

Why Not TCP for Interplanetary Links?

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Abstract

- This is a discussion of Delay Tolerant Networking (DTN) background, specifically the subset of DTN known as Interplanetary Networking as well the debate between modifying existing internet protocols and developing a whole new architecture for the Interplanetary Internet.

Outline

- What is a Delay Tolerant Network?
- Delay and Today's Internet
- Adapting the Internet to Space
- Rationale
- Terrestrial vs. Interplanetary Characteristics
- TCP in a Long-Delay Environment
- Common Applications in a Long-Delay Environment
- Conclusions
- References

What is a DTN?

- Delay Tolerant Network (in this case)
- Variety of possible scenarios
- We are interested in Interplanetary Links
- Delays are the speed-of-light delays

What kind of Delays?

- More than a disruption
- Long delays
 - 8-40min RTT to Mars [4]
 - 60-90min RTT to Jupiter [4]
 - 140-180min RTT to Saturn [4]
- Unpredictable delays
- Immutable for the foreseeable future

Delay & Today's Internet

- Delay indicates an abnormal condition
 - Network congestion
 - Busy server
 - No distinction
- Used for self-clocking
- No adaptation to delays above a fixed timeout (typically < 1 min)

Adapting the Internet to Space

- TCP Timeouts can be made longer
- Successful TCP/IP sessions established between Shuttle and Earth in 2003 [3]
- Telnet, FTP, SSH, and SCP used

Rationale

- Internet architecture very successful
- End-to-end model a key part of success
- Want to support current applications

Terrestrial vs. Interplanetary

	Earth's Internet	Interplanetary Links
Connectivity	Strongly Connected	Episodic
Error Rate [4]	$10^{-15} - 5 \times 10^{-3}$	$10^{-9} - 10^{-1}$
Cost	~\$1000 per month	~\$6000 per hour [4]

TCPs Defining Characteristics

- Slow Start
- Exponential Back-off
- Timer-based control loop
 - Short delay → Self clocks
 - Long delay → Assumes loss
- Loss, Corruption, Delay all treated alike
- No adaptation

TCP Throughput 1

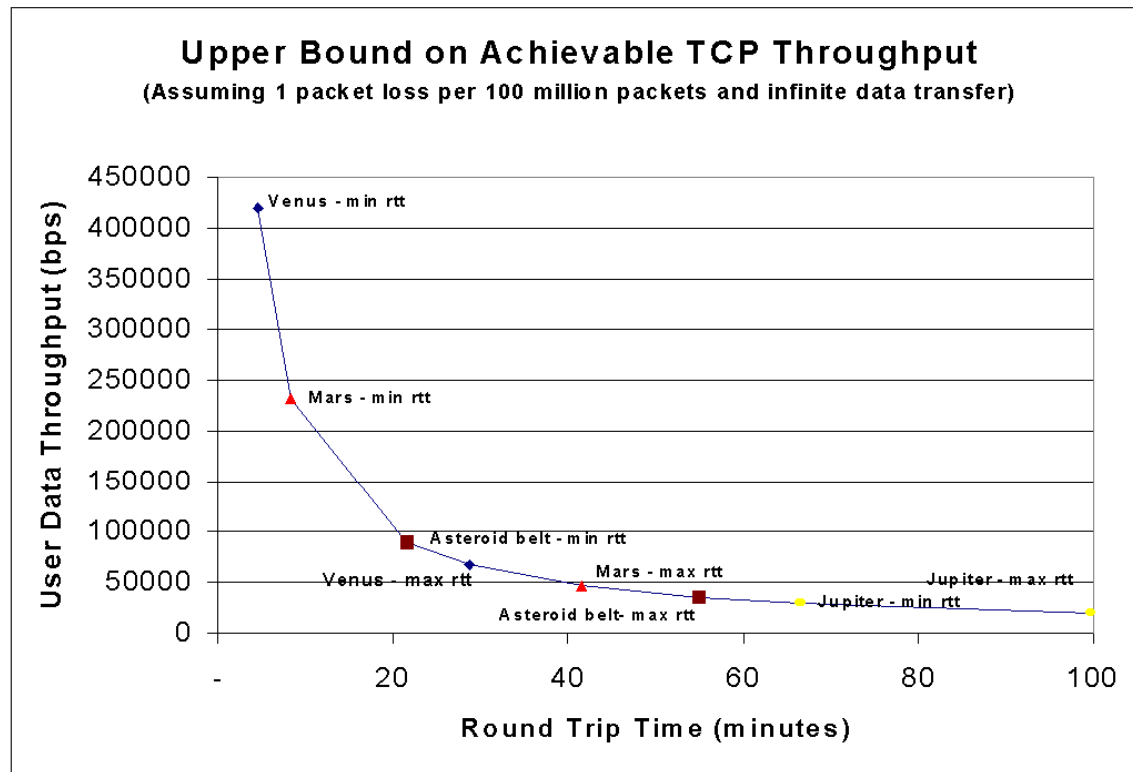


Figure 1. Upper Bound On TCP Throughput for Various Interplanetary Round Trip Times
Assuming $1e-8$ Packet Loss Rate

Source: [4]

TCP Throughput 2

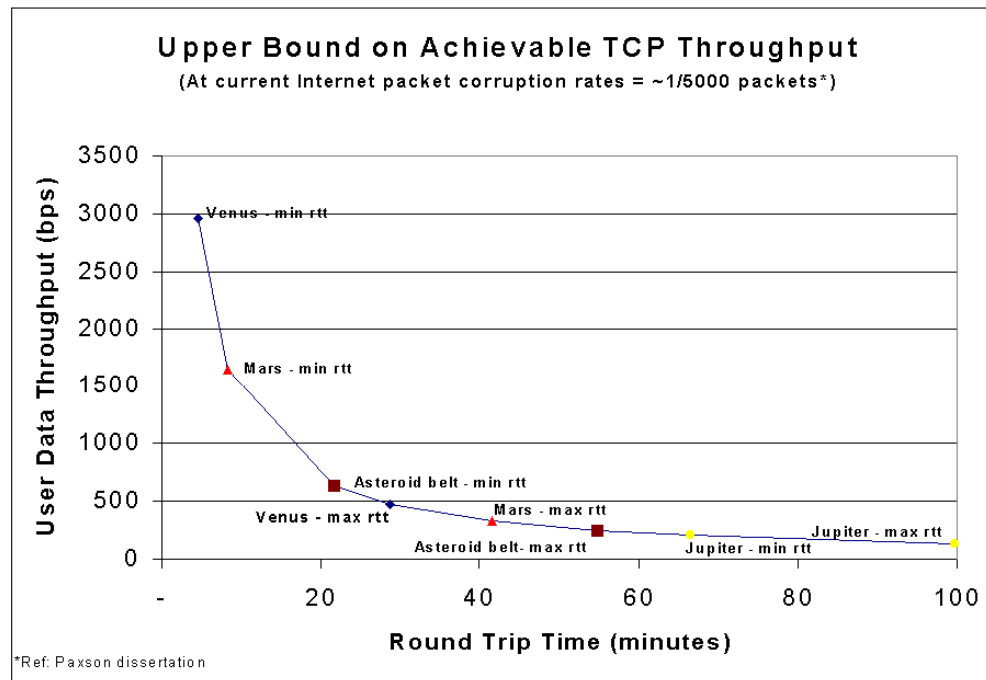


Figure 2. Upper Bound On TCP Throughput for Various Interplanetary Round Trip Times Assuming $2e-4$ Packet Loss Rate

Source: [4]

TCP Throughput 3

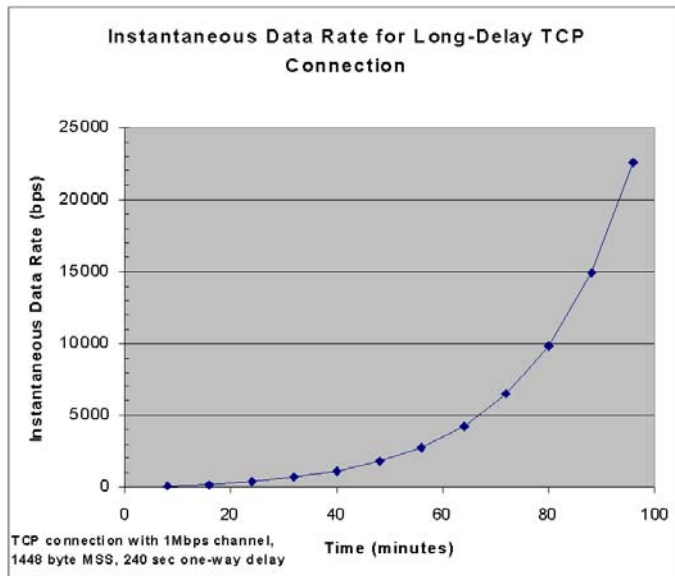


Figure 3. Instantaneous Data Rate for TCP Connection with Eight-Minute RTT)

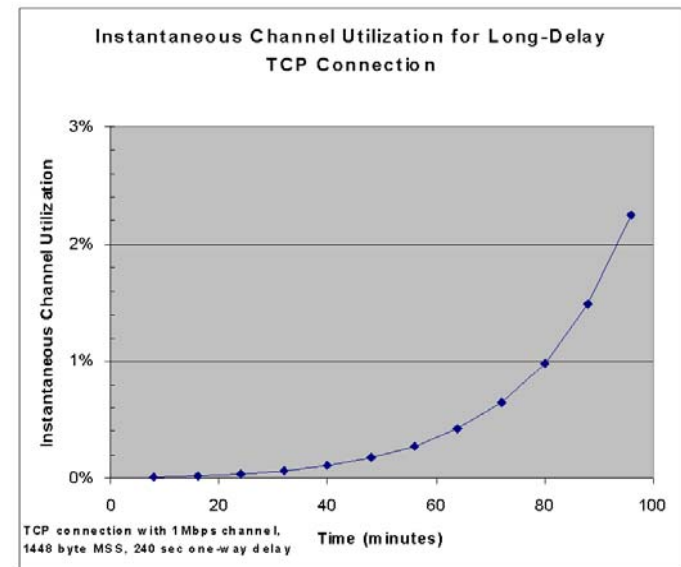
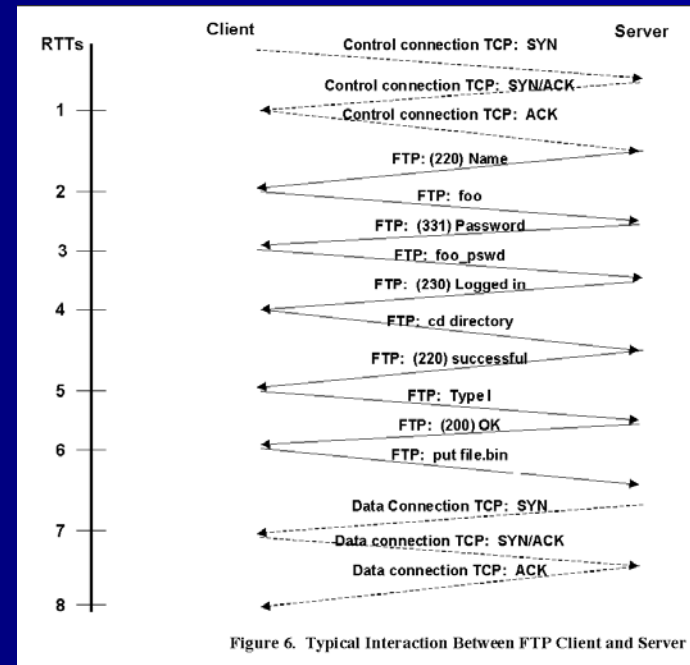


Figure 4. Instantaneous Channel Utilization for TCP Connection with Eight Minute RTT and 1 Mbps Channel

Source: [4]

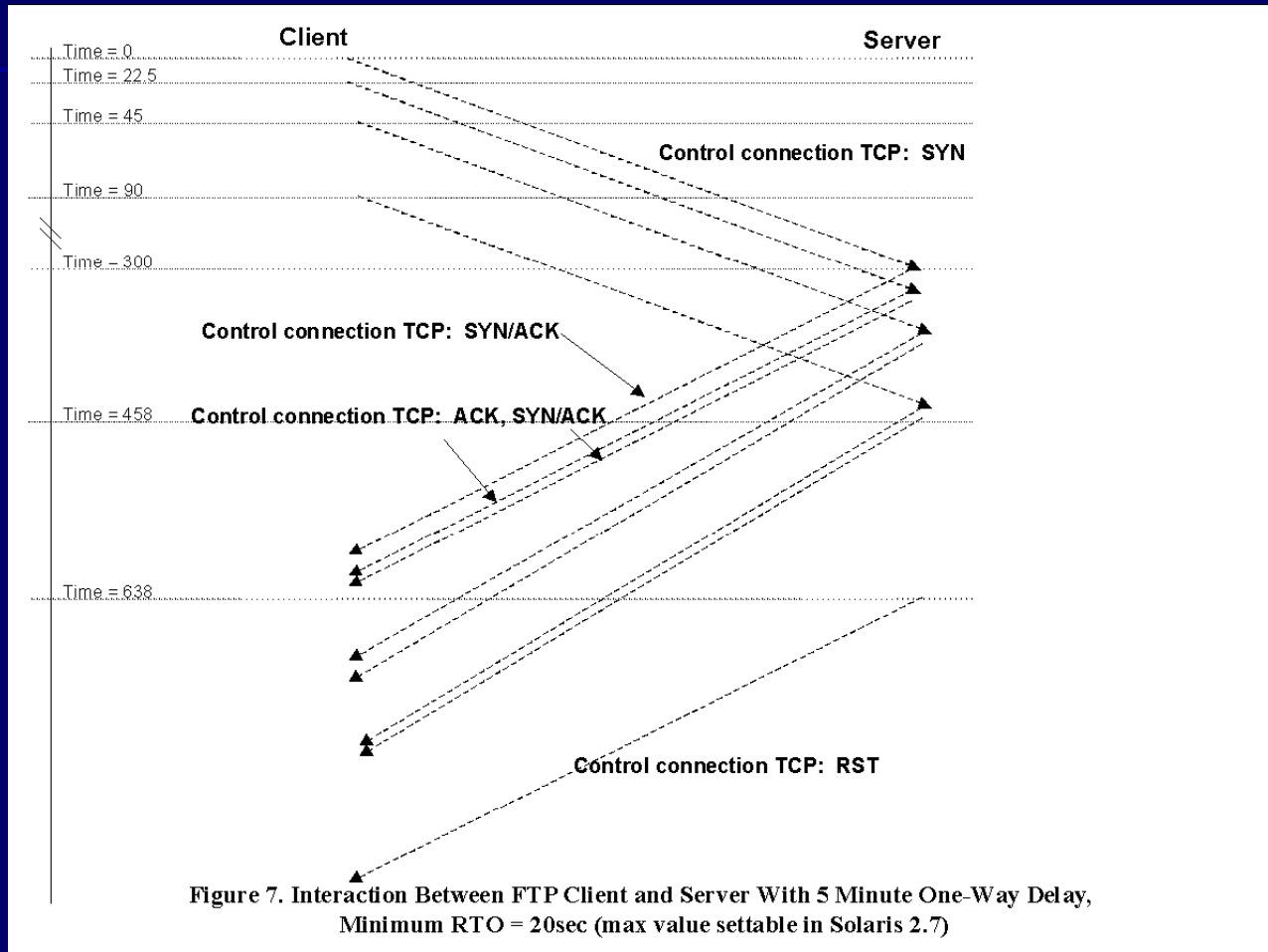
Applications: FTP 1

- Relatively Simple App.
- 8 RTT minimum before file transfer begins
- 1 – 5 hrs for mars RTT



Source: [4]

Applications: FTP 2



Source: [4]

Applications: SMTP

- Email model best suited to interplanetary environment
- However SMTP uses timeouts
 - ~5 minutes
 - Not adaptive
- Results comparable to FTP tests

Conclusions

- The Internet (TCP) was not designed for delay tolerance
- It could be modified
- Applications and ultimately users would still not be delay tolerant
- Therefore there is little reason to modify it

References

1. Forrest Warthman, *Delay-Tolerant Networks (DTNs): A Tutorial*, Warthman Associates, 2003.
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3. CANDOS Flight Test Website:
<http://ipinspace.gsfc.nasa.gov/CANDOS/>
4. Robert C. Durst, Patrick D. Feighery, Keith L. Scott, *Why not use the Standard Internet Suite for the Interplanetary Internet?*, The MITRE Corporation, 2000.