Tortoise and Hare: Ways of Thinking About Mission Communications

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DTN Is Here

- Delay-Tolerant Networking (DTN) technology has matured over the past twelve years.
  - Internet RFCs: 4838 (Architecture), 5050 (Bundle Protocol [BP]), 5326 (Licklider Transmission Protocol [LTP]).
  - Registered Uniform Record Identifier schemes: *dtn*, *ipn*.
  - Open-source (SourceForge) implementations: *dtn*, *dtn-ion*.
  - Many research studies, theses and dissertations.
  - In continuous operation on the International Space Station since July of 2009.

So Why Isn't It On Your Laptop?

- There's more to do, still – standardizing network management and routing in particular.
- Mainly, though: ***where are the applications?***

Is DTN a Niche Technology?

- DTN enables network communication when round-trip message latency – "delay" – is high, right?
  - But signal propagation latency is negligible on Earth and in Earth orbit, where almost all communication happens. Is DTN only useful in deep space?
  - Well, no, round-trip message latency is also caused by link disruption. But do we need a general solution for this? Why not just do some intensive engineering on the dodgy links: application-layer proxies, PEPs, TCP tweaks (BIC)?
- What can I do with DTN that I can't already do in the Internet? What's the "killer app" for DTN?

Toward an Answer

- There's a good answer to that question, but to reach it we may need a new perspective on DTN.

  Forget about delay for a moment: think of DTN as networking that is relentless.

- To be robust enough to use in interplanetary space, it has to be.
- If your home Internet Service Provider often returns transient "server not found" messages (mine does), you could seek a better ISP – or you could use DTN.

But wait…

- Isn't the Internet already "relentless"? Wasn't survivability what Paul Baran was aiming in 1964 – a network with enough redundancy and resilience to withstand even a nuclear attack?

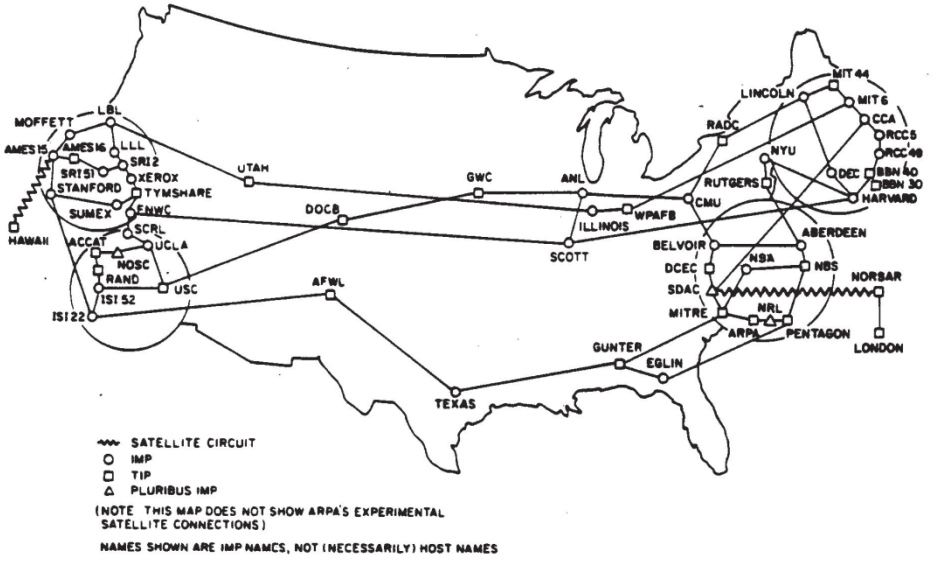


Figure courtesy of Defense Advanced Research Projects Agency.

Sure….

- ….but consider the nature of the redundancy:
  - The Internet is built on **connections**, continuous conversational data exchanges over end-to-end paths.
  - Multiple cross-links in the Internet enable a connection to switch immediately from one end-to-end path to another when a link is lost.
  - So in the Internet, connections are explicitly preserved. This implicitly preserves the data moving through the network.

Internet Robustness

- The Internet backbone of buried optical fiber cables is highly redundant and robust. However:
  - Tier 3 networks are not always as robust as the backbone.
  - ISPs' networks can be shut down by just throwing circuit breakers for a few key routers, as in Egypt in January 2011.
  - Wireless links extend the scope of the Internet but are far more fragile.
- When end-to-end paths become impossible, connections can't be preserved.
- Losing the connections causes data to be lost.

DTN Robustness

- In DTN there is no connection concept:
  - DTN is built on discontinuous atoms of data, **bundles**, that flow between topologically adjacent network nodes whenever transmission opportunities arise.
  - Multiple contact intervals between pairs of adjacent nodes enable each bundle to flow toward its destination in its own way, in its own time.
  - But between transmission opportunities, the bundles reside persistently and securely in nodes' local storage.
  - So the data themselves are explicitly preserved.

The Difference

- **Data preservation in DTN is explicit rather than implicit.** It is supported directly, by protocol design, rather than indirectly by infrastructure design. It is enacted in the general case, rather than only in the special case of connection preservation.
- What makes this possible is that DTN is based on a general model of *asynchronous* communication, of which the Internet's connection concept – a type of *synchronous* communication – is a special case.

Communication Structures

- Connections are *conversational*, synchronous structures, like phone calls:
  - Both communicating entities are concurrently engaged.
  - Latency in the exchange of data between the entities is minimal and predictable.
- Message (e.g., bundle) exchange is an *epistolary*, asynchronous structure, like sending postcards:
  - The communicating entities may or may not be concurrently engaged; no constraint.
  - Latency in the exchange of data may or may not be minimal and predictable; no constraint.

The Robustness of Asynchrony

- You can always use conversational infrastructure for successful epistolary communication – e.g., you can take turns reading postcards aloud over the phone. But the reverse doesn't work.
- Epistolary communication is the general case: the conditions required for its success are a proper subset of the conditions required for the success of conversational communication.
- Since it's less demanding, it succeeds in a larger number of operational scenarios. It's more robust.

This Is Nothing New

- Humans have used both asynchronous and synchronous communication for thousands of years.

The Conversational Model

- Conversational communication is “closed-loop”:
  - Say something.
  - Wait for the response.
  - Hear the response.
- This was the earliest communication: it began when humans acquired spoken and gestural language.
- It was only possible between people who were in the same place at the same time.
- But the bandwidth was very high.

The Epistolary Model

- Epistolary communication is “open-loop”:
  - Write a message and have it carried to another person.
  - Do other things while the message is carried and delivered, and a response message is returned.
  - Receive the response message.
- This began at the start of civilization, when written language was invented.
- It made communication possible across thousands of miles or hundreds of years.
- But the bandwidth was low: originally, limited by walking speed.

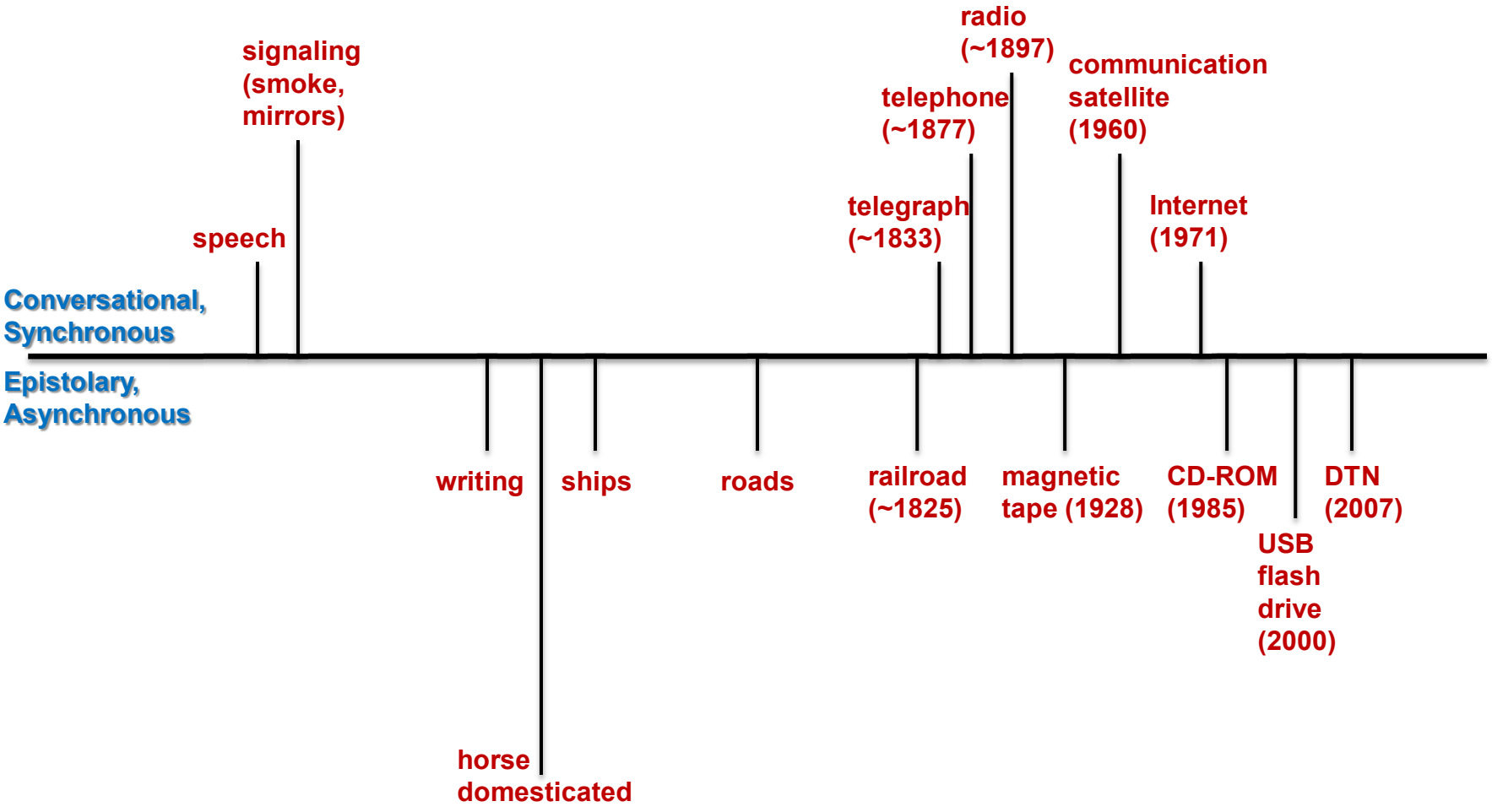
A Dynamic Balance

- The balance between reliance on the conversational and reliance on the epistolary is always changing:
  - With geographical expansion, round-trip time (signal propagation latency) increases and the role of asynchronous communication increases.

    Empires were operated by courier and postal systems.
  - With improvements in technology, round-trip latency decreases and the role of asynchronous communication decreases.

    The telegraph made the Pony Express obsolete.

Communications Technology Timeline



The Conversation Explosion

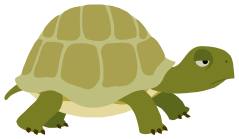
- Telegraphy: signaling by electricity.
- Telephony: audio telegraphy – speech by electricity.
- The design of Internet was inherited from telephony, though based on managing connections by packet switching instead of circuit switching.
- Many Web applications replace what you would otherwise do by telephone.

The Age of the Epistle

- But even in the era of the telephone we still rely on asynchronous communication – now more than ever:
  - Answering machines, voice mail.
  - Email.
  - Facebook.
  - Twitter.
- And as we expand into the solar system, the historical pattern re-emerges: with this immense geographical expansion, round-trip times again increase and we need DTN.

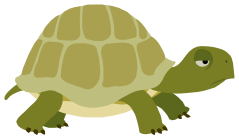
Tortoise and Hare

When a connection is possible:



Tortoise and Hare

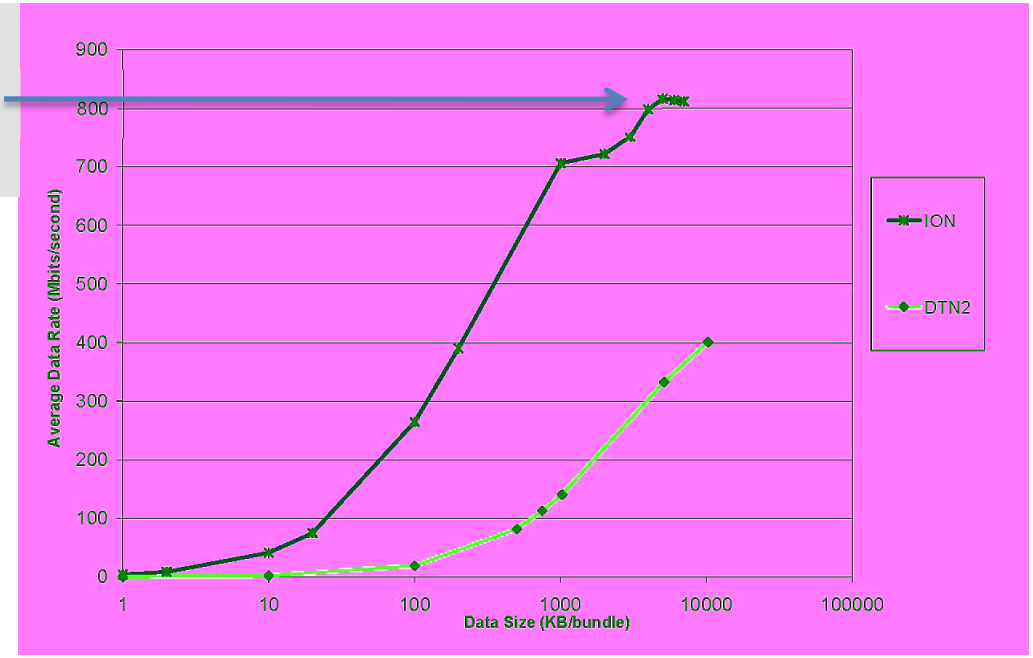
When connections aren't always possible:



Relentless Communication

- DTN is that tortoise, that keeps on working no matter what happens in the network – except that it does not have to be slow when conditions are good:

800 Mbps on a Gigabit Ethernet, sending 4-MB bundles*.



*Courtesy of The Mitre Corporation

Where Can DTN Help?

- If DTN is the latest step in the evolution of epistolary communication, what does that tell us it's best for?
- What have we always used postal systems for?
  - Transmission of data that must reach its destination, eventually.
  - Transmission of data that would be difficult to re-transmit from the source in the event of data loss.
  - Transmission of *policy* – information that enables the recipient to make correct decisions locally, instead of asking some central authority to make those decisions.

Applying DTN (1 of 2)

- Internet applications, not suitable for DTN:
  - telnet, ssh, Skype
  - most Massively Multi-player Online Games
  - interaction-intensive e-commerce, e.g., stock trading
- DTN applications already contemplated:
  - e-mail (Internet e-mail is already delay-tolerant)
  - file transfer (e.g., CCSDS File Delivery Protocol)
  - non-instant messaging (e.g., CCSDS Asynchronous Msg Svc)
  - policy-driven Web browsing (e.g., World Wide Web Offline Explorer [WWWOFFLE])

Applying DTN (2 of 2)

- DTN applications that nobody's working on (I think):
  - Warning systems, distress signals. "Black box"-like diagnostic transmissions. Digital message in a bottle.
  - Transmissions of formal agreements, documents of record.
  - Transmissions from security cameras.
  - Investigation logs. Research notebooks. Journalists' dispatches.
  - Transmissions of backup data.
  - Time-tagged state information, for managing confidence-weighted situational awareness displays.

The Killer App?

- Conversational communication is great for hands-on, interactive control – like running a power plant or piloting a UAV. But you can't use it to direct entities who are not in continuous contact.
- Humans and machines who venture outside of the Internet blanket must make operating decisions autonomously, using the best available information.
- *DTN-based distribution of policy and status is the best available technology for supporting operational autonomy*.

…As In Deep Space

- So we're back where we started – sure, we need DTN for interplanetary space – but maybe with a perspective on how that relates to problems closer to home.
- Now to get it running on my laptop…