Saratoga

fast data transfer… from space

draft-wood-tsvwg-saratoga

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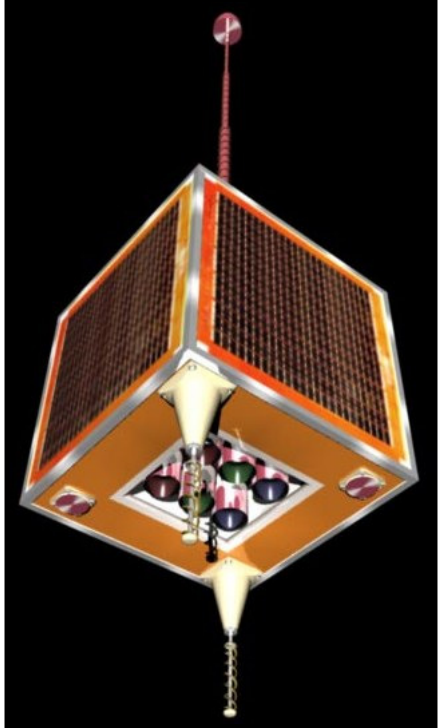
Short summary of *Saratoga*

- A simple, fast data transfer protocol ideal for file transfers across private links or for delay/disruption-tolerant networks (DTNs).
- Developed and in use by Surrey Satellite Technology Ltd (SSTL) to transfer remote-sensing imagery from IP-based LEO satellites.
- NASA Glenn has improvements to the base *Saratoga* design to create a new version of *Saratoga* described to the Internet Engineering Task Force (IETF): **draft-wood-tsvwg-saratoga**.
- We have developed and tested *Saratoga* with RTEMS-based computers on SSTL's UK-DMC satellite and in a ground-based testbed.
- We have multiple protocol implementations.



UK-DMC
satellite

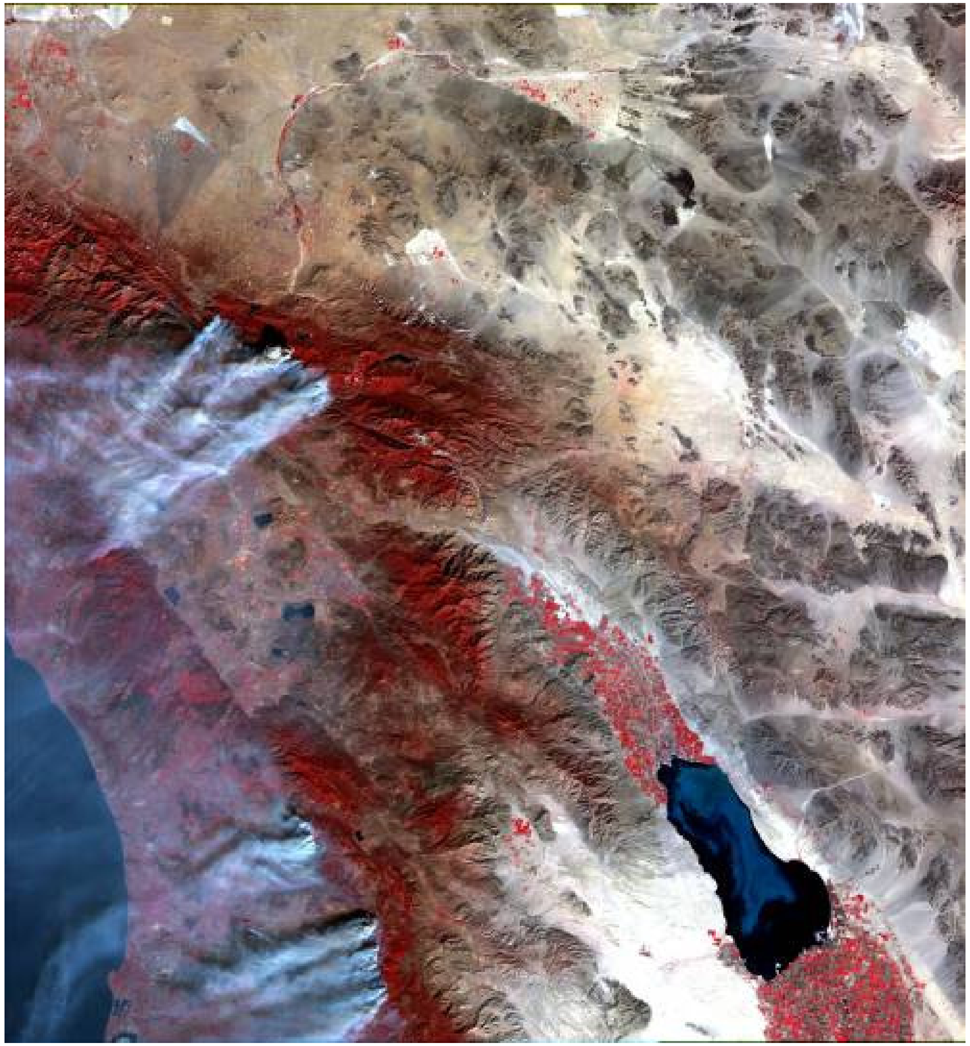
Disaster Monitoring Constellation (DMC)

SSTL build and help operate an international constellation of small sensor satellites.

These satellites orbit in 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. New satellites are being built and added to the constellation.

www.dmcii.com



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

DMC in use: after Hurricane Katrina, 2005

www.dmcii.com

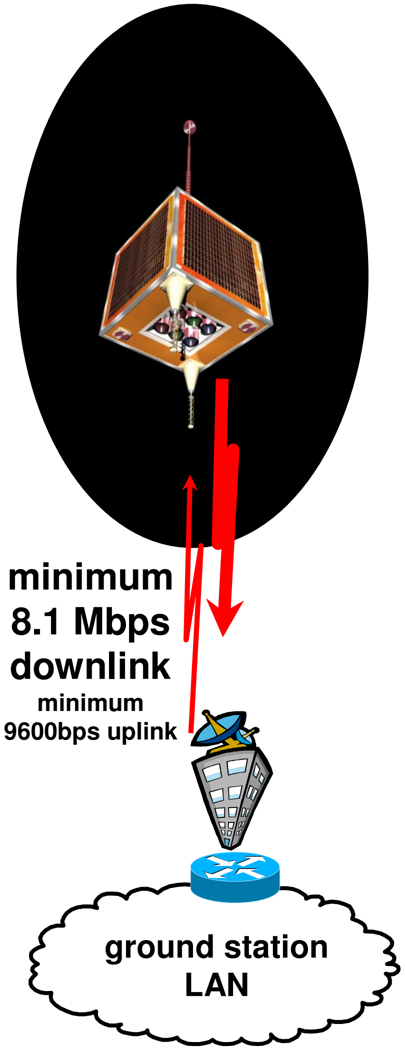
In this false-color image, dry land is red. Flooded and damaged land is shown as brown.

Small part of an image taken by the Nigerian DMC satellite on Friday 2 September 2005, for US Geological Survey.

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

All imagery delivered by using *Saratoga* over UDP/IP.
***Saratoga* is in daily operational use.**

How is *Saratoga* used in DMC operations?



Each DMC satellite has multiple onboard computers. The Solid State Data Recorders (SSDRs) control cameras and store and download images using *Saratoga* over UDP/IP.

DMC downlink for image files is a minimum of 8.1Mbps using S-band. Newer satellites also have 20/40/80 Mbps at X-band for added hi-res cameras; faster downlinks (100+ Mbps) are being readied for future missions. Uplink is only 9600bps for command and control. Uplink speeds are also likely to increase… but only 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 fourteen minutes, depending on elevation. At 8Mbps, that's approximately 650MB of useful data (about a CD-ROM-full) that can be transferred in a high pass – if the downlink is filled at line rate with back-to-back packets. Link utilization and efficiency *really matter*. SSDRs take scheduled turns filling downlink.

Ground-based testbed for development

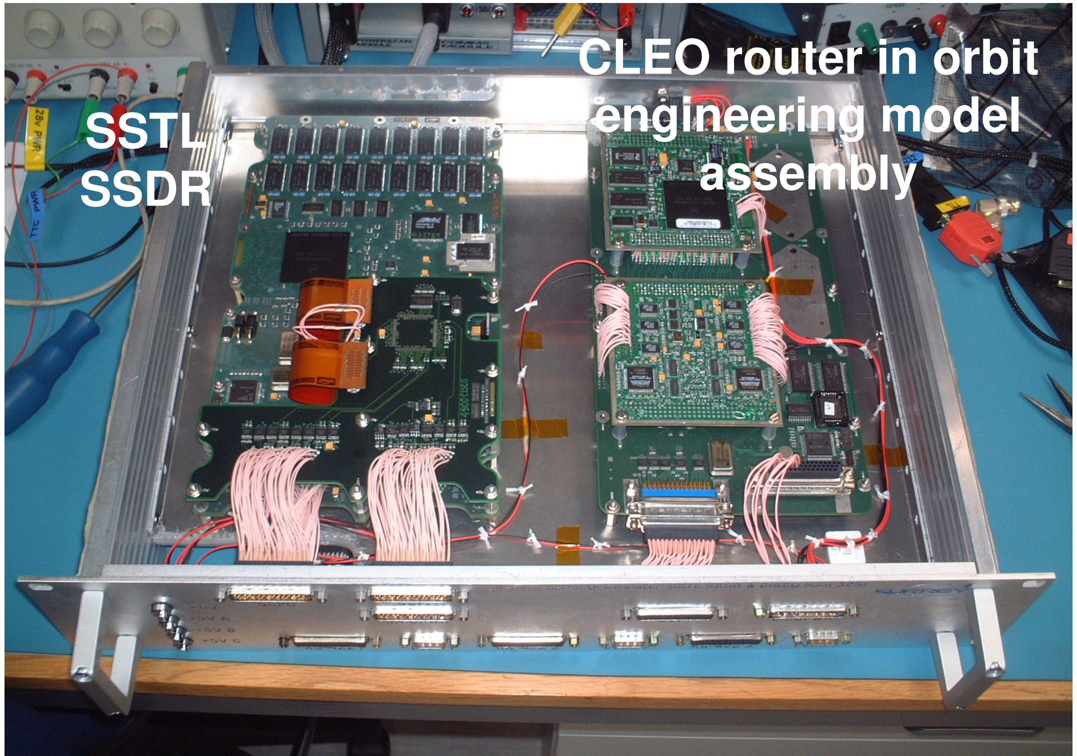
Originally built for Cisco's CLEO router in orbit on UK-DMC satellite.

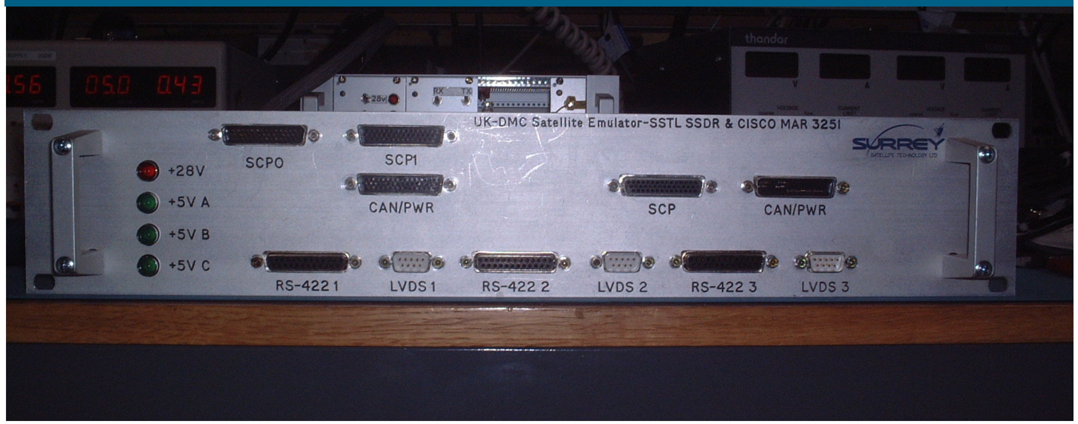
NASA Glenn needed to gain familiarity with UK-DMC and with operating and configuring SSTL's onboard computers.

Rack-mounted ground-based testbed ('flatsat') containing SSDR and networked it from NASA Glenn in Ohio, so NASA could get familiar with SSDR design and use.

Ground-based testbed allowed coding changes to be tested on the ground at leisure before being uploaded to onboard payloads during a pass over a ground station.

We have used testbed SSDR in development and testing role for flying *Saratoga* and DTN bundle code on UK-DMC satellite.





Basic *Saratoga* design

- Flood data packets out as fast as you can. No specified congestion control, since data is only going one hop over a private link. (No specified timers means no time*outs*, so *Saratoga* will be good for the very long propagation delays found in deep space.)
- Every so often, ask for a status 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 received packets and any gaps to fill with resent data (and with enough information so that intelligent sender rate control or congestion control can be optionally added if needed locally).
- Other telemetry can be multiplexed in as IP traffic.
- That's it. But just how big are the files being transferred?

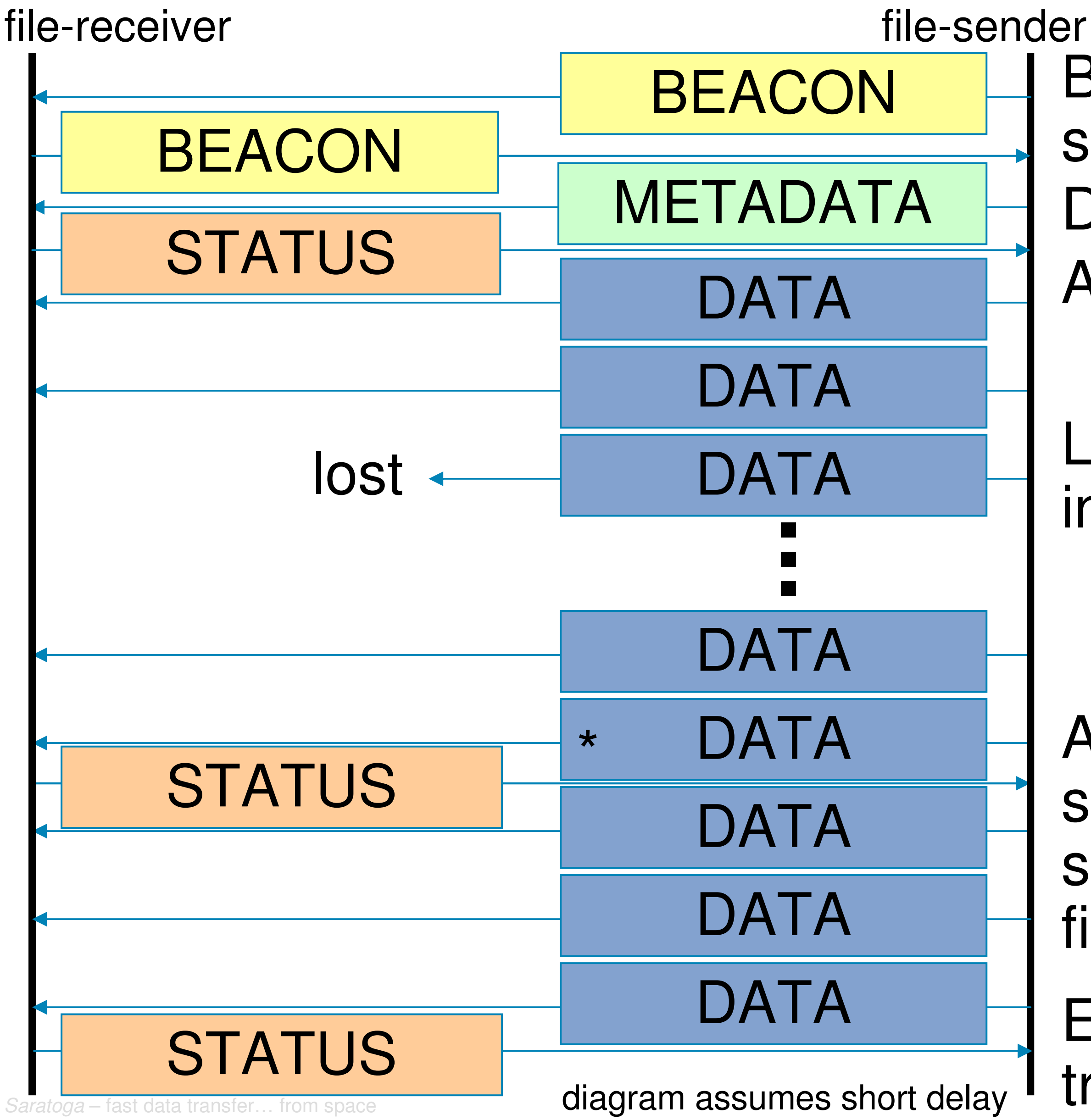
Filesizes can be *large*, streams can be f*ast*

- For the DMC satellites, imaging files are big – typically up to a few gigabytes at 32m resolution; larger for newer cameras. So we believe there is a need to transfer *large* amounts of sensor data – gigabytes and up. This will only increase over time as sensors and network links improve.
- But ad-hoc/sensor nets also need to transfer small files; guessing a range limits use.
- So we allow a range of file-descriptor pointers to be advertised: 16/32/64/128-bit file descriptors.
- If file is less than 64KiB, use 16-bit offsets. If file is larger but less than 4GiB, use 32-bit offsets…
- 16-bit offsets are *always* supported. Others are optional. Draft diagrams are all 32-bit, because that fits 80 columns.
- 128-bit descriptors are useful for petabyte-sized file transfers or for fast high-speed streams.

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 offsets 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.
STATUS	Selective negative ack (SNACK). ‘Holestofill’ hole edge offsets indicate missing ‘holes’ in data

Saratoga transactions: 'put'



Beacons (optional);
show filesize capabilities.

Describes chosen file.

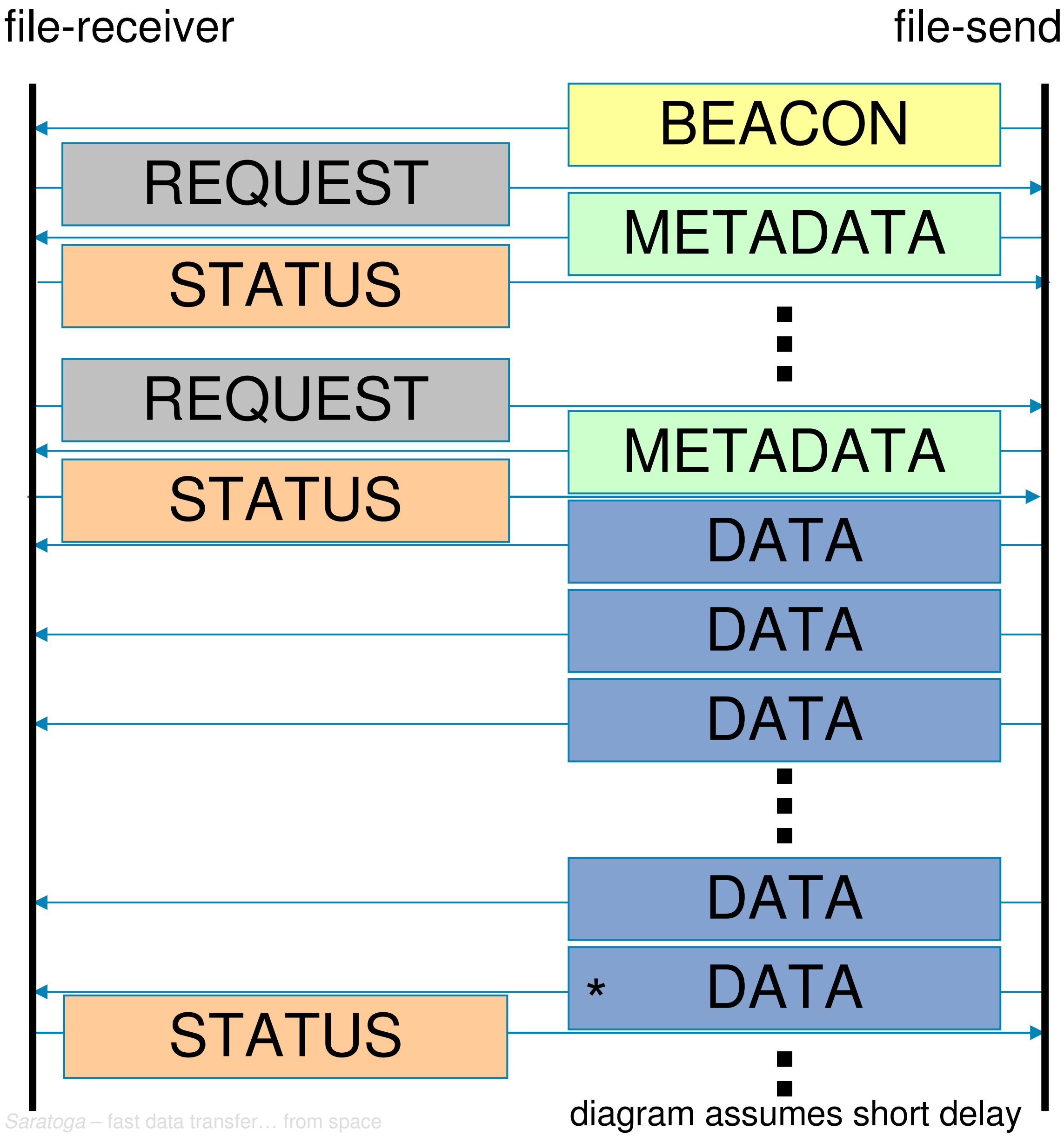
Ack indicates reception.

Lost data creates hole
in copy at receiver.

Ack requested and
selective negative ack
sent describing hole to be
filled with resend.

Empty ack indicates
transaction is complete.

Saratoga transactions: 'get'



Beacon heard (optional).
'getdir' can request file list.

File list sent as file…
DATA/'holestofill' STATUS exchange omitted

'get' requests a file.
File is described.
METADATA is acked.
File data is streamed out directly after METADATA, without waiting for ack.

Sender continues to send out DATA.
SNACK requested and sent.

Other optional *Saratoga* features

- **Streaming of data is supported. This allows *Saratoga* to be used for real-time delivery outside the file-based paradigm.**
- Can support checksums for reliable file delivery.
- Uses link-local multicast to advertise presence and discover peers. Data can be sent to local multicast addresses for multiple peers to receive.
- Also supports UDP-Lite for when errors in data received can be tolerated. Header content is always checked so that the information *about* the data is error-free. UDP-Lite use is expected to be rare; reliable transfers of data are the norm.
- *Saratoga* can also support “DTN bundle” delivery, and can act as a “bundle convergence layer.” We have experimented with *Saratoga* carrying DTN bundles from space. This is described in **draft-wood-dtnrg-saratoga**.

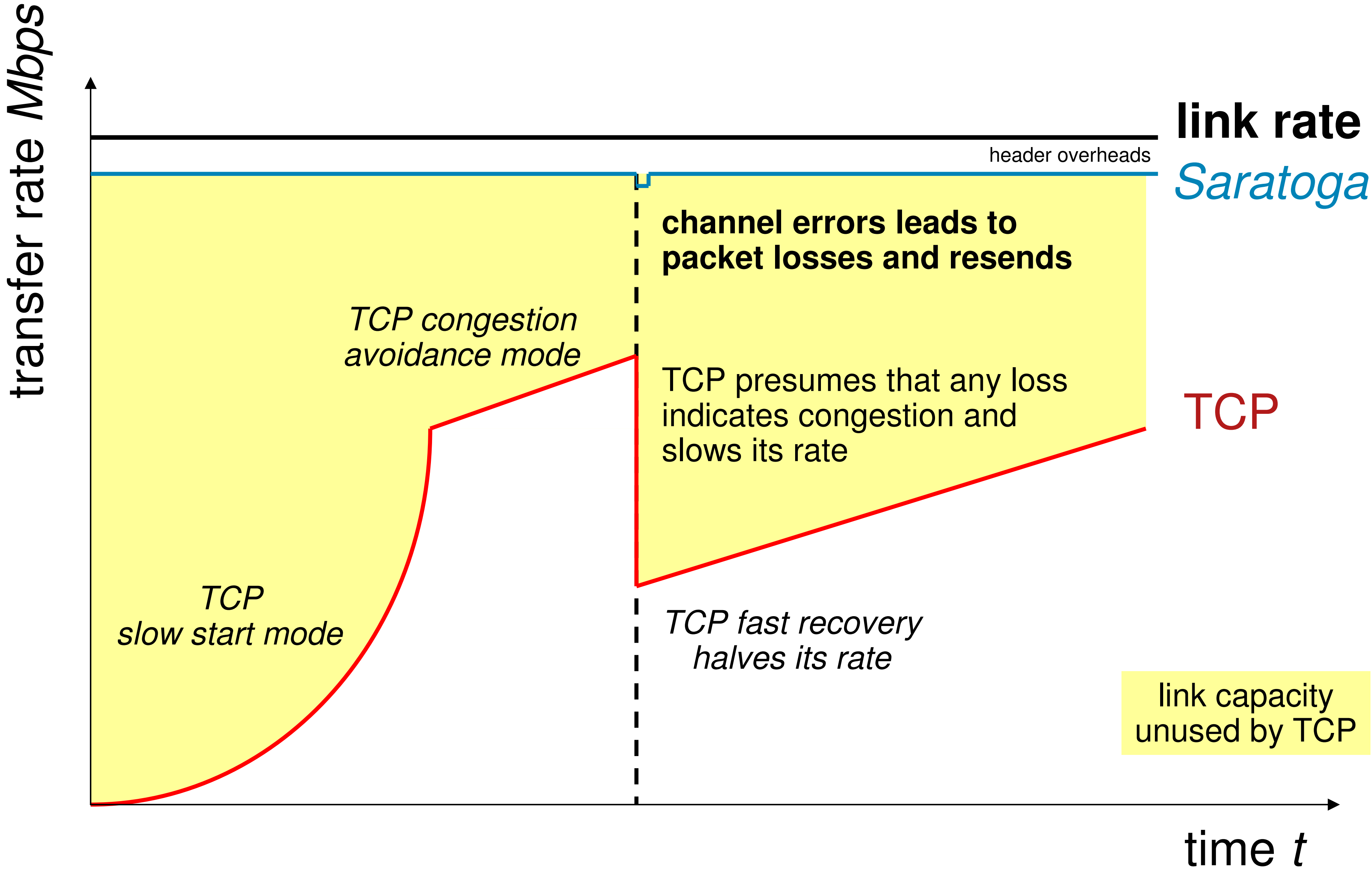
Saratoga can provide reliable transfers

- *Saratoga* uses the UDP checksum to cover header and payload. This is consistent but not that strong (one's-complement), and not end-to-end.
- An optional end-to-end checksum (CRC32c, MD5 or SHA-1) over an entire file being transferred can increase confidence that a reliable copy has been made, or that file fragments have been reassembled correctly. Strong link-layer checksums are optional.
- The alternative DTN research group "Bundle Protocol" and its convergence layers lack reliability checks. We have spent time examining that shortfall and proposing ways of adding reliability into the DTNRG bundle protocol.

Why *Saratoga* instead of TCP?

- For high throughput and link utilization on dedicated links, where a single TCP flow cannot fill the link to capacity.
- For links and link use where TCP’s assumptions about loss/congestion/competition simply don’t hold.
- Able to cope with high forward/back asymmetry (>850:1).
- Long delay use – eventually TCP will fail to open a connection because its SYN/ACK exchange won’t complete. TCP has many unwanted timers.
- Simplicity. TCP is really for a conversation between two hosts; needs a lot of code on top to make it transfer files. A focus on just moving files makes *e.g.* sequence nos. simpler. Having SNACKs means that handling sequence number wraparound when streaming becomes easy.

Saratoga vs TCP – a single flow



Our approach to DTN networking

- **We believe that the Internet Protocol (IP) is useful for operational use in delay or disruption-tolerant and in sensor networks.** IP runs across many links already; its engineering is well-understood.
- How IP is used differs between the public Internet and private space links (shared contention *vs* dedicated scheduling models – this discourages TCP reuse) but the base IP protocol is the same.
- DMC shows use of IP both on the ground and in space, with the ground station acting as a gateway between different types of network links and link use. DMC satellites provide a real DTN scenario, with long disruptions between contacts.

Possible applications of *Saratoga*

- In *any* private IP-based network where data must be moved as rapidly as possible over dedicated links.
- In private sensor networks generating large quantities of data and moving it from sensors to central processing, such as in remote-sensing satellites and for radio astronomy.
- In delay-tolerant networks.

Current status of *Saratoga*

- SSTL's initial *Saratoga* implementation remains in daily mission-critical operational use for downloads of Earth imagery.
- NASA Glenn Research Center has now conducted the first 'Interplanetary Internet' tests by sending DTN bundles using *Saratoga* from the UK-DMC satellite (2008).
- NASA Glenn and CSIRO continue to develop further *Saratoga* implementations with an eye to applications in other private sensor networks.

What prompted the name *Saratoga*?

Photo # 19-N-84312 USS Saratoga underway in Puget Sound, 15 May 1945

USS Saratoga (CV-3) is sunk off Bikini atoll.
Chris Jackson of SSTL has dived there.

http://tools.ietf.org/html/draft-wood-tsvwg-saratoga

http://info.ee.surrey.ac.uk/Personal/L.Wood/saratoga/

http://saratoga.sf.net/

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