Operating CFDP in the Interplanetary Internet

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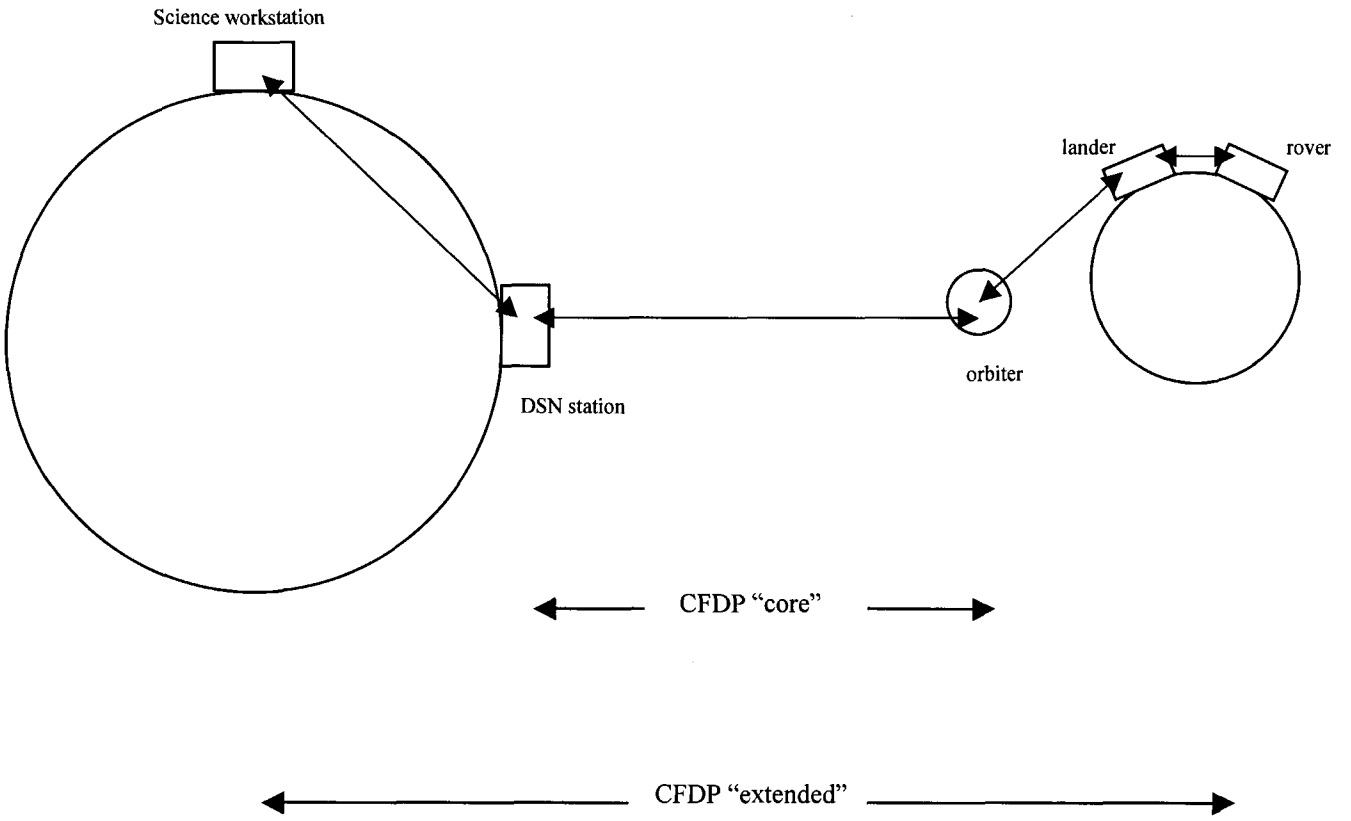
A CFDP Overview

- What is it?
  - CFDP is the CCSDS File Delivery Protocol, an international standard for automatic, reliable file transfer between spacecraft and ground (in both directions), built on the familiar CCSDS protocols.
- What's it for?
  - CFDP is designed to support the operation of spacecraft by means of file transfer and remote file system management.
  - It meets requirements developed by consensus in subpanel 1F of CCSDS, an international consultative organization of space agencies and industry associates.
  - Capabilities offered to the user:
    - Send a file from one entity (spacecraft or ground) to another.
    - Transmit arbitrary small messages, defined by the user, in the *metadata* accompanying a file.
    - Specify file system management commands to be executed at a remote entity – typically a spacecraft – upon complete reception of a file.

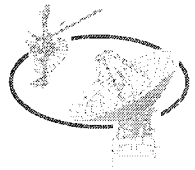
Operations Scenarios



Operational Features

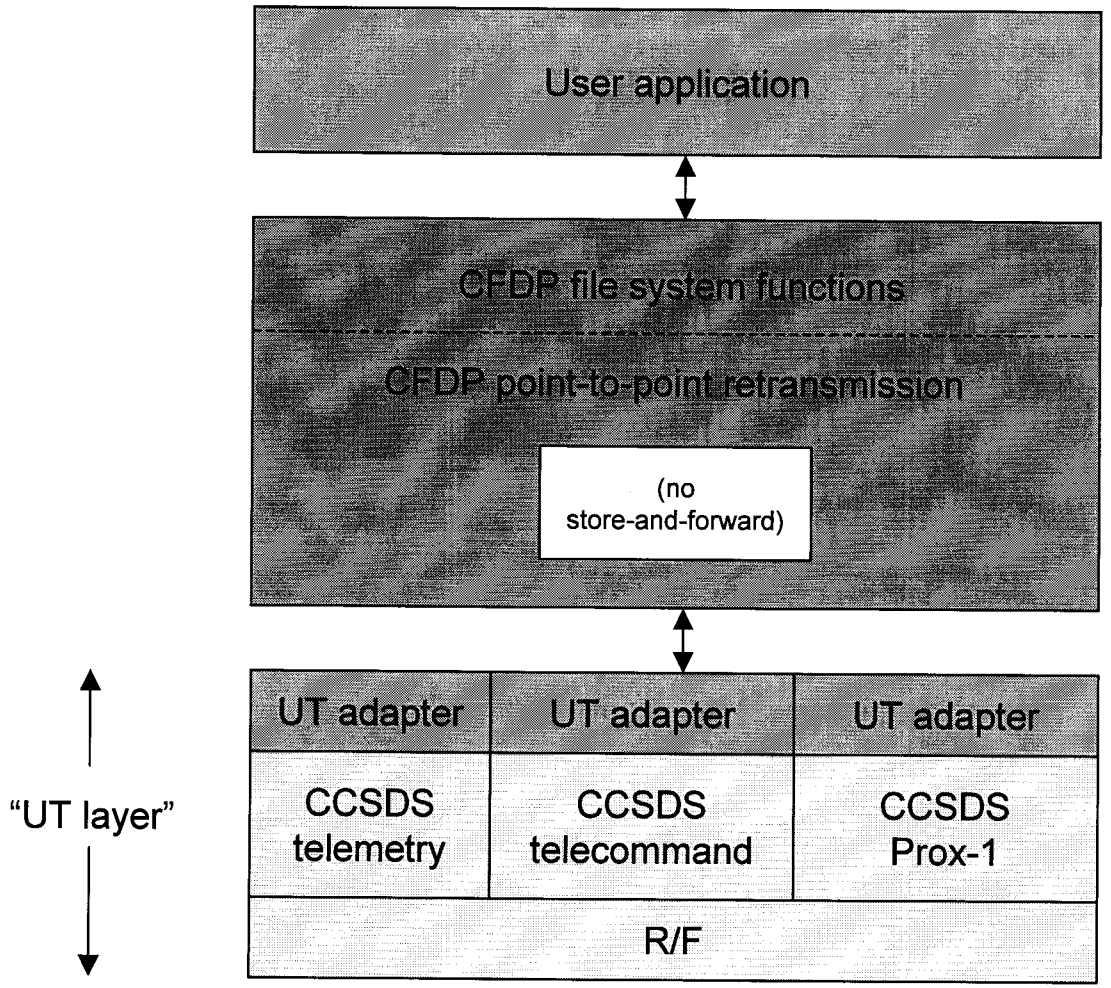
- Copies files between file systems across interplanetary distances. Tolerates arbitrarily long round-trip times.
- Deferred transmission: application can request a file transmission at any time, without knowledge of when the communication link will be available.
- Concurrent transfer transactions, multiple retransmission buffers, incremental (possibly out of order) delivery.
- Delivery is reliable: data are acknowledged, protocol automatically retransmits lost or corrupted data.
  - No operator intervention is required.
  - Unacknowledged transmission is also supported.
  - Native CRCs and file checksums, in addition to link layer FEC.
- "Flow labels" for control of transmission ordering.
- Files can be structured (e.g., CCSDS packets) or unstructured (octets). Segmentation on record boundaries as required.

Basic Deployment



- Premise: entities can communicate directly by R/F transmission.
  - Mutual line-of-sight visibility.
  - Compatible operating schedules: entity A can point at entity B and transmit at a time when entity B can point at entity A and receive.
  - Adequate links: sending entity has sufficient transmitter power and/or receiving entity has sufficient receiver power.
- Example: the Deep Impact comet investigation mission.
  - Paired spacecraft: impactor spacecraft will crash into comet Tempel 1, flyby spacecraft will use several instruments to observe results.
    - Spacecraft being built by Ball Aerospace for JPL.
    - Launch is in 2004.
  - CFDP will operate between the flyby spacecraft and mission control on Earth via DSN.
    - Unacknowledged transmission of science data to Earth.
    - Acknowledged (reliable) transmission of command files to spacecraft.

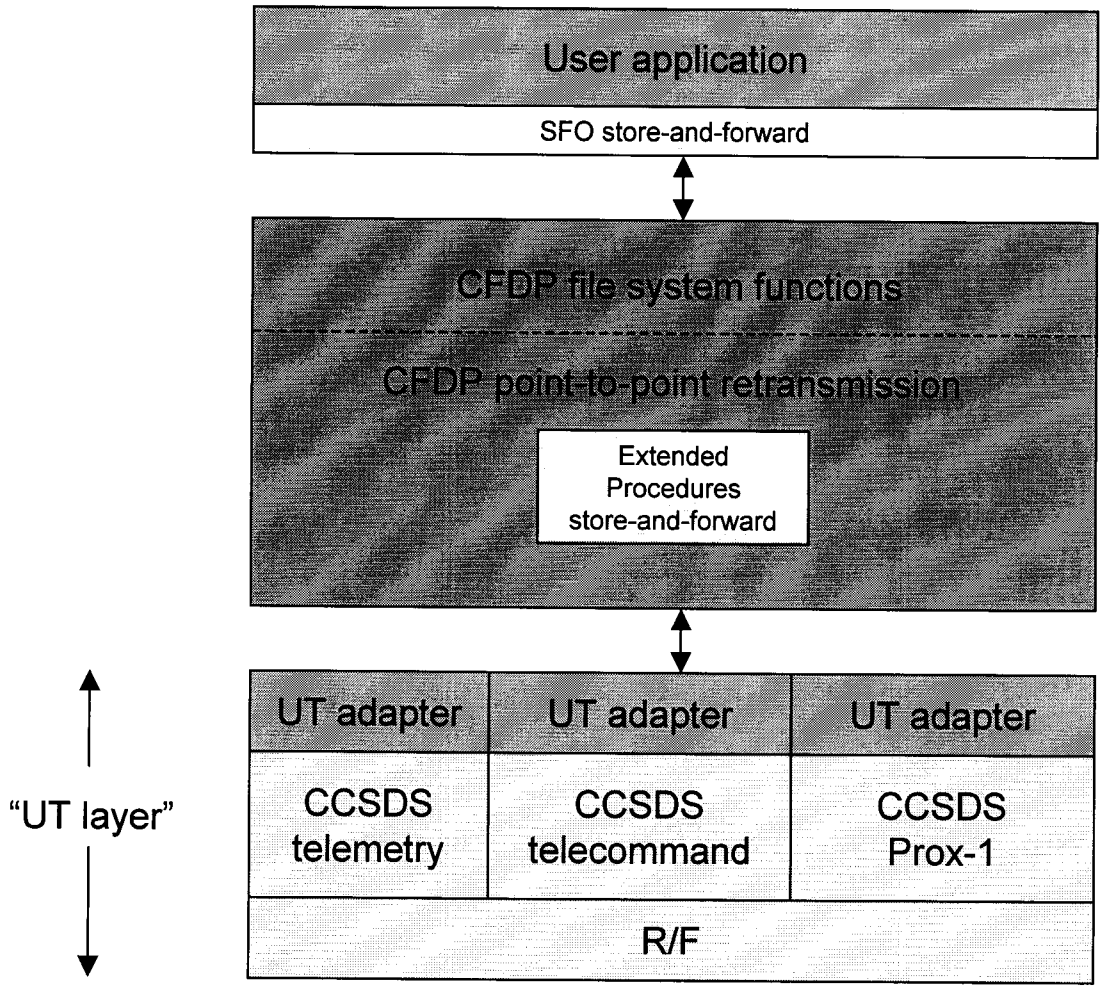
Core Architecture



Advanced Deployment

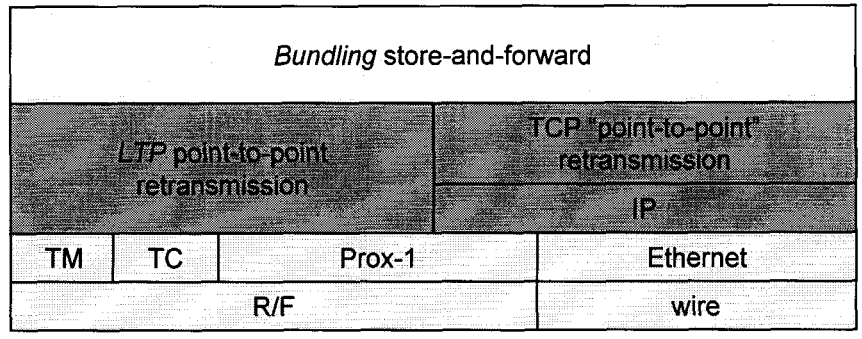
- Premise: entities cannot communicate directly.
  - No mutual visibility: intervening planetary mass, intervening Sun.
  - Incompatible operating schedules.
  - Insufficient transmission/reception power.
- So CFDP must support indirect communication, via "relay" or "waypoint" entities using store-and-forward techniques.
- Implementation options
  - Extended procedures
    - Additional functionality built into CFDP itself.
    - Implemented by ESA, will be implemented by JPL in FY03.
  - Store-and-forward Overlay
    - CFDP is left unchanged.
    - Additional functionality built into standard user application layer.
    - Implemented by JPL, may be implemented by ESA as well.

Extended Architecture

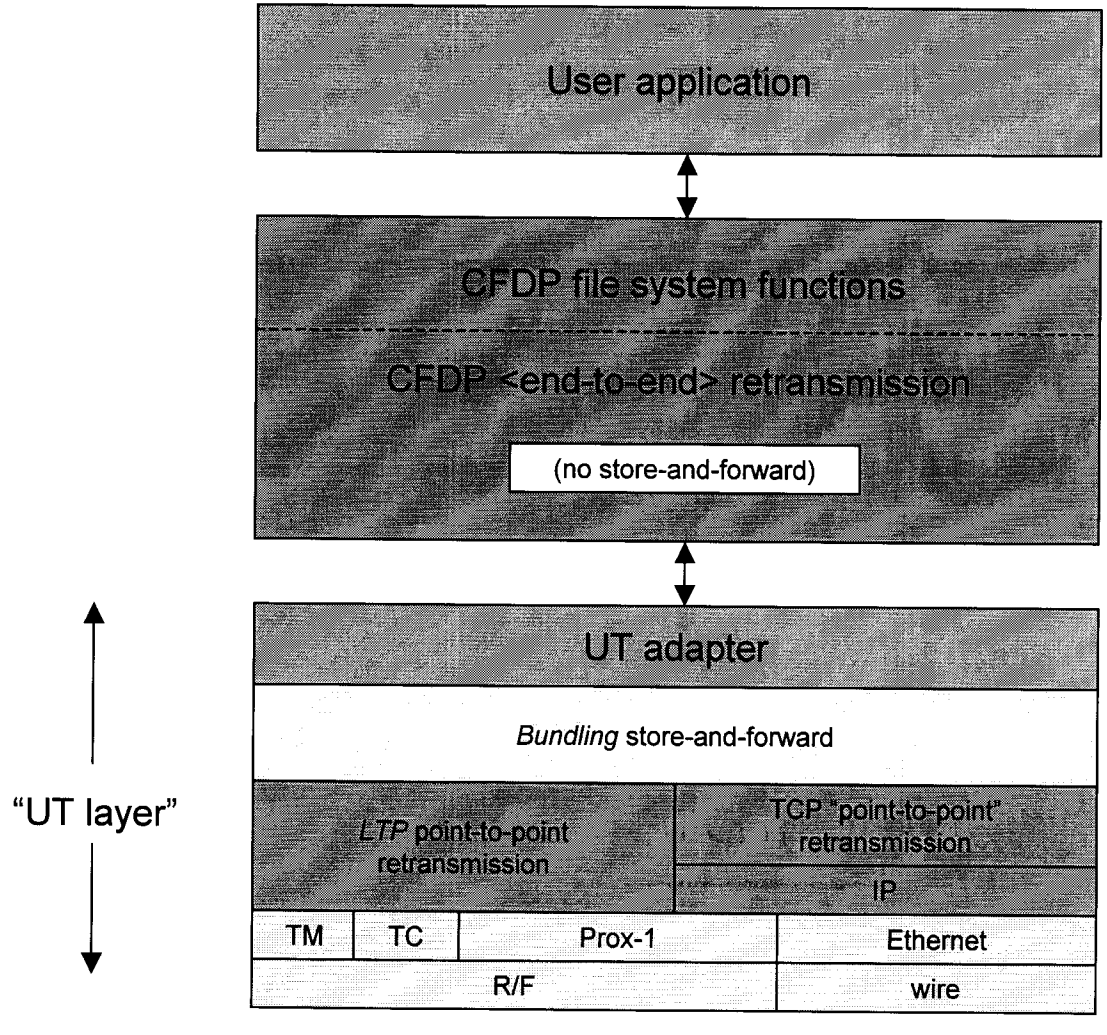


Interplanetary Internet

- General-purpose delay-tolerant networking capability.
- Operates within the same constraints as extended CFDP but scales better:
  - Built-in security (authentication and confidentiality).
  - Flexible, dynamic routing.
  - Less comprehensive than CFDP:
    - Gains greater leverage from capabilities of underlying protocols.
    - Better suited to end-to-end flow across heterogeneous environments.
    - Can be smaller and simpler.



Adapted Architecture



Status

- Prototype partial implementation of Bundling protocol has been developed.
  - Runs over TCP/IP and also over Sensor Net protocols.
  - Supports deferred transmission, non-volatile store-and-forward.
  - No security or schedule-driven routing yet.
- CFDP "UT layer" adaptation for Bundling has been developed.
- First informal demonstration of CFDP over Bundling at JPL on 23 May 2002.
- Planned for FY03:
  - Add security and schedule-driven routing to Bundling prototype.
  - Implement LTP and interface from Bundling to LTP.

CFDP: Looking Ahead

- A stable, internationally accepted mission operations standard.
- Supports reduced-cost mission operations based on reliable file transfer and remote file system management.
- Will become more capable and powerful as the Interplanetary Internet grows in scope and complexity.