Maximizing CCSDS Protocol Performance

...

William L. Van Besien
Principal Software Engineer, Gigantum Science

Workshop on Spacecraft Flight Software, December 2018.
bill@gigantum.com

Source Material

"Maximizing Data Return for the Europa Lander: A Trade Study in the Application of CCSDS Protocols".

Randy Ransier, Bill Van Besien, Ed Birrane, Dipak Srinivasan, Colin Sheldon.
Johns Hopkins University Applied Physics Lab

Survey presented at FSW 2016 in Pasadena, CA.
Manuscript published in Proceedings of the 2017 Aerospace Conference.

Objectives

Independently reproduce results to validate key claims in original publication.

Create a data artifact with code, data, and graphs for colleagues to easily **recreate**, **validate**, and **iterate** on our results.

Publish this data product in an open-data format on the FSW website.

Note: All material sourced only from published manuscripts, slide decks, and CCSDS technical reports. Absolutely no access or use of any proprietary material.

Claims to Reproduce

Phase 1 - Maximizing Link Efficiency

1. Link efficiency is maximized when Prox-1 frame size is maximized.
2. CFDP PDU segment-length is key metric of efficiency.
3. CFDP can sustain decent efficiency even in relatively high-error rates.

Phase 2 - RF Tradeoffs

1. Inverse relationship between minimal energy consumption and fastest data return - optimizing one at the cost of the other.
2. Inflection point beyond which *increasing* link performance actually *decreases* battery lifetime and data return.

Reproducing Phase 1 - Link Efficiency

Methodology

Created a new project - assembled Docker image loaded with Python, Jupyter, and other data science tools.

Developed a “medium”-fidelity CFDP and Prox-1 network stack.

Simulated file exchanges over varying CFDP PDU lengths, Prox-1 frame sizes, and uniformly-distributed bit error rates to measure link efficiency.

Link Efficiency

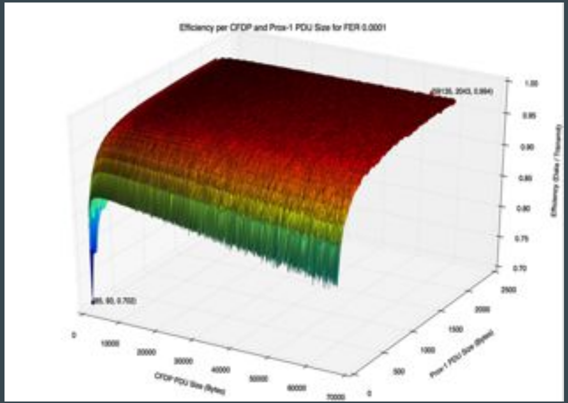
Ratio of bits in data file to bits transmitted.

Smaller packets and frames decrease efficiency (more overhead).

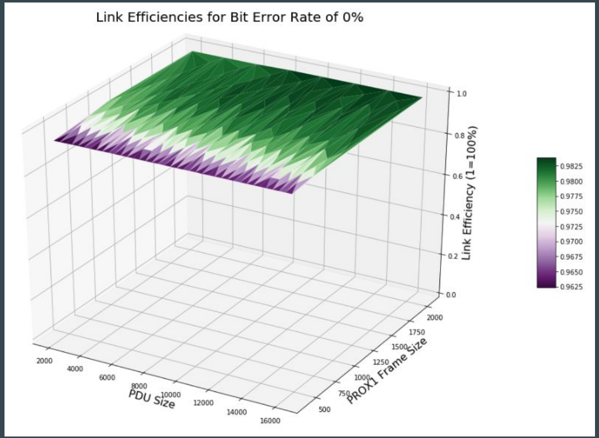
Dropped frames and packets decrease efficiency (more retransmissions).

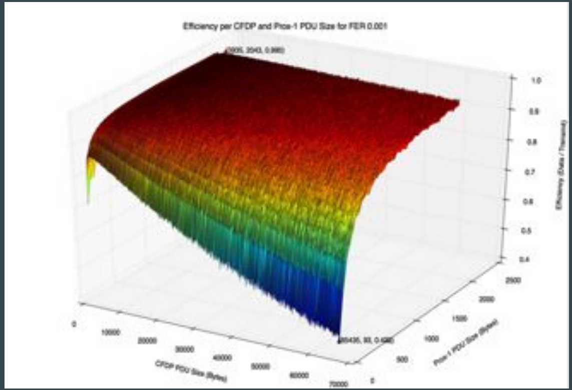
Original Research

Our Reproduction



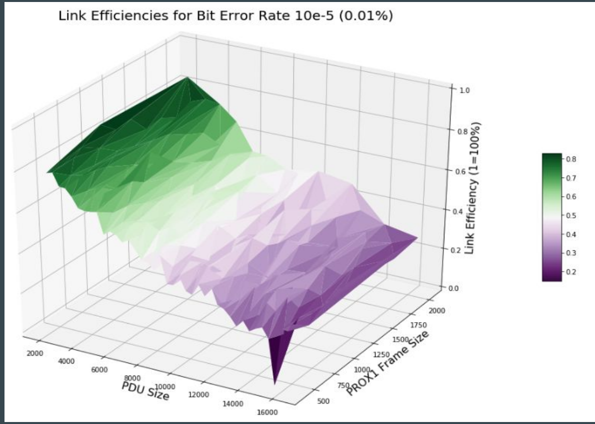
In near-perfect links, link efficiency near 95% (except for fringe cases).





On lossy links, efficiency quickly degrades with increasing PDU size.

Note the different scales!



Reproducing Phase 2 - RF Tradeoffs

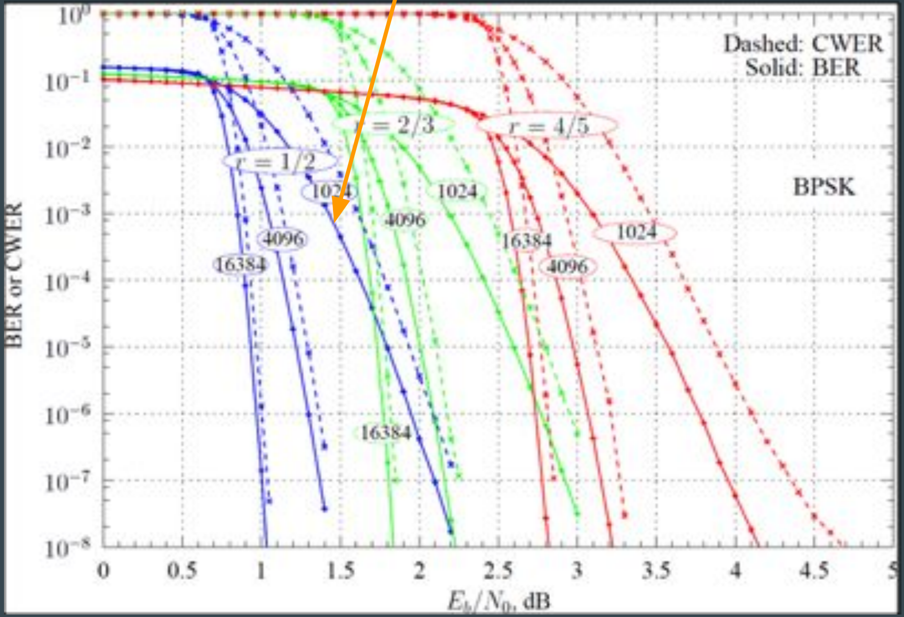
Only consider the solid, blue line labelled “1024”.

Methodology

Used “medium”-fidelity CFDP/Prox-1 from Phase 1 to measure downlink efficiency for error rates from 10^{-3} to 10^{-8}.

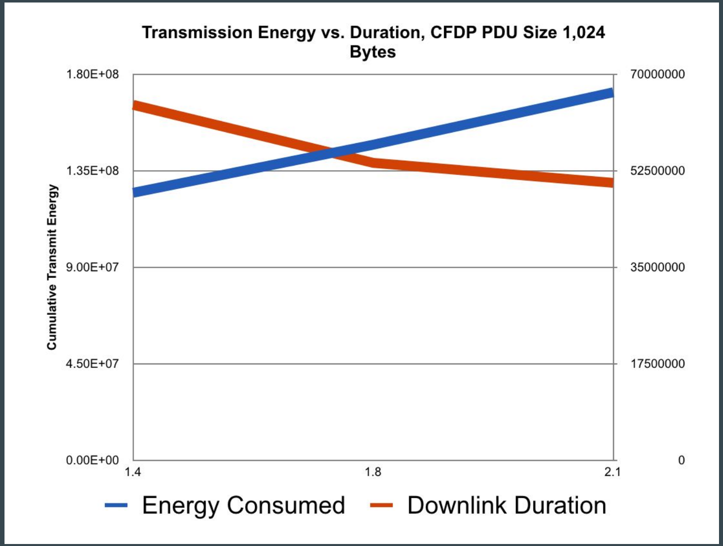
Computed estimated energy consumption and transmission time from RF engineering tables.

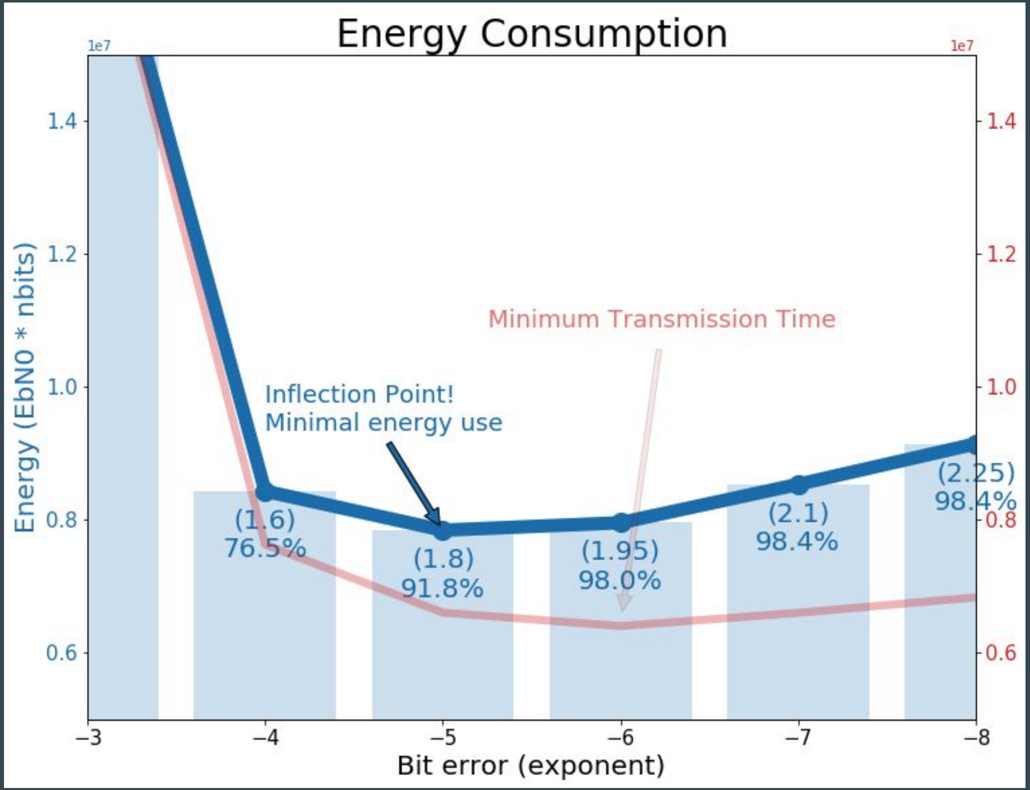
Understand interrelationship between link, efficiency, bitrate, and energy consumption.



Original Research

Our Reproduction





- Original uses FER; reproduction BER.
- Note different scales.
- Reproduction plots broader range of EbN0/Error rate.

Conclusion: Affirming and Refining

Phase 1: Optimizing Link Efficiency

Data suggests the three initial claims for maximizing link efficiency stand.

Phase 2: RF Layer Tradeoffs

(1) Pronounced results that reproduce optimal energy use; but (2) divergent results on relationship between energy and transmission time.

Further Work

Observing the energy tradeoff effect for other rates and data encodings along in the EbN0 graph.

More accurate modelling of bit error distributions for Jovian environment.

Higher-fidelity modeling of networking stack (with actual CFDP engines).

Docker image, code, Jupyter Notebooks to reproduce and iterate on this work available as Gigantum project (readily accessible in zip format)

http://billvb.github.io/fsw-telecoms-study.zip
http://gigantum.com/billvb/fsw-telecoms-study

About Gigantum Science

Open Source, Open System for collaborative, reproducible science.

Founded by academics and data scientists to solve problems reproducing and validating published research.

Gigantum.com
github.com/gigantum