Where Should We Store in Deep-Space IP?

Juan A. Fraire

(based on draft-many-tiptop-ip-architecture-02, §3.1)

Context and Question

- The draft proposes extending IP to deep space by queuing packets across long and intermittent links (minutes to hours).
- It recognizes that **buffering** may occur at **different layers**
  - *"This queuing may be implemented at **layer 2** as is currently done by the Mars orbiters…"*
  - *"If an **IP forwarder** has an interface on an intermittent link ... it buffers the IP packets locally…"*
- It leaves open where this function should reside in a generalized architecture.
  - At **which layer** should we store packets (or data units) to preserve **end-to-end semantics** and **performance**?

Storage Trade-Off by Layer

Shown for discussion — not prescriptive

Layer	Example Mechanism	Pros	Cons
Physical (PHY)	Analog or coded buffering in **modem storage**	Can absorb **micro-outages** **Simple and transparent** (minimal protocol awareness)	**No routing or re-tx awareness** **Expensive** and limited to **short-term** buffering
Link (L2)	CCSDS AOS, Prox-1, USLP **frame storage**	Proven **implementation heritage** **Simplifies IP and above layers**	**No per-flow prioritization/drop policy** Large buffers **complicate FEC states**
Network (L3)	**Pre- & Post-forwarding deep queues** in routers	Allows for **per-flow policies** Supports **multiple next-hops**	Requires extended **state management** Risk of **buffer exhaustion** at IP nodes
Transport (L4)	QUIC profile with **long-lived re-tx caching**	**End-to-end awareness** Supports **partial reliability & streams**	**Endpoints must maintain state** and **awareness on tx times** in-sync with lower layers
Above (L4+)	HTTP/CoAP caching, DTN **Bundle Protocol**	**Explicit Close-to-App control**	Requires **deep integration** and **app modifications** (not "just IP")

TIPTOP Forwarder (?)

Out of TIPTOP scope

Storage Scope by Layer

Shown for discussion — not prescriptive

TIPTOP Forwarder (?)

Layer
Physical (PHY)
Link (L2)
Network (L3)
Transport (L4)
Above (L4+)

Out of TIPTOP scope

Data Awareness	Policy Granularity	Internet Buffering	Deep Space IP Storage	Trade-Off
Bit level	No Policy Possible	Micro-seconds	Seconds/Minutes Hours/Days ?	Transparency Simplicity
Frame/Packet level	Per-Flow Policies	Milliseconds	Seconds/Minutes Hours/Days ?	
Transaction level	App-defined Policies	Tens of Milliseconds	Seconds/Minutes Hours/Days ?	Control Performability

Do we need a canonical answer?
Are there Interop risks (e.g., timers)?