An Overview of Architecture and Applications of Delay Tolerant Network for Korea Pathfinder Lunar Orbiter

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***Abstract*— This paper describes the structure and applications of a delay tolerant network (DTN) to be operated using a DTN payload (DTNPL) mounted on the Korea pathfinder lunar orbiter (KPLO), which was launched in August 2022. DTN is a communication technology to support reliable communication even in space where communication is frequently disrupted. ETRI has researched a core technologies of DTN, and developed DTNPL as a space testbed. With the DTNPL, we plan to test various applications of DTN such as message exchange, file transfer, and video streaming between the lunar orbiter and the Earth.**

Keywords—Delay Tolerant Network, KPLO, Lunar exploration

I. INTRODUCTION

Since communication in space causes a long propagation delay and frequent communication disruption, it is very difficult to achieve reliable communication compared to the Earth. As a technology for solving the communication problem in space, DTN is receiving a lot of attention. DTN is a communication technology that is being researched led by NASA of the United States and the consultative committee for space data systems (CCSDS), and aims to enable stable communication even in space where communication is frequently disrupted, and is expected to become a core technology for space communication in the future.

The Electronics and Telecommunications Research Institute (ETRI) has also researched and developed various applications of DTN to enable reliable space communication for deep space exploration. Recently, in order to test the DTN technology in space, ETRI developed a DTNPL that can be operated in space, and it was mounted on the KPLO, which was launched in August 2022. When the KPLO enters the orbit where it can perform its missions in the future, various applications using DTNPL will be tested in cooperation with NASA, Korea aerospace research institute (KARI) and ETRI. In this paper, the structure of the KPLO DTN, the hardware specification of the DTNPL, and the applications of the DTNPL are described.

II. CONFIGURATION AND APPLICATIONS OF DTN FOR KPLO

A. Architecture of DTN for KPLO

The DTN in the KPLO project consists of a total of six DTN nodes. In space, DTNPL is located in lunar orbit, and five DTN nodes are located on Earth's ground. On the ground, the DTN Control Center (DCC) sends tele command (TC) to the DTNPL and receives telemetry (TM) and mission data from the DTNPL. Mission Operation Center (MOC) and DSN DTN node are responsible for relaying DTN data between DTNPL and DCC. Lander communication model (LCM) and rover communication model (RCM) are emulator of lander and rover, respectively, located on the moon in the future. They communicate with DCC through DTNPL. KPLO DTN will be operated by a total of three organizations. DCC, LCM, RCM, and DTNPL are operated by ETRI, and MOC and DSN DTN nodes are operated by KARI and DSN, respectively. Figure 1 shows the configuration diagram of KPLO DTN.

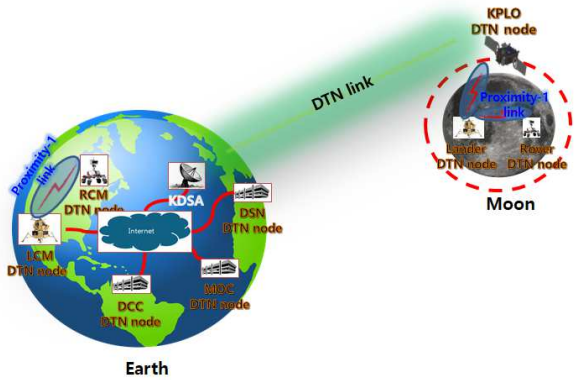

Fig. 1. Configuration of DTN for KPLO

This work was supported by the Development of Lunar Exploration Program of NRF. [NRF-2016M1A3A9005564, Development of space internet technology for lunar exploration]

B. Hardware Specification of DTNPL

DTNPL is designed with radiation tolerance. Therefore, all the parts of DTNPL including processor are chosen as space-grade parts. Fig.2 shows the flight model (FM) of DTNPL, and Table 1 shows the major hardware specification of DTNPL FM.

Figure 2. DTNPL flight model

TABLE I. HARDWARE SPECIFICATION OF DTNPL FM

Item	Value
Processor	32-bit Leon3
MIPS	49.3 MIPS
OS	RTEMS 4.11
Memory type	MRAM for program
	NAND flash for mission data
Mass	0.8 kg
Size	120 (width) x 170 (length) x 39 (height) mm

C. Applications of DTN for KPLO

KPLO DTN aims to provide the three DTN application services described below.

- CCSDS file delivery protocol (CFDP) based file transfer: It is a file transfer service using bundle protocol (BP)/Licklider Transmission Protocol (LTP) and performs uplink/downlink bidirectional file transmission/reception between DCC and DTNPL and between DCC and RCM.
- BP based message exchange: As a message exchange using BP/LTP, it performs uplink/downlink bidirectional message transmission/reception between DCC and DTNPL and between DCC and RCM.
- Bundle streaming service protocol (BSSP) based video streaming: This is a video streaming service using BP/ BSSP. When DTNPL receives a video streaming command from DCC, DTNPL streams video to DCC.

III. FUNCTIONAL EVALUATION

ETRI conducted a functional test using the global DTN test bed with NASA and KARI for verifying the DTN functions for the DTNPL. Also, repeated the test with ETRI internal test bed. Figure 2 shows the ETRI's internal testbed, which consists of DCC, LCM, RCM, a qualified model (QM) of DTNPL, and an emulators of MOC and DSN DTN node.

A total of nine tests were conducted to verify the function of DTNPL. Uplink/downlink message exchange and file transmission and reception were performed between DCC and DTNPL, respectively. Also, uplink/downlink message exchange and file transmission/reception between DCC and RCM were performed respectively. Considering the actual communication speed between the moon and the earth, the speed of the uplink path was set to 1 kbps and the speed of the downlink was set to 1 Mbps. Because of low speed of uplink path, video streaming was performed only in the downlink path from DTNPL to DCC. As shown from fig. 3, and Table 2, DTNPL performed DTN application service correctly in all tests.

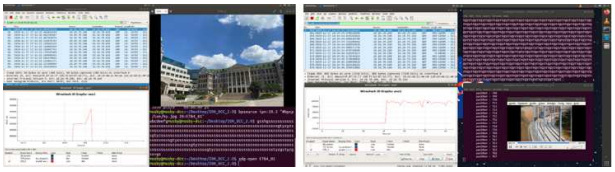

Fig. 3. Test results of file transfer and video streaming

TABLE II. TEST RESULTS

Test	Source	Relay	Destination	Result
Message transfer	DCC	MOC, DSN	DTNPL	Success
	DTNPL	MOC, DSN	DCC	Success
	DCC	MOC, DSN, DTNPL	RCM	Success
	RCM	MOC, DSN, DTNPL	DCC	Success
File transfer	DCC	MOC, DSN	DTNPL	Success
	DTNPL	MOC, DSN	DCC	Success
	DCC	MOC, DSN, DTNPL	RCM	Success
	RCM	MOC, DSN, DTNPL	DCC	Success
Video streaming	DTNPL	MOC, DSN	DCC	Success

IV. COLCLUSIONS

In this paper, the structure and various applications of DTN to be tested in DTNPL are described. It was confirmed that the DTNPL successfully provided DTN application services in ETRI's internal test bed and international joint test bed. Currently, the DTNPL is flying towards the moon by the KPLO launched in August 2022, and will be used for DTN functional tests in space after KPLO enters lunar orbit.

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