Space Network Time Distribution and Synchronization Protocol Development for Mars Proximity Link

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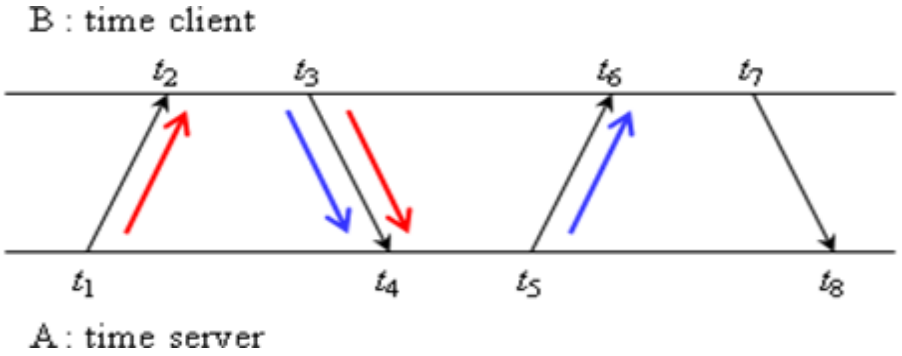
SpaceOps 2010
April 30th 2010
NASA-MSFC, Huntsville

Outline

- Introduction
  - Background: Time Synchronization
  - Overview: Space Time Synchronization Architecture
- Proximity-1 Interleaved Time Synchronization (PITS) Protocol
  - PITS Protocol Algorithm : Basic Mode and Interleaved Mode
  - Time Capturing comparison between PITS and the current method
- Simulation
  - Setup
  - Result
- Conclusion

Introduction

Time Synchronization between two nodes:



Ranging

For A,

offset = ½{[(*T*2 - *T*1)] + [*T*3 - *T*4]}

delay = [*T*4 - *T*1] - [*T*3 - *T*2]

For B,

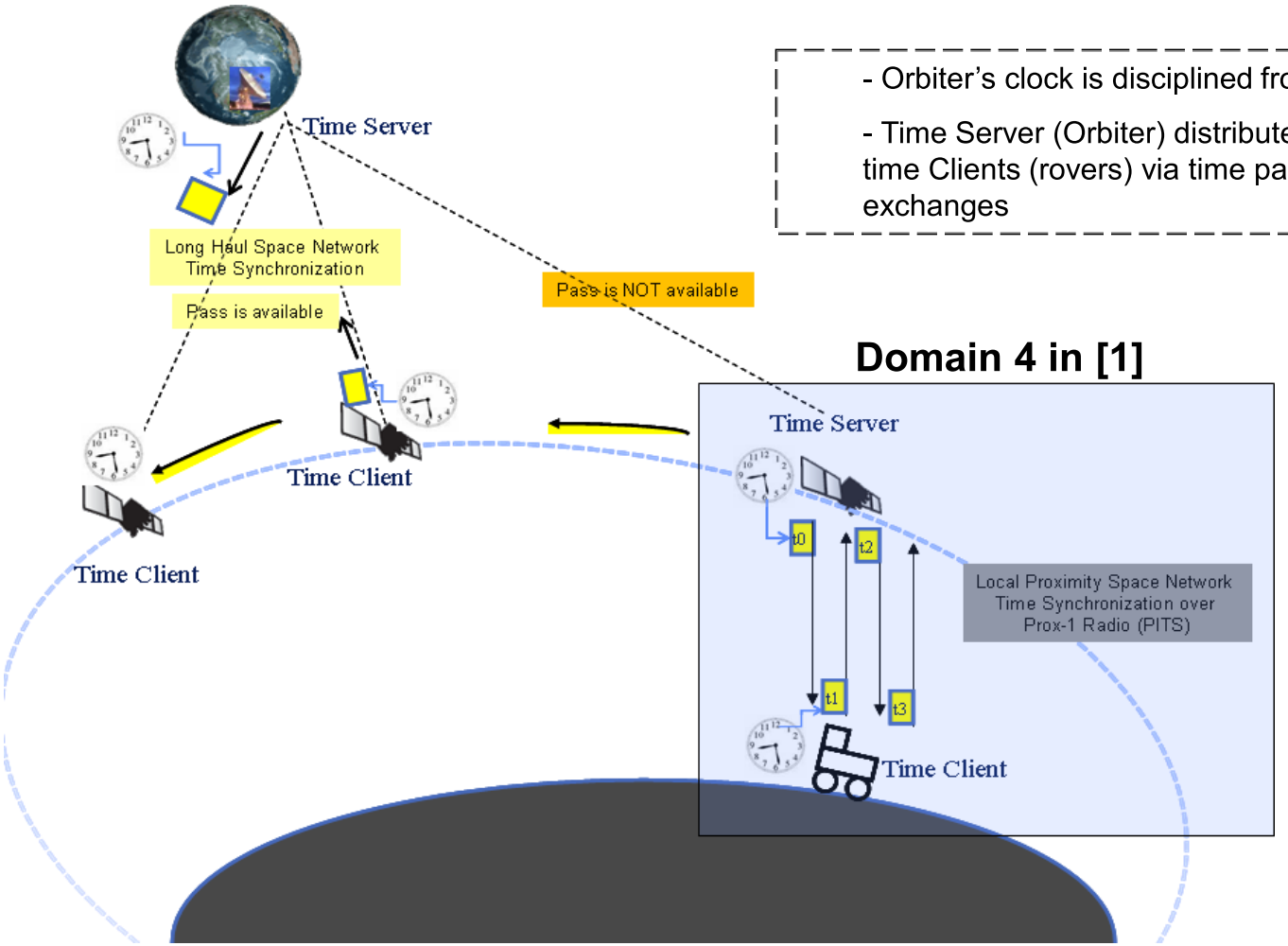
offset = ½{[(*T*4 - *T*3)] + [*T*5 – *T*6]}

delay = [*T*6 - *T*3] - [*T*5 – *T*4]

Assumptions:

1. Symmetric (statistically equivalent) path
2. No errors in the link
3. Not measuring synchronization accuracy but evaluate the protocol interactions

Overview of Space Time Synchronization Architecture



- Orbiter's clock is disciplined from Earth.
- Time Server (Orbiter) distributes time to time Clients (rovers) via time packet exchanges

PITS Algorithm

- Basic Symmetric Mode

Packet Fields

t_{org} : origin-timestamp
t_{rec} : receive-timestamp
t_{xmt} : transmit-timestamp

State Variables

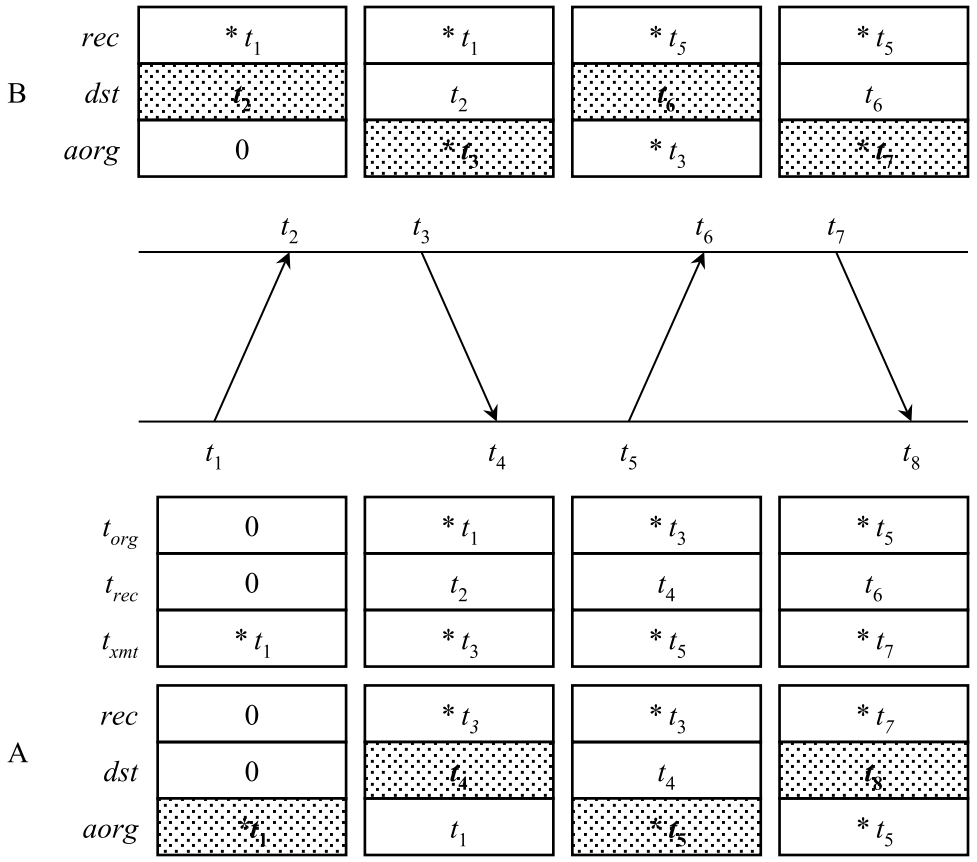
rec : receive-timestamp
dst : destination-timestamp
aorg : origin-timestamp
borg : origin-timestamp used for Interleaved Mode

Offset between A and B

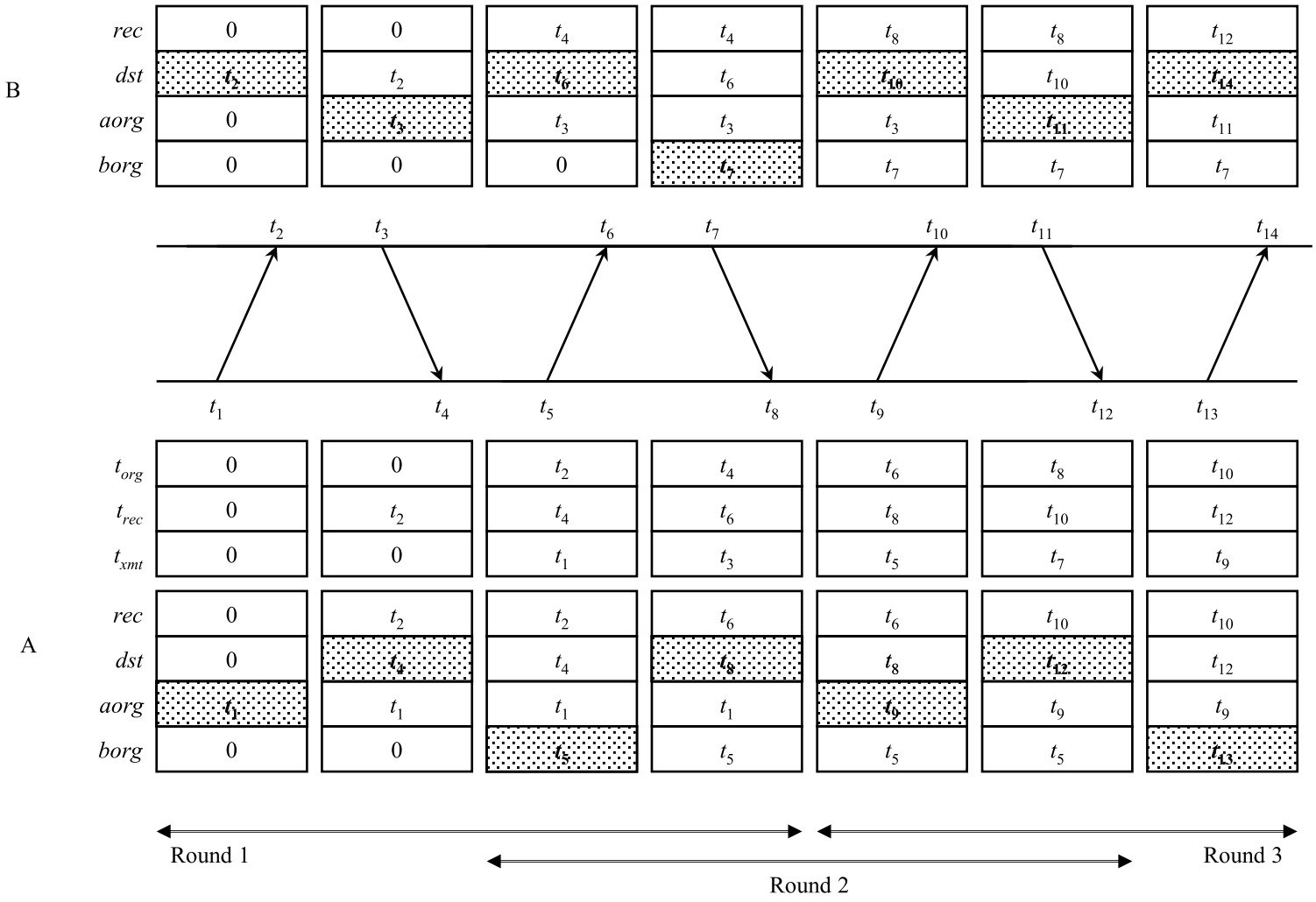
$= ½ [(T_2 - T_1) + (T_3 - T_4)]$

RTT Delay between A and B

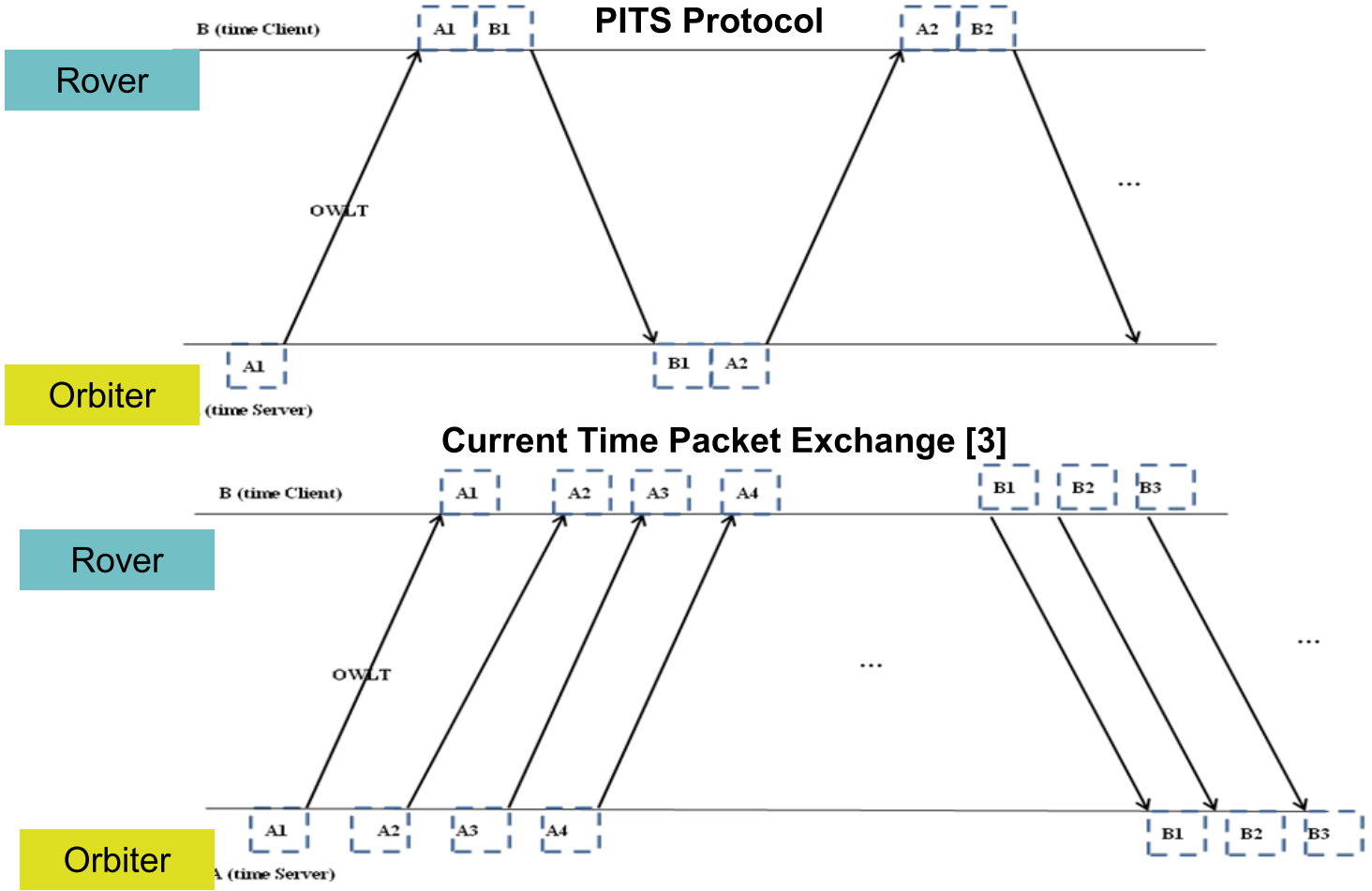
$= (T_4 - T_1) - (T_3 - T_2)$



PITS Protocol Interleaved Mode[2]



Protocol interaction Comparison between PITS and existing approach



Simulations

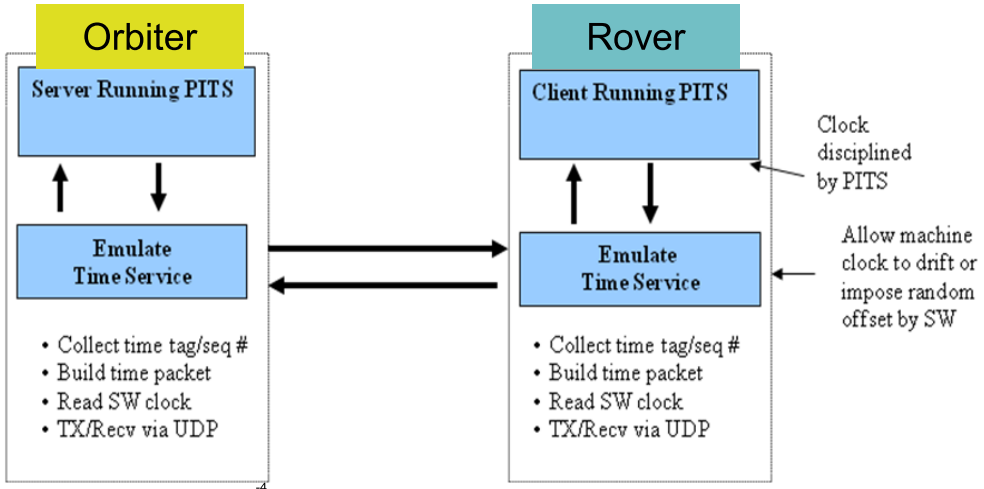
Simulation Setup

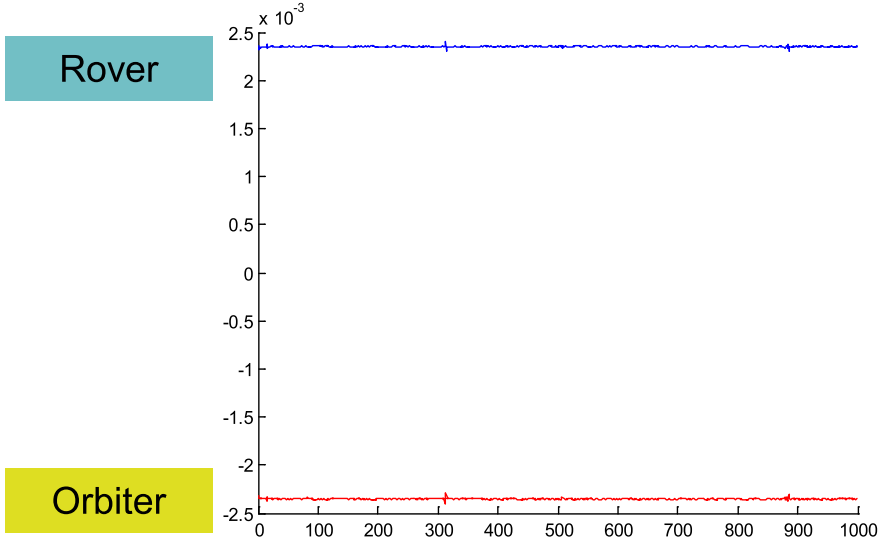
-Implemented PITS in C

-Tested over UDP

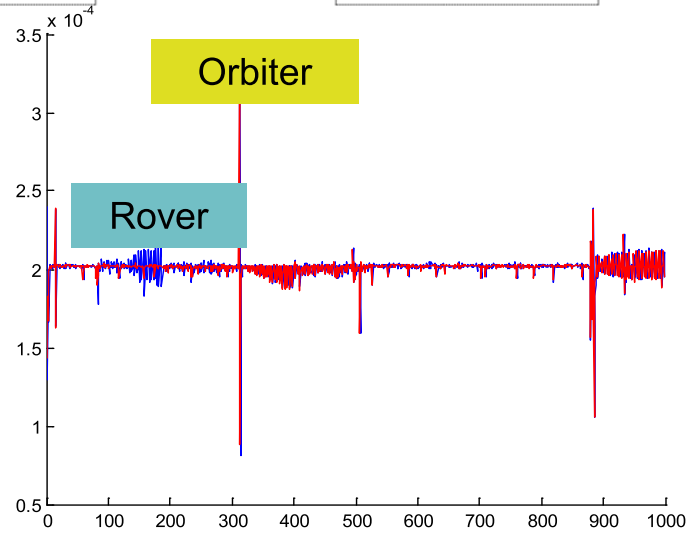
-Emulated the time differences

-Collected 1000 Time Samples to compute offset and delay





Calculated Offset between A and B



Calculated RTT between A and B

Conclusions

- Proposed the NTP based PITS protocol to provide common time in Mars proximity domain.
- Provide the onboard time distribution capability at the spacecraft which would be a key component for *In Situ Time Distribution Service*.
- Verified the correctness of the PITS algorithm, validated the design, and provided the preliminary simulation results.
- Will be an effective method to distribute time to other spacecraft through proximity links, as the number of space assets increases.
- Further prototype development and hardware integration and testing will be necessary to capture accuracy.
- Applicable to multi-spacecraft formation flying missions to provide accurate and periodic time updates as well as Space-Based Positioning, Navigation, and Timing (PNT) system[4] to enable integrated communications.

Acknowledgements

The authors like to acknowledge John Veregge at JPL for originally implementing the PITS algorithm. The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

References

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2) NTP Interleaved On-Wire Protocol, http://www.cis.udel.edu/~mills/onwire.html
3) CCSDS Proximity-1 Space Link Protocol, CCSDS 211.0-B-4: https://ccsds.org
4) The Positioning, Navigation and Timing (PNT) Overview, https://www.spacecomm.nasa.gov/spacecomm/programs/system_planning/PNT/default.cfm

Q&A