Convergence-layer Protocols in Space Applications

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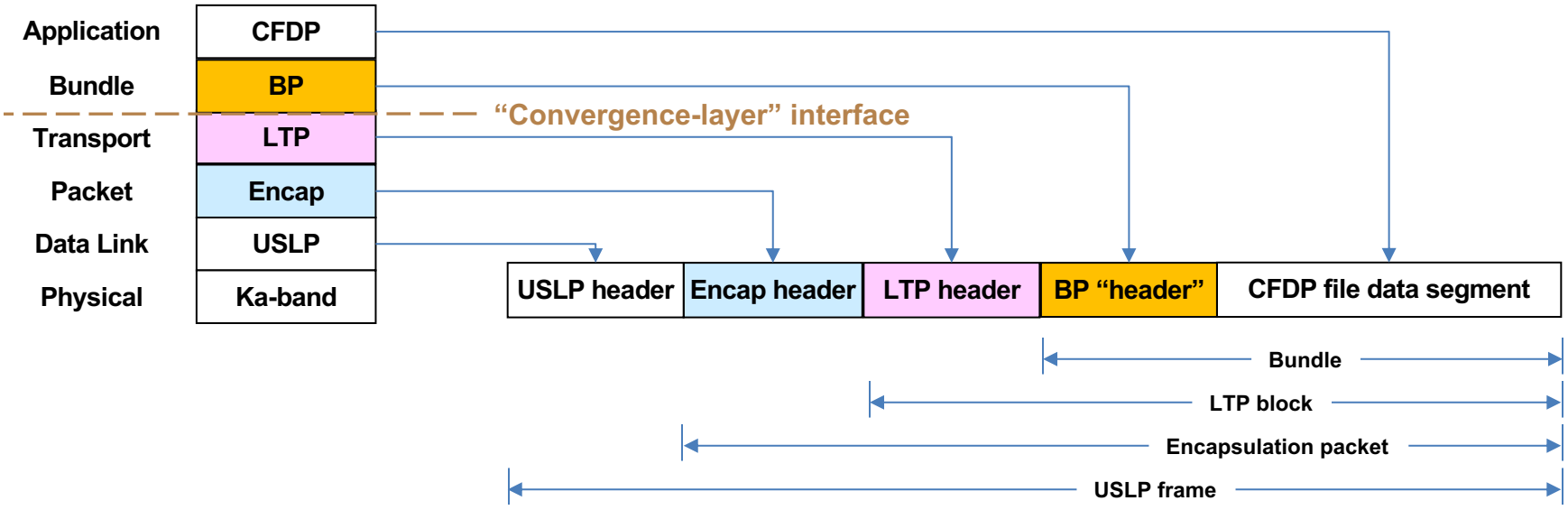
Quick Review (1 of 2)

- Just as in the Internet, the stacking of protocols for DTN is reflected in the structure of the protocol data units that are transmitted over the network.



Quick Review (2 of 2)

- The BPA doesn't physically radiate bundles; it invokes the services of other underlying protocols that are appropriate for the communication regime in which the bundles must be transmitted.
- Those underlying protocols form a subordinate stack of their own, as they perform communication functions of their own that ultimately rely on the electromagnetic radiation performed at the "physical" (lowest) stack layer.
- The topmost protocol in this subordinate stack – the protocol that directly interoperates with the BPA – is termed a *convergence-layer protocol (CLP)*.
- In order to invoke the service of the convergence-layer protocol (directly) and the other protocols in that subordinate stack (indirectly), additional software must be provided that accesses BPA functionality in a standard way and also utilizes the application programming interface of the convergence-layer protocol. This software is termed a *convergence-layer adapter (CLA)*.

Reliability

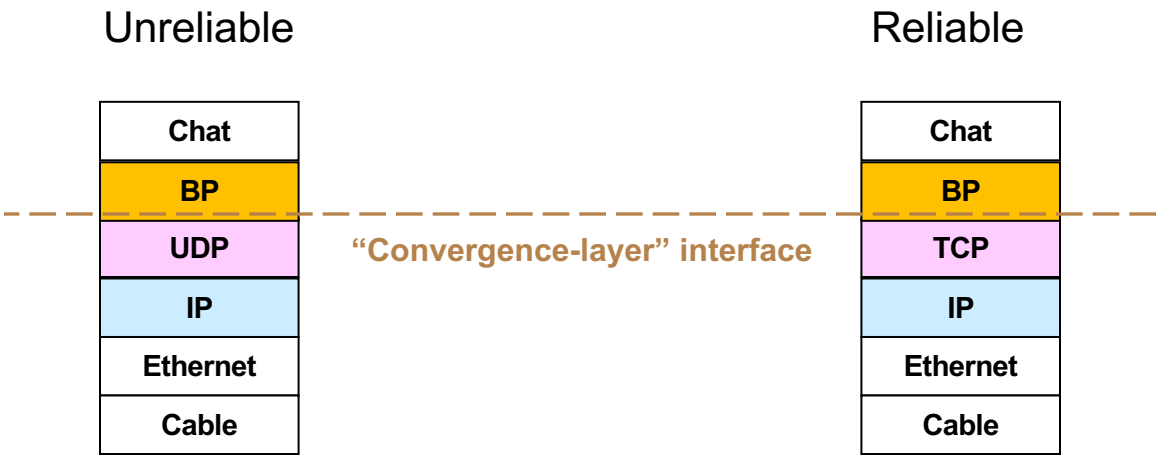
- *Reliability* in data transmission might be defined as simply the probability that a given item of transmitted data will arrive at its destination.
- Reliability is never 100%, because it is always (remotely) possible that the destination will no longer exist at the time the data item arrives.
- Network users don't demand the same level of reliability for all data:
  - For streaming video, arrival timeliness is typically more important than extremely high reliability: loss of an occasional isolated frame may not be noticeable.
  - For financial transactions, extremely high reliability is mandatory.
  - For emergency communications, failures in either timeliness or reliability may be fatal.
- Network protocols employ various mechanisms for increasing reliability:
  - Redundant transmission.
  - Data encoding, enabling recovery of lost data from concurrently issued "parity" data.
  - Retransmission upon reception of notices of data loss.

Reliability in DTN

- BP itself does not include any mechanism for increasing reliability in bundle transmission.
- So mechanisms for increasing reliability in bundle transmission must be implemented either:
  - At the application layer above BP in the protocol stack: bundles may include application-requested solicitation of data reception messages from the receiving application.
  - At the convergence layer below BP.
- Convergence-layer stacks may therefore be classed as either reliable (i.e, implementing some mechanism for increasing transmission reliability) or unreliable (i.e., not).

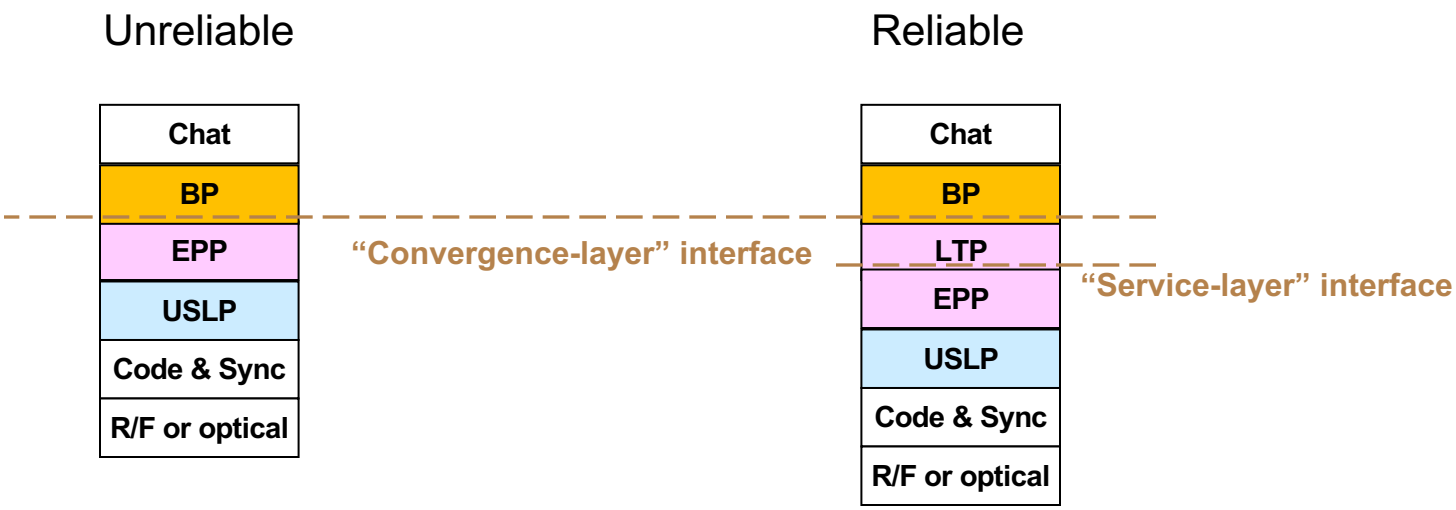
Internet-based CLPs

- An end-to-end network path in DTN may include one or more “hops” through the Internet, one or more “hops” over deep space links, or both.
- When a bundle is forwarded from one BP node to another through the Internet, the convergence-layer stack that is used may or may not be reliable.



Space-based CLPs

- Similarly, when a bundle is forwarded from one BP node to another over deep space links, the convergence-layer stack that is used may or may not be reliable. The protocols that are used are not as familiar as the Internet protocols, but they have similar properties.



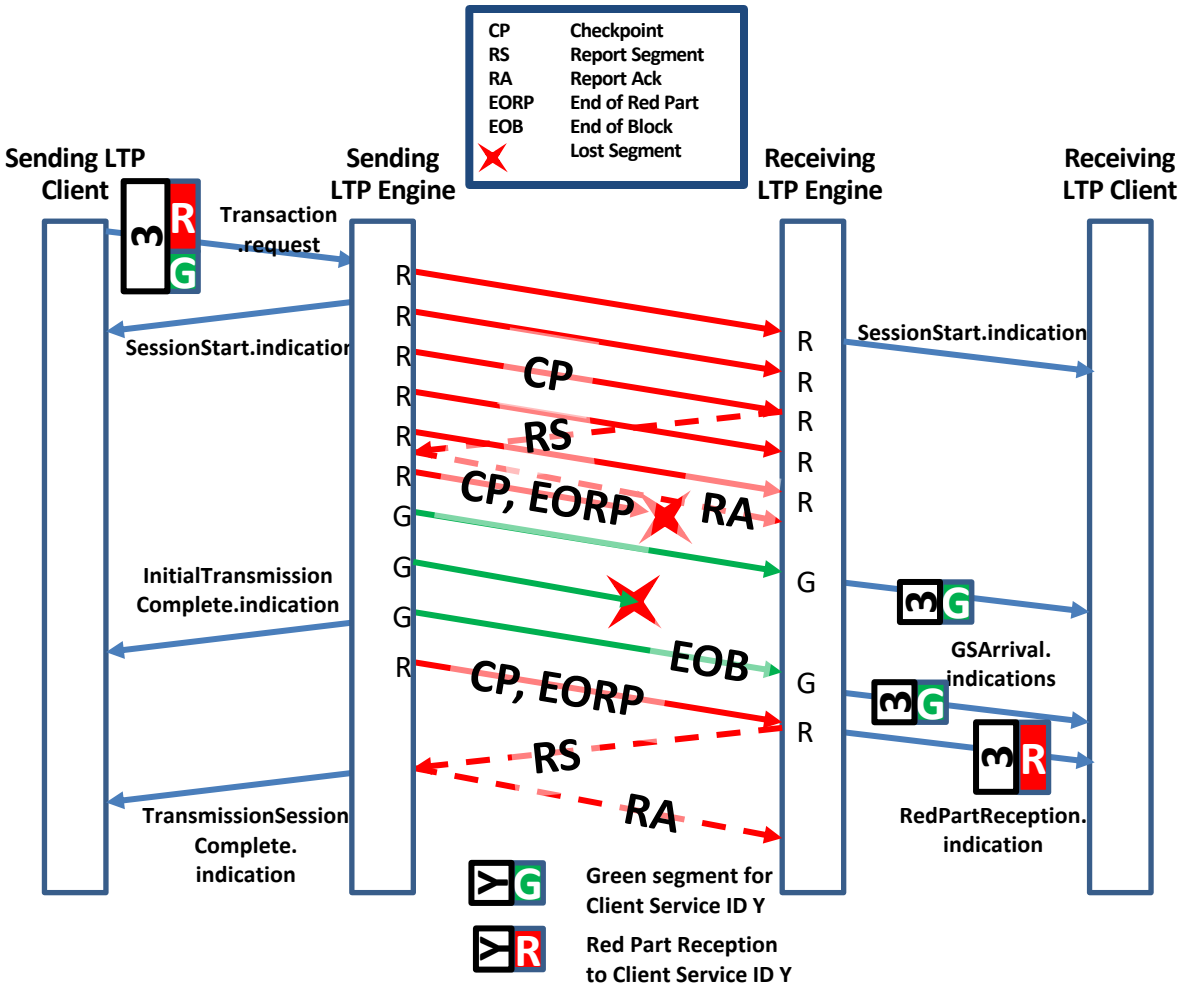
Space Link Protocols

- Development of internationally standardized protocols enabling successful communication over interplanetary distances began in 1982 when the Consultative Committee for Space Data Systems (CCSDS) was formed.
- A wide variety of communication protocols for space flight missions have been devised since then. Leading candidates for use in DTN include:
  - Encapsulation Packet Protocol (EPP) – see https://ccsds.org/Pubs/133x1b3e1.pdf.
  - Unified Space Data Link Protocol (USLP) – see https://ccsds.org/Pubs/732x1b3e1.pdf.
- These protocols implement forward error correction procedures that reduce the chance of data loss during transmission, but they don't include procedures that recover from any data loss that does occur. As with UDP/IP/Ethernet, we would not consider them reliable CLPs.
- The most widely implemented reliable CLP for space flight missions is Licklider Transmission Protocol (LTP).

LTP (1 of 3)

- Licklider Transmission Protocol is named in honor of Dr. J. C. R. Licklider, whose vision of the use of computers to augment and enhance human capabilities led ultimately to development of the Internet.
- The design of LTP is intended to enable retransmission-based reliability that is comparable to that of TCP but is suitable for use in a network where message round-trip times may be measured in hours or even days.
- To make this possible:
  - LTP is connectionless. When notified by a predefined *contact plan* (we'll talk about this later) that a communication opportunity has begun, it starts transmitting and receiving.
  - LTP computes retransmission timers from knowledge of the distance between nodes, not from analysis of acknowledgment latency.
  - LTP never waits for acknowledgment of one data item before sending the next. Data sent by LTP will not necessarily arrive in transmission order and there is no suppression of duplicate data arrival.

LTP (2 of 3)


CP Checkpoint
RS Report Segment
RA Report Ack
EORP End of Red Part
EOB End of Block
Lost Segment
Sending LTP Client
Sending LTP Engine
Receiving LTP Engine
Receiving LTP Client
Transaction request
SessionStart.indication
SessionStart.indication
CP
RS
CP, EORP
RA
InitialTransmission Complete.indication
EOB
GSArrival. indications
CP, EORP
RS
RA
TransmissionSession Complete. indication
RedPartReception. indication
Green segment for Client Service ID Y
Red Part Reception to Client Service ID Y

LTP (3 of 3)

- Like BP (and, in fact, like EPP), LTP does not physically radiate bundles; it invokes the services of other underlying protocols just as BP does, and again those underlying protocols form a subordinate stack of their own.
- The topmost protocol in this subordinate stack – the protocol that directly interoperates with the LTP engine – is termed a *service-layer protocol (SLP)*. In testing on the Internet, UDP is commonly used as the service-layer protocol; in real space flight operations, EPP will be more common.
- And again, in order to invoke the service of the service-layer protocol (directly) and the other protocols in that subordinate stack (indirectly), additional software must be provided that accesses LTP engine functionality in a standard way and also utilizes the application programming interface of the service-layer protocol. This software is termed a *service-layer adapter (SLA)*.

CLPs for Internet of Things

- Yet another class of convergence-layer protocols are being developed to support BP operations in a terrestrial Internet of Things. More on this from Samo.