Saratoga

a Delay-Tolerant Networking convergence layer with efficient link utilization

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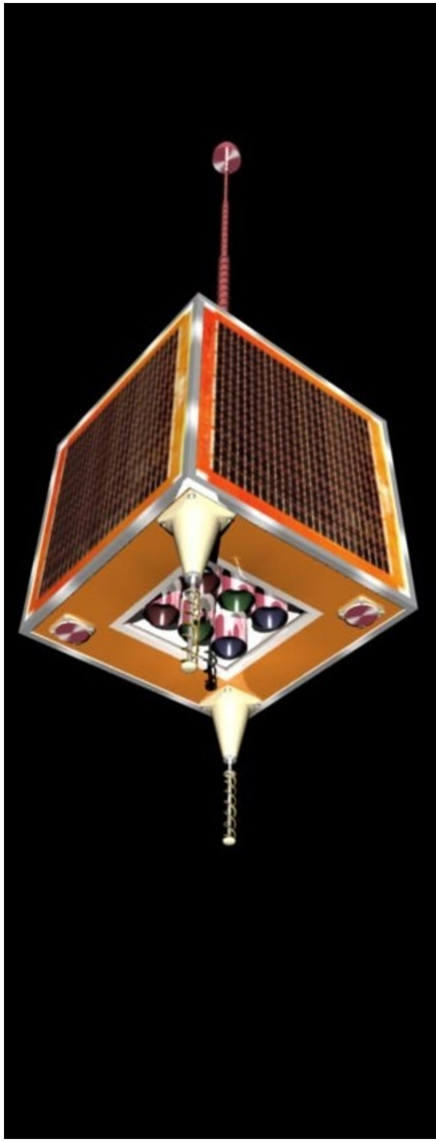
Introduction

- *Saratoga* is a simple file transfer protocol that can also be used to transfer DTN bundles.
- Developed by Surrey Satellite Technology Ltd (SSTL) to transfer remote-sensing imagery from its IP-based LEO satellites to ground.
- *Saratoga* is a good DTN convergence layer because it:
  - fully utilizes downlinks, even with a high degree of link asymmetry
  - runs over UDP/IP and/or UDP-Lite/IP, and thus many link layers



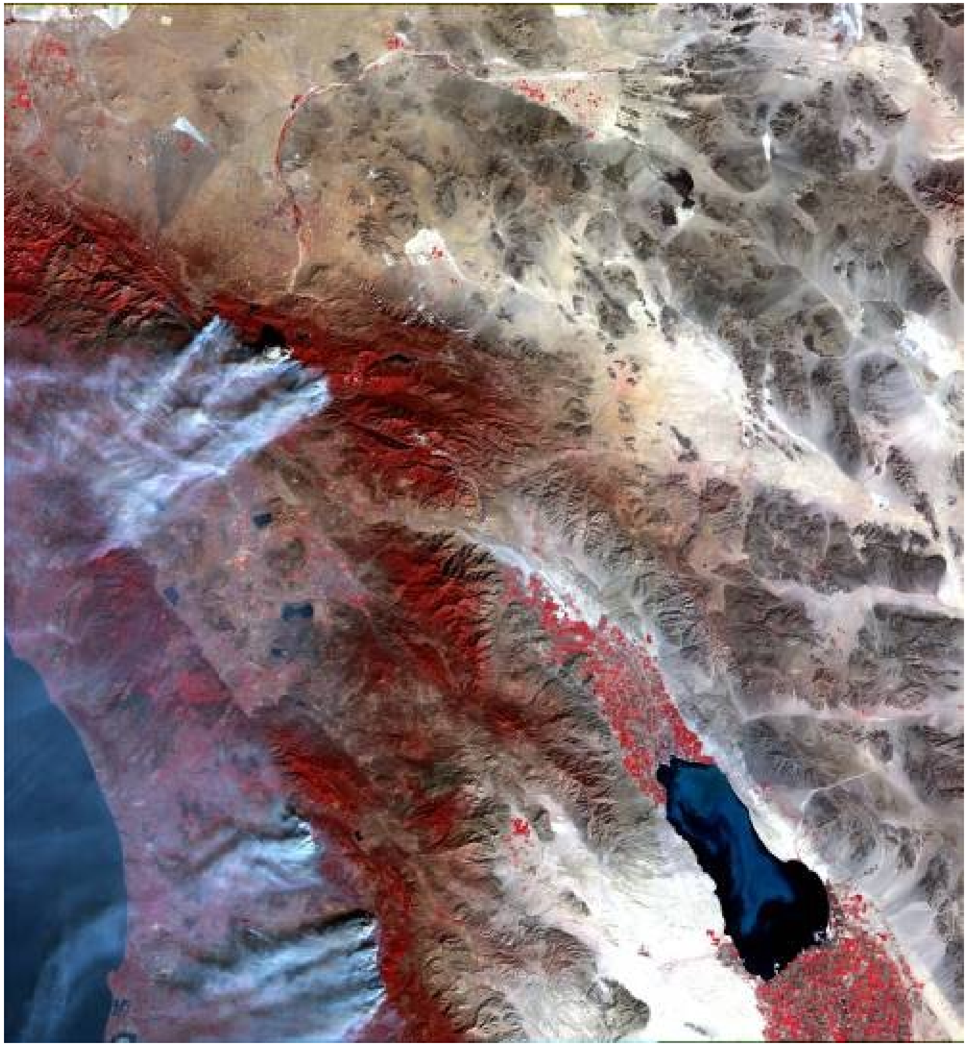
Disaster Monitoring Constellation (DMC)

Surrey Satellite Technology Ltd (SSTL) build and help operate an international constellation of small sensor satellites.

The satellites share a sun-synchronous orbital plane for rapid daily large-area imaging (640km swath width with 32m resolution). Can observe effects of natural disasters. Imaged the effects of Hurricane Katrina and the Indian Ocean Tsunami.

Government co-operation: Algeria, Nigeria, Turkey, United Kingdom, and China. Each government finances a ground station in its country and a satellite. Ground stations are networked together. Three more satellites have been announced and are being built.

www.dmcii.com



fires in California, 28 October 2003 (UK-DMC)

DMC in use: after Hurricane Katrina, 2005

In this false-color image, dry land is red. Flooded and damaged land is shown as brown.

Small part of an image taken by the Nigerian DMC satellite on Friday 2 September, for the US Geological Survey.

DMC is working as part of the United Nations International Charter for Space and Major Disasters.

Imagery delivered by using Saratoga over UDP.

Saratoga is in daily operational use.

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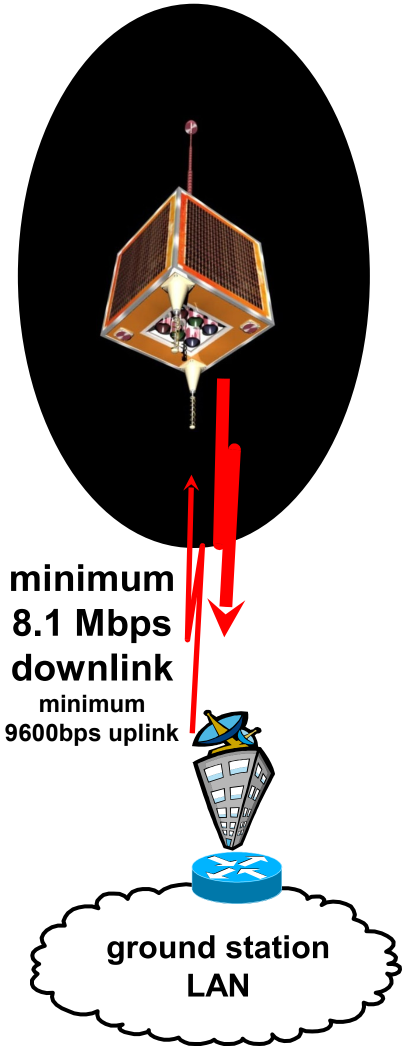
What environment does *Saratoga* live in?



Satellite: each DMC satellite has multiple onboard computers. For housekeeping (the On Board Computer, OBC), for image capture and packetised transmission (the Solid State Data Recorders, SSDRs), for redundancy and survival. Interconnected by IP over 8.1Mbps serial links for data and slower CANbus for backup control. Each satellite is a custom-built local area network (LAN).

Newer satellites also have 20/40 Mbps X-band downlinks for added hi-res cameras; faster downlinks (100+ Mbps) are planned for future missions. Uplink is only 9600bps for command and control. Uplink speeds are also likely to increase… to 38400 bps.
Very asymmetric; 850:1 or worse downlink/uplink ratio.

As much data as possible must be transferred during a pass over a ground station. Passes may be up to twelve minutes, depending on elevation. At 8Mbps, that's approximately 650MB of useful data (about a CD-ROM's worth) that can be transferred in a high pass – if you fill the downlink with back-to-back packets at line rate.
Link utilization *really matters*. SSDRs take scheduled turns filling link.

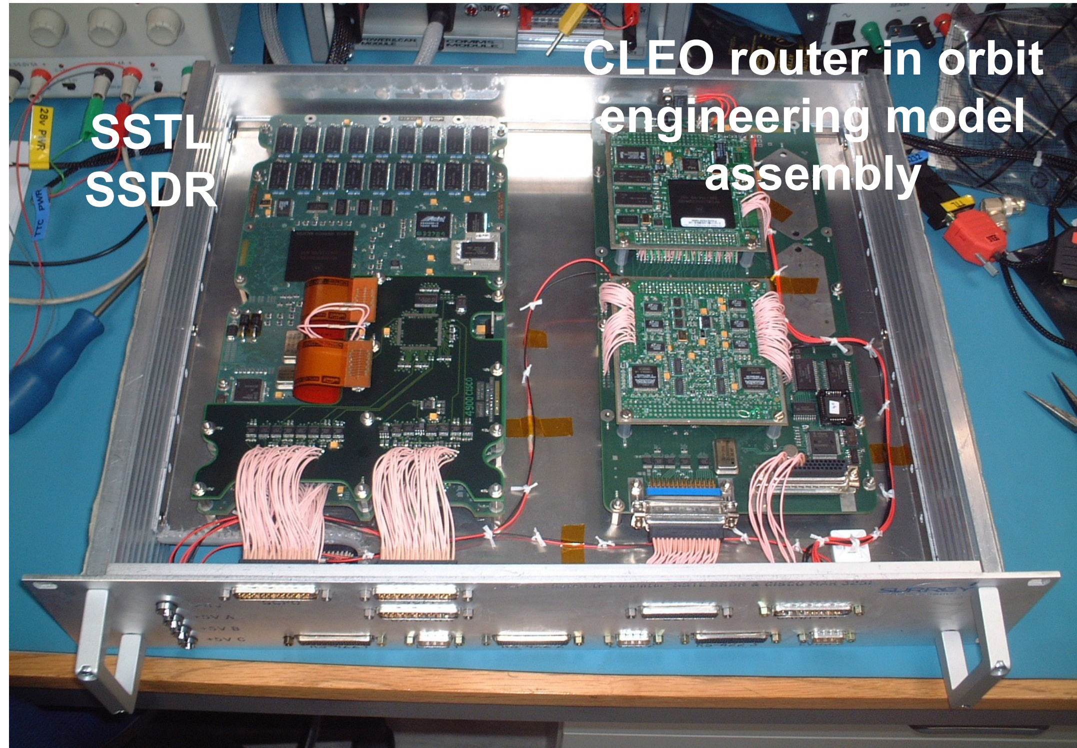
Ground-based testbed for development

NASA Glenn needed to gain familiarity with operating and configuring SSTL's onboard computers.

Ground-based testbed allowed configuration changes to be tested on the ground at leisure before being made to CLEO router in orbit or SSDRs during a ten-minute pass over a ground station.

Now using testbed in development role for flying *Saratoga* and DTN bundle code on UK-DMC satellite.

First actual bundle transfer from space planned in September 2007, using Saratoga.



Why are we pursuing DTN with DMC?

- **We believe IP is useful for operational use of DTN** – not *just* convenient/cheap for prototyping DTN code. (Being convenient/cheap are compelling reasons to use IP for DTN.)
- Because the DMC is an example of using IP both on the ground and in space, with the ground station acting as a gateway between types of use.
- Assumptions governing IP use (link use, shared contention *vs* dedicated scheduling models) differ between ground/space, but the protocol used remains the same. DMC can be seen as a prototypical DTN scenario, with long disruptions between passes over ground stations.

Basic *Saratoga* design

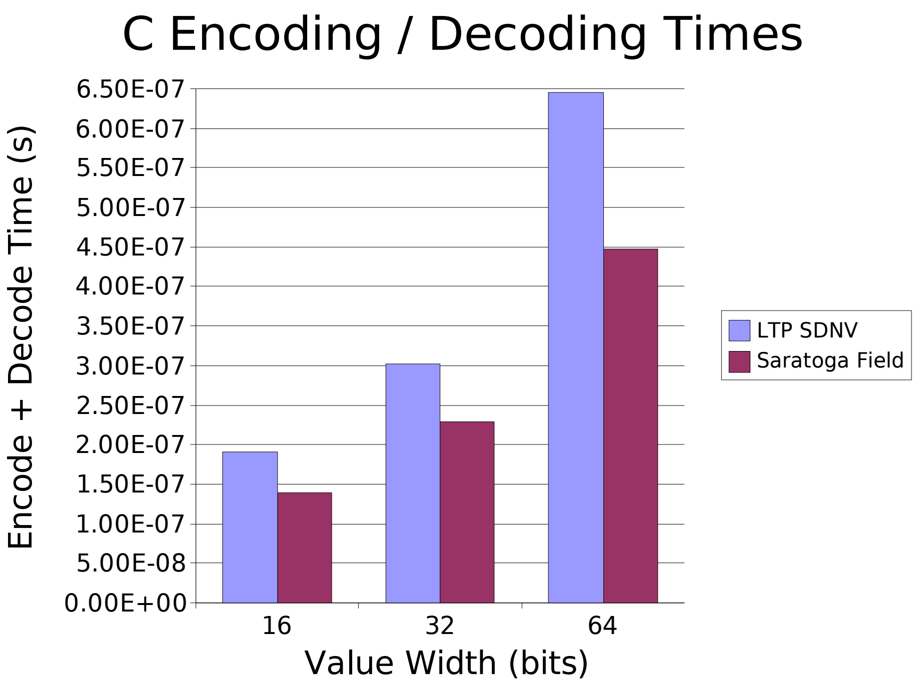
- Flood data packets out as fast as possible.
  - At link rate over satellite downlink or other private link
  - Using TFRC if in a shared Internet setting
- Every so often, ask for an acknowledgement from the file receiver. Receiver can also send ACKs if it thinks it needs to, or to start/restart/finish transfer.
- ACKs are Selective Negative Acknowledgements (SNACKs) indicating left edge and any gaps to fill with resent data.
- That's it. But just how big is a file/bundle?

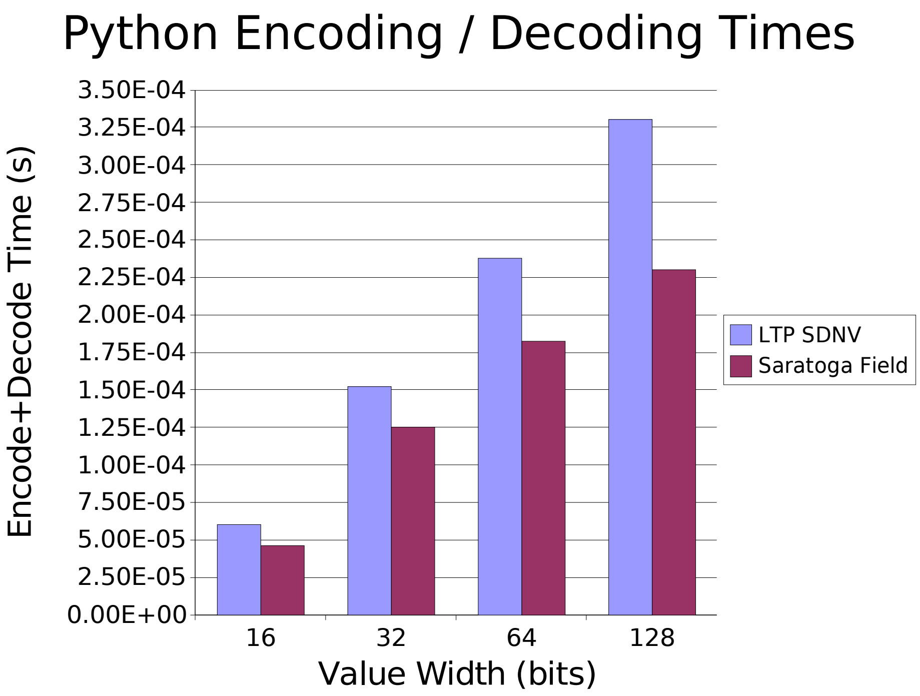
Filesizes can be *large*

- For the DMC, imaging files are big – typically up to a few gigabytes at 32m resolution; larger for newer cameras. So we think bundles will also be *large* – gigabytes and up.
- But ad-hoc/sensor nets also need to transfer small files/bundles; guessing a range limits use.
- So we allow a range of file-descriptor pointers to be advertised: 16/32/64/128-bit file descriptors.
  - Field width in use is determined by the needs of each particular transfer

Field Processing Overhead

- Using multiple fixed-length field widths is overall 25 - 33% faster than the SDNVs used in the Bundle Protocol and LTP.

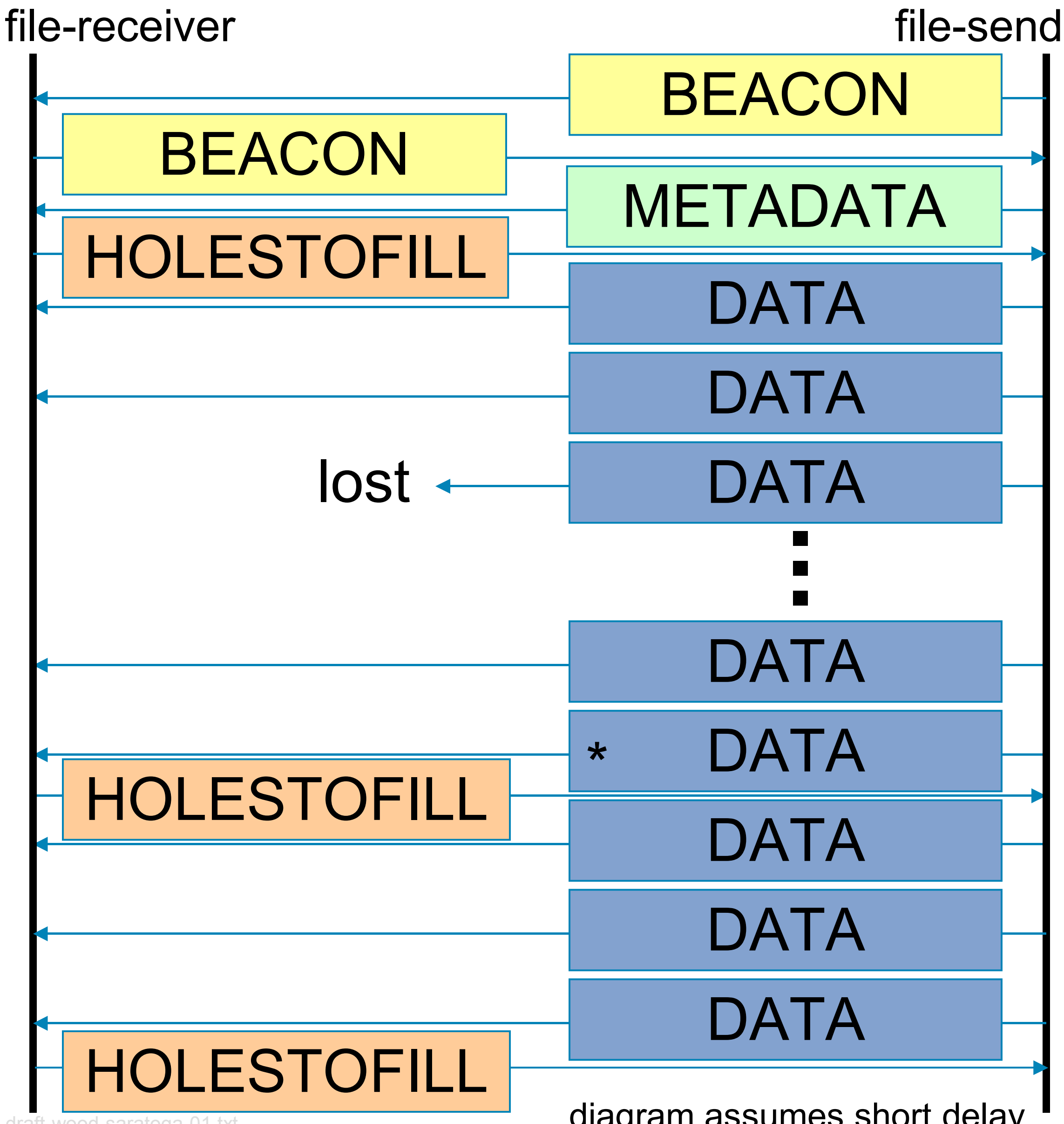




Saratoga packets

BEACON	Sent periodically. Describes the *Saratoga* peer: Identity (e.g. EID) capability/desire to send/receive packets. max. file descriptor handled (16/32/64/128-bit).
REQUEST	Asks for a file via ‘get’, directory listings, deletes.
METADATA	Sent at start of transaction. Describes the file/bundle: identity for transaction file name/details, including size. descriptor size to be used for this file (one of 16/32/64/128-bit pointer sizes.)
DATA	Uses descriptor of chosen size to indicate offset for data segment. May request an ack.
HOLESTOFILL	Ack. Can use the descriptor size to indicate offsets for missing ‘holes’ in data.

Saratoga transactions: 'put'



Beacons (optional); show filesize capabilities.

Describes chosen file.

Ack indicates reception.

Lost data creates hole in copy at receiver.

Ack requested and sent describing hole to be filled.

Empty ack indicates transaction is complete.

Saratoga transactions: ‘get’

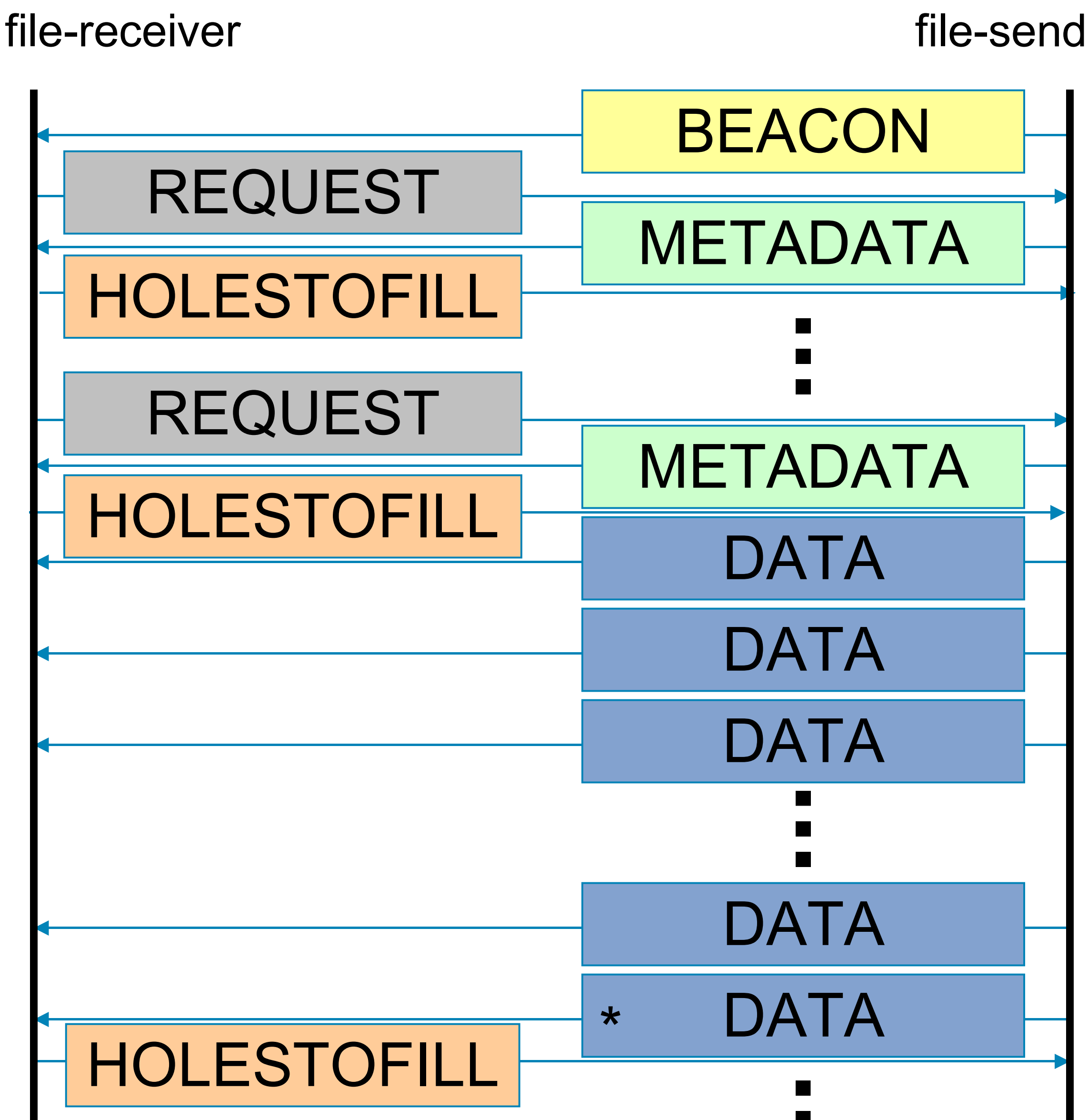


diagram assumes short delay

Beacon heard (optional).

‘getdir’ can request file list.

File list sent as file…

HOLETOFILL/DATA transaction omitted

‘get’ requests a file.

File is described.

METADATA is acked.

File data is streamed out directly after METADATA, without waiting for ack.

Ack requested and sent. Sender continues to send DATA.

Transport protocol matrix – where this fits

Characteristic / Reliability factor	congestion controlled	can be uncontrolled to fill dedicated links
permits delivery of errored content	DCCP (still uses checksum across headers for reliability)	*Saratoga* (reliable headers) UDP-Lite (reliable headers) LTP (green packets, headers are not checked for errors)
unreliable packet delivery	DCCP SCTP (with 'partial reliability' support)	*Saratoga* (streaming/no acks) UDP/UDP-Lite LTP (green packets, unacked)
error-rejecting reliable packet delivery	SCTP TCP	*Saratoga* LTP (but only with security/authentication)

Licklider (LTP) and *Saratoga* – comparison

Feature	*LTP*	*Saratoga*
large object transfers	yes (SDNV)	yes (descriptors)
works under high latency	yes	yes
robust checksummed format	via extension	**yes**
object integrity checksums	only with authentication	**yes**
supports delivery of errored data	yes (but not robust!)	**yes** (UDP-Lite)
includes object metadata	no (left to bundle)	**yes** (optional)
directory listings for file selection	no	**yes**
supports 'push' transfers	yes	yes
supports 'pull' transfers	no	**yes**
beacons for discovery and automated transfers	no	**yes** (optional)
multicast to many receivers	no	**yes**
handles asymmetry	yes	yes