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An approach to Interplanetary Internet

DELAY-TOLERANT NETWORKING

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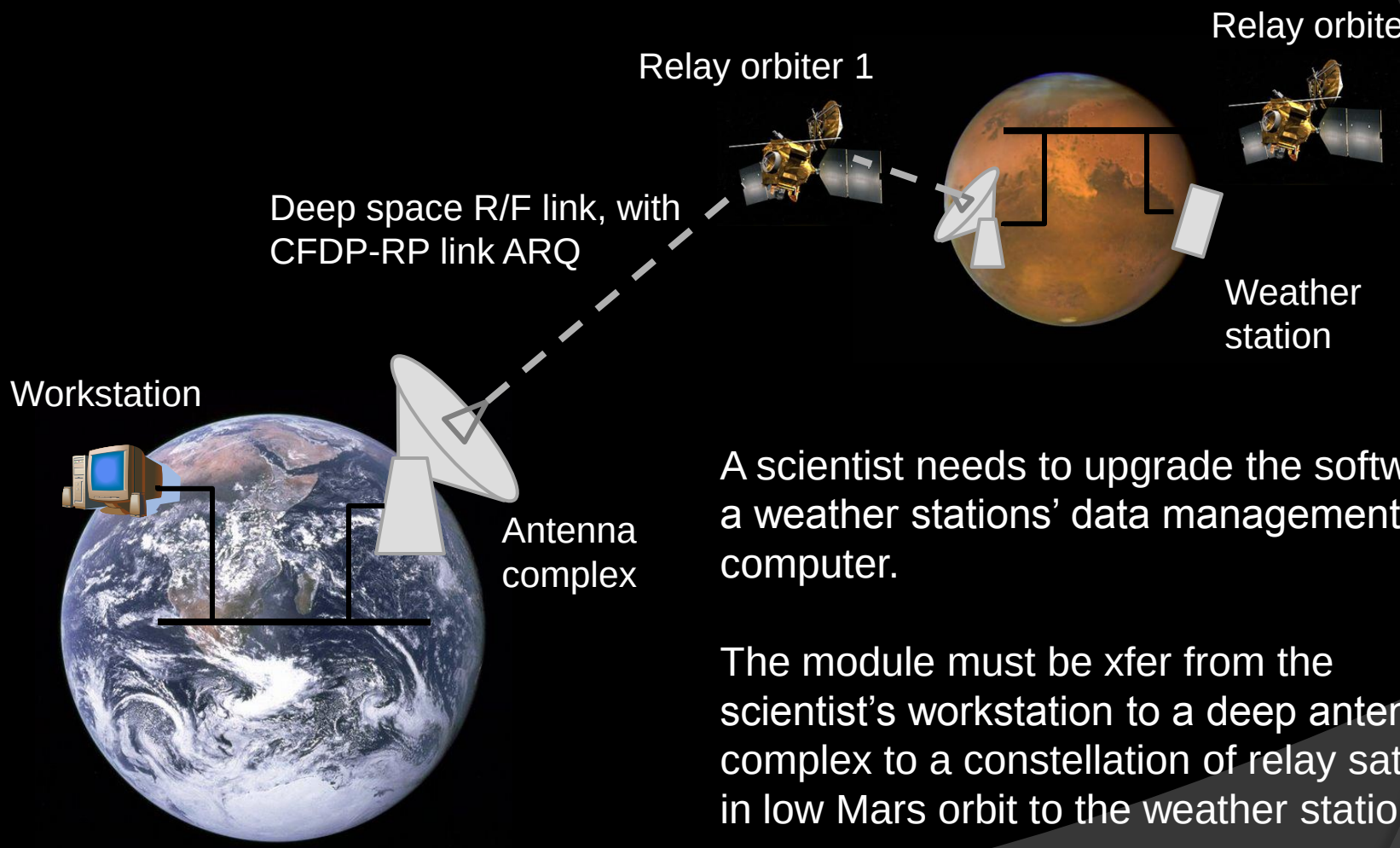
Upgrading a Martian's weather station software



A scientist needs to upgrade the software in a weather stations' data management computer.

The module must be xfer from the scientist's workstation to a deep antenna complex to a constellation of relay satellites in low Mars orbit to the weather station

Internet and Deep-space

- TCP/IP over Internet
  - Relatively small signal propagation delays (milliseconds)
  - Relatively high data rates
  - Bidirectional communications always
  - Continuous end-to-end connectivity
  - On-demand network access with high potential for congestion
- Communication in deep space
  - Very large signal propagation latencies (minutes)
  - Relatively low data rates (8-256 kb/s)
  - Time-disjoint periods of reception/transmission
  - Intermittent scheduled connectivity
  - Centrally managed access to the communication channel w/ essentially no potential for congestion

CCSDS & its File Delivery Protocol (CFDP)

- Consultative Committee for Space Data Systems (CCSDS)
  - Introduced a number of standards for deep space communication
- CFDP – reliable FT across interplanetary distances
  - To deal with high latencies in CFDP
    - Time to establish a connection > communication opportunity – no connection protocol, but managed communication parameters
    - RTT >> time to transmit file – don't wait for ACKs
    - Large number of concurrent file transfers – keep retransmission buffers in stable storage
  - Not suitable stack works well for end-to-end use

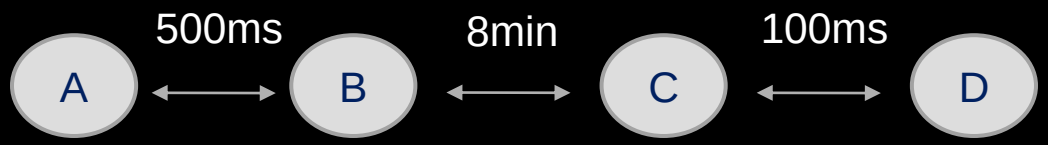
Why not the Internet protocols?

- Reliable transport – many applications need reliable transfers
  - Issues with TCP
    - Sender and receiver must negotiate a connection – this requires a least one round-trip before application data can be sent
    - TCP delivers received data in transmission order, any data loss requiring retransmission will delay delivery of all subsequent data transmitted
    - TCP throughput drops as RTT increases

Why not the Internet protocols?

- Issues with TCP
  - TCP transmission is end-to-end, an issue when the links involved are quite different
  - Consider a three hop route

One-way signal propagation delay



  - For retransmission, A must keep copy of messages until is sure retransmission is not necessary
    - If end-to-end – A must retain msgs for 961,200 ms
    - If hop-by-hop, 1000ms (500ms x 2)
    - And think of the buffer space needed!
- UDP
  - You will have to re-invent retransmission

Delay-Tolerant Network architecture

- DTN
  - Use the best suited protocols at each layer
  - Add a new overlay layer bet/ application and locally optimized protocols
  - Overlay acts as application-level gateway, offering and end-to-end transmission service that is reliable & efficient
- The design of the overlay cannot assume
  - Continuous connectivity
  - Low or constant transmission latency
  - Low error rate or low congestion
  - High transmission rate or symmetrical data rates
  - Common name or address expression syntax/semantics
  - In-order data arrival
- … but should take advantage of any if available

DTN fundamental principles

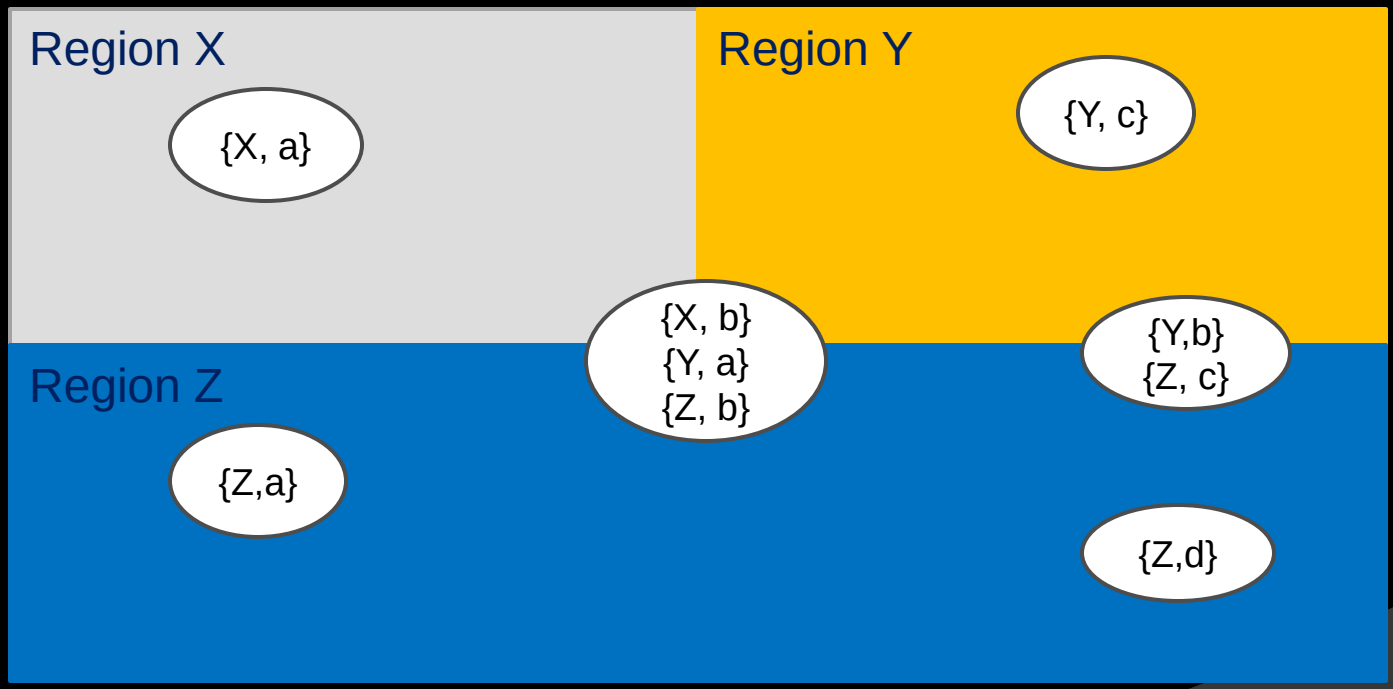
- A postal model of communication
  - Arbitrary transmission latencies – no conversational interchange
  - E.g. to transfer a file, *bundle* together in one message everything you need (requesting user's name and password, name of the file, encoding instructions, etc)
  - Bundles ~ functionally similar to email messages
- Tiered functionality
  - *Bundling protocol* performs any additional function that the locally optimized protocol can't
- Terseness
  - Aim at low bandwidth usage even at the price of processing complexity

DTN main structural elements

- Tiered forwarding
  - DTN nodes in a region use the locally optimized protocol
  - Forwarding of bundles among DTN nodes in != regions is performed by *Bundling* through gateway nodes
    - Gateway nodes – nodes with I/F in each adjacent region
  - Bundling's store-and-forward operation may require long deferred transmissions
- Tiered naming and addressing
  - Destination identifier of a bundle must map to an address in the destination address space
  - But we need a region identifier to route at the bundling layer
  - *{region ID, regional destination id}*
    - Regional destination id are late bound

DTN main structural elements

- Six DTN nodes within three regions; each node has an I/F for each region within which it operates



DTN main structural elements

- Tiered routing
  - Route computation at the bundling layer must be sensitive to new link opportunities or contacts
    - Maybe scheduled – manually or automated
    - Discoverable in real time
    - Predictable – mobility patterns or orbital dynamics
    - Stochastically computed – based on prior contact history
- Tiered automatic retransmission
  - Regional retransmission is the most efficient
  - Still, to handle regions with long RTTs, Bundling supports *custodial retransmission* – a node takes custody of a bundle (keeping a copy) until a downstream node takes over it

DTN main structural elements

- Tiered security
  - If necessary, exchange of bundles between adjacent nodes may be subject to verification of cryptographic credentials
  - The certificate must travel with the bundle, however, and it may be too large considering the terseness principle
- Tiered congestion control
  - DTN relies on regional measures, either protocol-based or reservation/management based

DTN main structural elements

- Resilient delivery
  - Ultimate source and destinations are service agents (processes, threads, …)
  - End-to-end latency may be so long that agent is off when bundle arrives
    - Keep a copy for deferred delivery
    - Potentially reanimate the agent for delivery
- Postal service level
  - QoS levels based on the US Postal service
  - Three levels of priority: low, standard, high
  - Three postal service notifications
    - Notice of initial transmission (notice of mailing)
    - Notice of delivery to ultimate destination (return receipt)
    - Report of route taken (delivery record)

Final comments

- Building DNT to work within UDP/IP, without bundling
  - Familiar to application developers
  - Split of bundling functionality is too messy, fragile and costly
- Interplanetary Internet → Generalized DTN
  - Research group on DTN as part of the Internet Research Task Force
    - http://www.dtnrg.org/wiki
  - Prototype implementation build by guys at Berkeley; later release v2.5.0, Oct. 2007