Delay Tolerant Networking
Internet Draft
Intended status: Informational
Expires: November 2018

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May 8, 2018

software defined dtn-based satellite networks
draft-li-dtn-sd-dtn-sat-net-04.txt

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Abstract

Delay/Disruption Tolerant Networking (DTN) is designed for a severe environment where communication quality is not guaranteed. It works as an overlay network associated with Bundle Protocol (BP) and some convergence layer protocols like Licklider Transmission Protocol (LTP). DTN is suitable for satellite networks. Because communication delay is long and peer-to-peer communication is not guaranteed in satellite networks. We implement SDN to solve the problems of controllable, manageable, and flexible in satellite networks. In this document, we propose a framework of Software Defined DTN-based satellite networks, using Bundle tunnel and protocol translation gateway.

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1. Introduction

Delay/Disruption Tolerant Networking (DTN) [RFC4838] is designed for a severe environment where connectivity of network is intermittent and communication quality is not guaranteed. It works as an overlay network associated with Bundle Protocol (BP) [RFC5050] and convergence layer protocols like Licklider Transmission Protocol (LTP) [RFC5325] [RFC5326].

We implement DTN in the satellite networks to meet the need of high transmission delay with the help of Interplanetary Overlay Network (ION) [BURLEIGH07]. ION is an implementation of DTN architecture and is designed to enable inexpensive insertion of DTN functionality into embedded systems.

SDN [NUNES14] is a state-of-the-art network concept, introducing new possibilities for network management and configuration methods by decoupling the control decisions from forwarding hardware. A controller communicates with the switches by southbound interface, such as OpenFlow [LARA14], which is the core technology of SDN. We apply the idea of SDN to satellite network by separating control plane and forwarding plane in satellite network control structure and taking advantage of the global view of a controller.

In this document, we propose a framework of Software Defined DTN-based satellite networks, using Bundle tunnel to deploy OpenFlow over DTN and protocol translation gateway to achieve protocol translation between Bundle packets and IP packets.

2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

3. Key points of the design

The idea of SDN is applied in the proposed framework. The control link between the control plane and the forwarding plane is Bundle tunnel. Because we use DTN protocol stack in space network and the protocol stack of ground network is TCP/IP. There should be a

protocol translation gateway to achieve protocol translation between Bundle packets and IP packets.

3.1. Separated control plane and forwarding plane

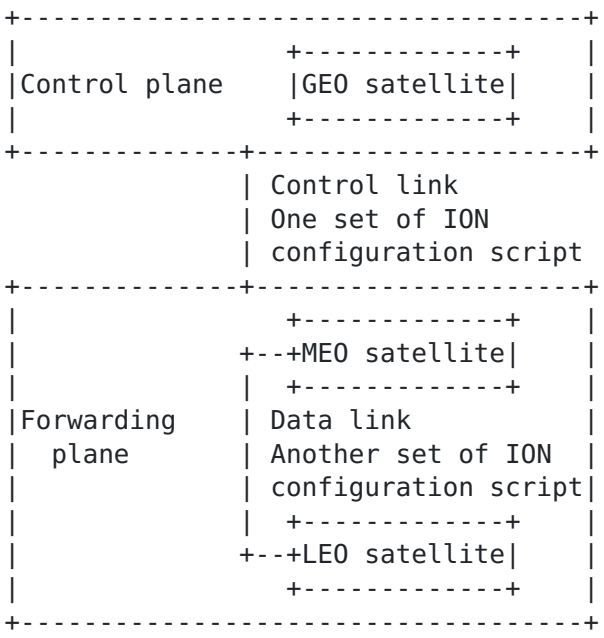

Figure 1 Illustration of the two planes

We apply the idea of SDN to satellite network by separating control plane and forwarding plane in satellite network control structure and taking advantage of the global view of a controller. The whole space network is divided into two parts, control plane and forwarding plane. The control plane contains Geosynchronous Earth Orbit (GEO) satellites, on which SDN controllers are deployed. The forwarding plane contains Medium Earth Orbit (MEO) satellites and Low Earth Orbit (LEO) satellites, and OpenFlow enabled switches are deployed on them.

We implement DTN with the help of ION in space network. The topology configuration mode of ION is reading the configuration scripts (.rc file), which contains the information of connections and nodes. As is shown in Figure 1, to achieve the goal of separating the control plane and forwarding plane in the space network, we adopt two set of unrelated ION configuration scripts when creating the topology. One is the script of Bundle tunnel (or we can say the control link). The

other one is the script of data link. Two ION processes run in the MEO/LEO satellite nodes without affecting each other.

3.2. Bundle tunnel

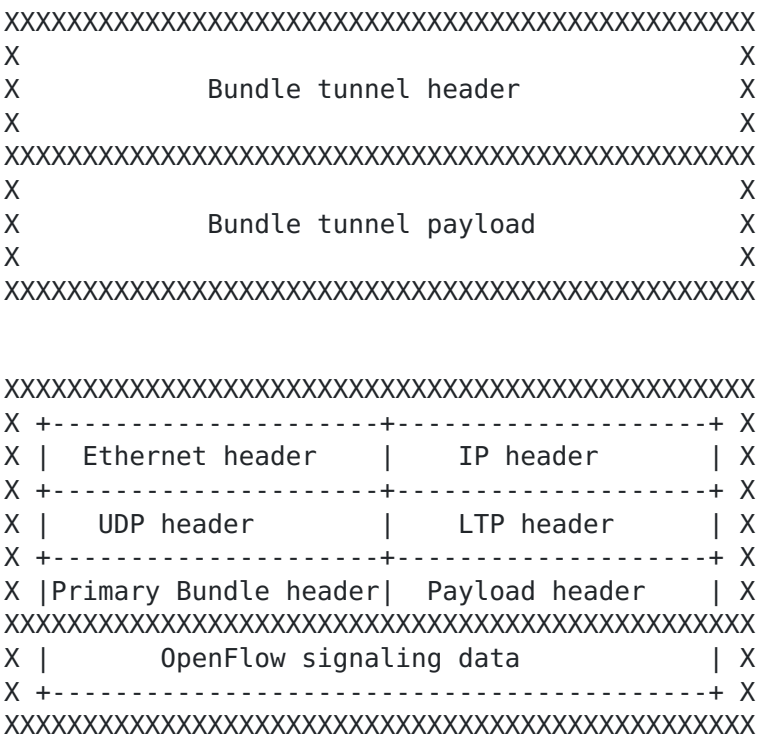

Figure 2 Illustration of bundle tunnel

We deploy OpenFlow over DTN by a method of tunnel. That is, signaling packets are transmitted in bundle tunnel when controller (GEO satellite) sets up connection to switches (MEO satellites) and when controllers send instructions to switches. The encapsulation format of the bundle tunnel is shown in Figure 2. Because DTN is implemented in ION in an overlay way, the first half of the Bundle tunnel header is the same as normal IP packets. The difference is that there are a 4-byte LTP header, a 14-byte Primary Bundle header, and a 5-byte Payload header before the payload data field due to the protocol stack of DTN. The link layer field is removed from the OpenFlow signaling packets between controller and switches and then the remaining fields are encapsulated in payload data.

The design of the Bundle tunnel adopts a dual process approach. One process is responsible for receiving OpenFlow signaling packets from

the local controller or switches. Then signaling data are separated out and encapsulated in the Bundle packets. Finally, the Bundle packets are sent to the control link. The other process is responsible for receiving Bundle packets from the control link and decapsulating the Bundle packets and get the OpenFlow signaling data. Then the signaling data are sent to the local controller or switches. In this way, the SDN controller in GEO satellite can communicate with the OpenFlow enabled switches in MEO/LEO satellites.

3.3. Satellite gateway

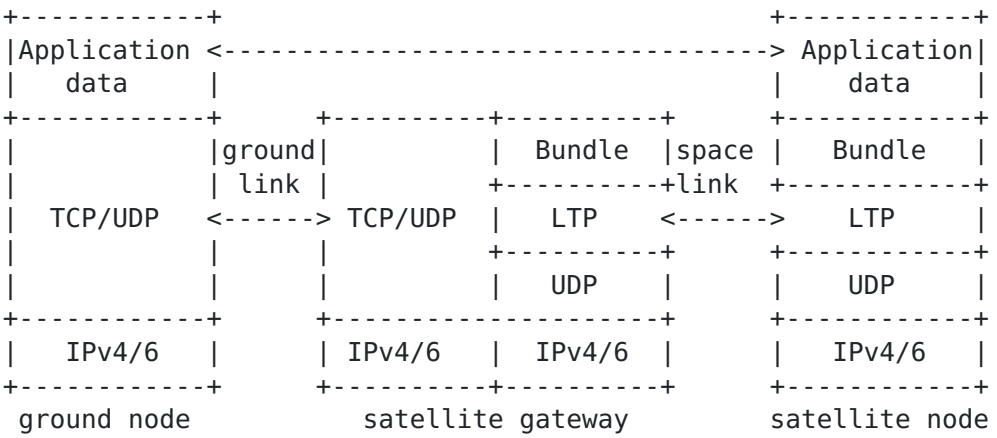

Figure 3 Protocol stacks

We use DTN protocol stack in space network and TCP/IP stack in the terrestrial network, so there should be protocol translation for data transmission and service delivery in the Software Defined DTN-based satellite networks framework. We develop DTN to TCP/IP bidirectional protocol translation and deploy this function on the satellite gateways. We deploy DTN with Interplanetary Overlay Network (ION) and modify ION to adapt to IPv6. In this way, ION is IPv4/6 dual stack. If the ground nodes run in IPv6 stack, there is no need for complex protocol translation between IPv4 and IPv6 at the satellite gateway.

The protocol stacks of the ground node, satellite gateway node, and satellite node are shown in Figure 3. The physical layer and the data link layer are omitted because they are not involved in the proposed framework. The bidirectional translation between IP packets that belongs to TCP/IP stack and the Bundle packets that belongs to DTN stack is achieved at the satellite gateway by adopting

hierarchical, modular, and multi-process protocol translation function.

4. Use case

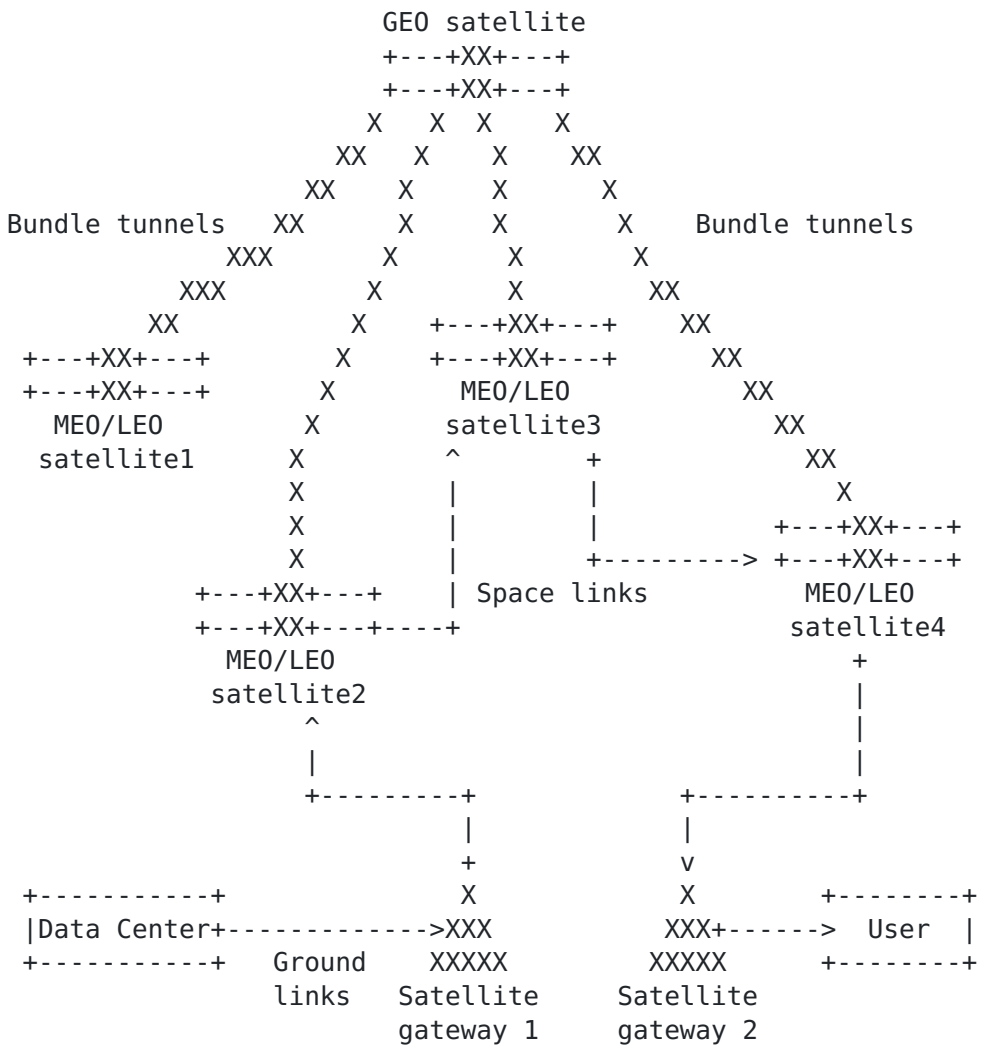

Figure 4 Use case of the proposed framework

The use case of proposed framework is shown in Figure 4. The GEO satellite set up control link to the four MEO/LEO satellites. The data center data are transmitted among the four MEO/LEO satellites. The ION configuration script of the control plane is about the connections of one GEO satellite to four MEO/LEO satellites. The ION configuration script of the forwarding plane is about the

connections among the four MEO/LEO satellites. That is to say, two sets of unrelated ION processes are running in the four MEO/LEO satellites.

A user applies for data from the data center via satellite networks. The traffic is sent to satellite gateway 1 and converted from IP packets to Bundle packets. The controller in GEO satellite send instructions to the MEO/LEO satellites and configure the flow tables of the switches in MEO/LEO satellites. Then the traffic is forwarded via the path: satellite2-->satellite3-->satellite4 under control of GEO satellite. Then, the traffic is sent to satellite gateway 2 and converted from Bundle packets to IP packets. Finally, the data are sent to the user.

5. Security Considerations

Introducing SDN in DTN-based space network can bring in some problems that any SDN-based frameworks have. The proposed framework adopts a centralized control architecture. So if GEO satellite is attacked (by viruses or physical attack), security problem should be considered. The possible solution may be reserving spare GEO satellite. When the GEO satellite in use breaks down, the spare one will take on the responsibility.

6. IANA Considerations

This document does not update or create any IANA registries.

7. Conclusions

This document describes the key points of the design of the proposed Software Defined DTN-based satellite networks framework: Separated control plane and forwarding plane in space network, Bundle tunnel, and satellite protocol translation gateway. And we describe the use case of the proposed framework in this document.

8. References

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9. Acknowledgments

This work in this document was supported by National High Technology of China ("863 program") under Grant No.2015AA015702.

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