Nanosatellites for Universal Network Access

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ABSTRACT

Historically, a fundamental obstacle to providing universal network access has been the difficulty of extending network infrastructure to under-served users at affordable cost. The desperately poor are not the only ones affected:

- Relatively affluent users may be in locations that are too geographically remote (and too sparsely populated) to justify the deployment of wired infrastructure or even cellular telephone service.
- Locales that normally enjoy high-speed network service may lose access in the event of a natural or political disaster that disables infrastructure just when it is most needed.

Communication satellites are an obvious solution: no location is so remote or depopulated that satellites may never appear overhead, and satellite operations are unaffected by earthquakes and hurricanes. However, the digital communication services offered by communication satellite operators to date have been too expensive for some purposes and too limited in bandwidth for others. These limitations are a natural consequence of communication satellite and constellation design:

- A satellite in geosynchronous orbit is stationary in the sky; as such it can easily sustain continuous wireless Internet connections among points on Earth's surface that are within its field of view. However, launching a satellite into geosynchronous orbit is very expensive. Multiple satellites are required for complete coverage of Earth's inhabited surface, and each such satellite is a single point of failure.
- Satellites can be launched into low-Earth orbit (LEO) at far less cost. But because they are in continuous motion relative to Earth's surface they can only sustain continuous Internet connections if they are cross-linked, so that connections can be handed off from one satellite to the next. This additional capacity and complexity makes LEO satellites expensive as well, and many more of them are needed in order to provide complete coverage of the service area.

Note that the key constraint on these designs is the requirement to sustain continuous Internet connections: the Internet architecture is built on the expectation that effective network communication is possible only when there is a continuous end-to-end connection from data source to data destination.

Delay-Tolerant Networking (DTN) challenges that expectation, supporting end-to-end data exchange between network nodes even when network paths are concatenations of time-disjoint transient communication links. Universal, perpetually available DTN network service could therefore be provided by a constellation of simple, inexpensive LEO satellites – potentially nanosatellites, perhaps no larger than CubeSats – that communicate only with network nodes that are currently in their immediate field of view. We explore this architecture, suggesting that the cost of such a service would be low enough to bring routine network access within the reach of the most economically disadvantaged, while additionally sustaining ongoing remote science investigations and standing ready to support relief efforts in emergencies.

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Categories and Subject Descriptors

A.1 Introductory and Survey

Keywords

Communication satellite; CubeSat; nanosatellite; Delay-Tolerant Networking.

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BIOGRAPHY

Scott Burleigh is a Principal Engineer at the Jet Propulsion Laboratory, California Institute of Technology, where he has been developing flight mission software since 1986. A member of the Delay-Tolerant Networking (DTN) Research Group of the Internet Research Task Force, Mr. Burleigh is a co-author of the DTN Architecture definition (Internet RFC 4838). He is also a co-author of the specification for the DTN Bundle Protocol (BP, Internet RFC 5050) supporting automated data forwarding through a network of intermittently connected nodes. In addition, he is a co-author of the specifications for the Licklider Transmission Protocol (LTP, Internet RFCs 5325 through 5327) supporting data block transmission reliability at the data link layer.

Mr. Burleigh leads the development and maintenance of implementations of BP and LTP that are designed for integration into deep space mission flight software, with the long-term goal of enabling deployment of a delay-tolerant Solar System Internet. This software is now in continuous operation on the International Space Station and is offered on SourceForge as open source code. Mr. Burleigh has received the NASA Exceptional Engineering Achievement Medal and four NASA Space Act Board Awards for his work on the design and implementation of these communication protocols.