 ms. Encoding and decoding delays can be neglected. If a packet arrives too late, it will be considered lost. The acceptable packet loss rate is at most 5%. The CCTV camera is constantly streaming video, and the upload from the astronauts' computer to the FTP-server is one large file transfer, which lasts the whole simulation, while other astronauts continuously browse the lunar web. Each device uses only one application at a time. The operating systems' Transport Control Protocol (TCP)/IP implementations are based on TCP New Reno and the receiver side advertises a window of 1000 times the maximum segment size (MSS).

3 Task

Bottlenecks in the system for the case of FTP upload (i.e., uploading science data to the control station) while other HTTP and UDP based applications are also active must be investigated. To achieve this, the described scenario must be abstracted into a simulation model. You will gather data through simulations, and analyze it for the relevant aspects. Your work should answer, but is not limited to the following questions:

- How to model the inter arrival times of HTTP requests based on the given trace file?
- How does the number of active HTTP users influence the QoS of the video connection between science and control stations?
  - Your evaluation should cover the absence and presence of HTTP users. According to recent surveys, the number of active HTTP users can grow up to at least 30.
  - The impact on the QoS of the video connection should be shown for both science station and control station side.
- What is the impact of reducing the receiver advertised window to 10 times the maximum segment size (MSS)? Hint: Simulate for 1 and 0 HTTP users and try to justify your answers.

The researchers emphasized that they are still considering how to improve the quality of the system, which manifests in the general questions above. They are, however, thankful for any help you can provide, especially regarding the improvements for their lunar system that go beyond the general questions.

4 Formalities

4.1 Time Schedule and Submission

- The submission deadline of the final task is **Tuesday, August 20th 08:00 UTC time**.
- The submission including a presentation and the simulation model (all `.ned`, `.ini`, `.cc`, `.h`, ... files) as well as result scalar files (not vector files) must be uploaded to your repository on GitLab by the deadline (**Tuesday, August 20th 08:00 UTC time**). After this time, your repository membership will be expired and you won't be able to upload your files anymore.
- We generally expect a discussion of the results, and a presentation of your approach. Please do not simply answer the given questions one by one.
- Please clean up your code for the final submission.

4.2 Presentation

- The presentation should show and discuss the problem that you have investigated, how you have investigated it and your results. Details of your implementation and the configuration of your simulation model **should not** be part of the presentation.
- The presentation should be held by all members of your team. Try to share the presentation time equally.
- The presentation **must not exceed** 30 min; 20 to 25 min are recommended.
- You can expect a discussion and possibly follow-up questions on the presented results, about implementation details and about all the theoretical background taught in the lecture and exercises. Please prepare accordingly.

4.3 Comments

- Read the task description carefully! Ask us if anything is not clear.
- You are a consultant. The customer has no interest in implementation details and codes, and so your presentation should contain as little of those as required. However, you must still be able to answer questions on them.
- The task is designed for 1 to 2 weeks of full-time effort – if you seem to require more time than this, please contact us to get advice.
- Please make use of our offer of consultation if anything is not clear. A reasonable amount of discussion will give us a positive impression!
- Official consultation hours are on **every Tuesday from July 16th August 13th, from 10:00 to 11:00 CEST** at our institute E1.022.
- Please use our **SimCN 2024 Mattermost channel** to discuss with us and your peers about problems that you have.
- You can use the ComNets virtual machines to run your simulations. You can login via Secure Shell (SSH) from home as well.

4.4 Hints

- Unspecified connection parameters can be assumed as being ideal or default.
- For Ethernet, the Maximum Transmission Unit (MTU) is 1500 B and this limits the size for the Protocol Data Units (PDUs) of the upper layers. However, the PDUs of upper layers (e.g., TCP) should be as large as possible to reduce protocol overhead.
- Keep in mind that WLAN stations have to associate with the access point before they can transmit data.
- Give indications for the confidence of your simulation results.
- Sound knowledge of TCP/IP, UDP and WLAN (IEEE 802.11) protocols are needed to discuss the simulation results.

5 Evaluation Criteria

Table 1: Evaluation criteria

30 % – **Engineering Work**	• Modeling correctly (ned file) • Parameters correctly chosen (ini file) • All results obtained
40 % – **Scientific Analysis**	• Justification of simulation parameters • CI used in the figures and explained • Expected results calculated/reasoned • Analysis of results (will be judged based on the "presentation + discussion") • Improvement proposed and justified • Scientific language, graphs, units
10 % – **Presentation Style & Discussion**	• Slides and presentation • Discussion
20 % – **Continuous assesment**	• All the points you earned during the exercises

References

[1] Richard S Johnston and Wayland E Hull. "Apollo Missions". In: *Biomedical Results of Apollo, eds RS Johnston, LF Dietlein and C. Berry (Washington, DC: National Aeronautics and Space Administration)* (1975), pp. 9–40.

[2] *The Future Lunar Communications Architecture*. Tech. rep. Interagency Operations Advisory Group, 2022. URL: `https://www.ioag.org/Public%20Documents/Lunar%20communications%20architecture%20study%20report%20FINAL%20v1.3.pdf` (visited on June 20, 2024).

[3] Jessica Flahaut, J Carpenter, J-P Williams, et al. "Regions of interest (ROI) for future exploration missions to the lunar South Pole". In: *Planetary and Space Science* 180 (2020), p. 104750.

[4] P Gläser, F Scholten, D De Rosa, et al. “Connecting Ridge-A Landing Site at the Lunar South Pole with Extended Illumination”. In: *European Planetary Science Congress 2014*. Vol. 9. 2014.

[5] German Aerospace Center (DLR) and Arizona State University (ASU). *Connecting Ridge Potential Landing Site for ESA Lunar Lander DTM*. URL: `https://wms.lroc.asu.edu/lroc/view_rdr/NAC_DTM_ESALL_CR1` (visited on June 20, 2024).

[6] NASA. *Artemis III*. URL: `https://www.nasa.gov/mission/artemis-iii/` (visited on June 20, 2024).

[7] European Space Agency. *Moon Village*. URL: `https://www.esa.int/About_Us/Ministerial_Council_2016/Moon_Village` (visited on June 20, 2024).