

The InterPlaNetary Internet Bulletin



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OVERVIEW

Phase I of the InterPlaNetary Internet project (the IPN conceptual phase, funded by the DARPA Next Generation Internet initiative) is nearing completion. For Phase II, sponsorship has now transitioned to the InterPlanetary Network and Information Systems Directorate at NASA's Jet Propulsion Laboratory.

During Phase I we focused on definition of the overall IPN architecture and identification of key new protocols. The fundamental concept is that local in-situ short delay Internets, distributed across the Solar System on free flying spacecraft and on and around other planets, are interconnected via a long delay deep space backbone network. Just as the TCP/IP suite unites the Earth's Internet as a "network of networks", a new protocol suite called "Bundling" unites the IPN into a "network of Internets".

In Phase II we will test the architectural concepts by beginning the detailed definition and prototyping of Bundling, and will chart a strategy whereby today's space systems can evolve smoothly into the Bundling era throughout the coming decade. We have also broadened the scope of the IPN so that it is a member of a new class of "Delay Tolerant Networks" that we believe will have growing importance to terrestrial communications, and we shall seek partnerships with developers of such systems in order to widen our pool of expertise.

DELAY TOLERANT NETWORKS

The IPN architecture recognizes that in many environments – such as interplanetary communications – a real time end-to-end path between two users may never exist as a connected entity. Instead, communications must occur by stitching together a series of time-disjoint individual hops. The Bundling protocol suite is the vehicle by which the stitching occurs. Interconnection of adjacent hops may occur nearly instantaneously, or may be separated by variable and arbitrarily long time delays. Nodes at the termini of the hops operate in a store and forward mode, and many of them may also be "custodial" - they will accept responsibility for relaying an incoming Bundle, thus releasing a prior node from this responsibility and liberating its processing, storage and communications

resources. By using such techniques, a highly robust network may be built that is tolerant of delay and disconnectedness. Note that delay can be introduced by several factors, including a lack of bi-directional communications capability that makes it impossible to verify that data have been reliably delivered in real time.

While deep space communications (with their enormous propagation delays) are obvious examples of Delay Tolerant Networks (DTNs), we expect that this mode of operation will become increasingly important to terrestrial communications. Examples of other emerging terrestrial DTN “profiles” are described below.

Mobile Tactical Networks

Battlefield and civil emergency operations are becoming increasingly dependent on the use of digital communications among untethered nodes. Some communication resources (e.g. satellites, helicopters, and fixed-wing aircraft) are highly mobile and hence intermittently - although perhaps predictably - available. Connectivity in these networks may become episodic and sometimes unidirectional because of distance, terrain or policy (radio silence), so network partitioning must be accommodated. Additionally, delays within connected portions of the network may be extremely variable due to the nature of the communication media. Under these conditions, reliable Internet protocols perform poorly, and unreliable protocols (e.g. UDP) require application layer support to provide acceptable service. The DTN protocols can provide this robust application layer overlay, and potentially dramatically improve the performance of tactical communications systems.

Sensor Webs

These types of networks may comprise a large collection of primitive sensor devices interspersed with a smaller collection of more capable nodes, all interconnected by some form of wireless communications. Complicated by node mobility and operation in harsh environments with extremely limited power, such devices benefit directly from the ability to offload their end-to-end communications to more capable custodians and thus extend their operational lifetime by allowing their derived information to only be harvested occasionally. The DTN architecture and protocols are well suited to these kinds of communication restrictions; data can incrementally move toward the destination, with custody progressing forward along a series of relay hops, thus avoiding the need to establish a contemporaneous end-to-end path for reliable transmission and consequently making judicious use of the power resources of the network.

Intelligent Highways

As vehicles become more complex, they increasingly contain multi-node networks. Services such as “OnStar” provide very limited real time satellite connectivity between vehicles and monitoring sites. Incorporation of DTN protocols into vehicles and into communication nodes placed at intervals along highways (and eventually streets) can reduce the required infrastructure cost by taking advantage of delay tolerance and the ability to route via other vehicles to

reach fixed infrastructure. Enhanced driver services may be enabled, such as en-route traffic congestion avoidance, alternate route calculation, point-of-interest location, vehicle health and safety monitoring and breakdown assistance.

The Emerging Internet

With the number and diversity of "Internet capable" devices relentlessly increasing, we are witnessing a growing heterogeneity among the stub networks that connect them to the Internet backbone. These differences are manifesting themselves not only in the interconnection technologies (optical, cable, wireless) but also in capabilities of the devices themselves (constrained power, weight and volume) and their associated communications policies (security, quality of service, usage charges). The result of this Internet evolution is that user devices are becoming increasingly mobile, and the end-to-end data path is traveling across a wider variety of environments. Mobility coupled with power, weight, volume constraints suggests that end-to-end communications dialogs across time disjoint connectivity are going to be highly likely, if not inevitable. The DTN protocol mechanisms could significantly enhance the Internet's ability to accommodate the extreme heterogeneity that is emerging, by bridging between islands ("regions") of homogeneity to support end-to-end delivery of information.

IPN PHASE II: THE NEXT STEPS

A critical next step is to begin the mainstream development of the Bundling suite and to show its relevance to current systems and capabilities. We are committed to use experimentation and prototyping as an integral part of this development lifecycle. By the summer of 2002 we plan to re-articulate the IPN architecture in a DTN context and to demonstrate a working prototype that exercises Bundling in three different DTN profiles:

- the space IPN
- a terrestrial sensor net
- a mobile battlefield communications system.

We will use this prototyping experience to develop draft written specifications of the key protocols, which along with working code may be shared with others so that they may themselves implement prototype Bundle nodes.

For interplanetary applications we plan to demonstrate the potential evolution of the current "CFDP" protocol towards Bundling. We will also seek collaborations with other parts of JPL and the private sector to help refine a deep space concept of operations and possibly to experiment with the integration of Bundling techniques into Web-based public involvement with space missions.



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