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A Brief Survey of Media Access Control, Data Link Layer, and Protocol Technologies for Lunar Surface Communications

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April 2009

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Abstract

This paper surveys and describes some of the existing media access control and data link layer technologies for possible application in lunar surface communications and the advanced wideband Direct Sequence – Code Division Multiple Access (DS-CDMA) conceptual systems utilizing phased-array technology that will evolve in the next decade. Time Domain Multiple Access (TDMA) and Code Division Multiple Access (CDMA) are standard Media Access Control (MAC) techniques that can be incorporated into lunar surface communications architectures. Another novel hybrid technique that is recently being developed for use with smart antenna technology combines the advantages of CDMA with those of TDMA. The relatively new and sundry wireless LAN data link layer protocols that are continually under development offer distinct advantages for lunar surface applications over the legacy protocols which are not wireless. Also several communication transport and routing protocols can be chosen with characteristics commensurate with smart antenna systems to provide spacecraft communications for links exhibiting high capacity on the surface of the Moon. The proper choices depend on the specific communication requirements.

I. Introduction

The current U.S. vision to return to the Moon and then explore Mars will require extensive planning for all aspects of the mission including communications.[1] As newer technological advances in communication methods appear, decisions into those planning stages will be affected and modifications will be incorporated. Media Access Control schemes and the data link layer technologies are beneficial to terrestrial surface communications and can be used in lunar surface communications applications.

II. Media Access Control (MAC)

The development of a conceptual MAC layer protocol will be critical in enabling physical and MAC layer technologies with sub-network level protocols to support flexible (*e.g.*, formation, cluster, constellation, "*ad hoc*") spacecraft communications for networking among various satellite constellations. A simulation model is needed which uses "abstractions" of the physical layer mechanisms to demonstrate protocol scalability and performance to assess the connectivity and throughput comparisons between alternative MAC layer technologies (*i.e.*, TDMA and TCeMA). The two most common access schemes utilizing digital technology to support multiple links on the same channel are Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). One other interesting scheme incorporates the prominent features of TDMA and CDMA. This recently developed technology is called Time Domain with CDMA-encoding Multiple Access (TCeMA).[2]

A. Time Division Multiple Access (TDMA)

Time Division Multiple Access (TDMA) is a technology for digital transmission of radio signals. In TDMA, the frequency band is separated temporally so that several users can share a single channel without interfering with one another. TDMA is a growing technology. It is one of the most widely deployed digital wireless systems in the world. The technology is also known as D-AMPS (Digital Advanced Mobile Phone Service). In this system, three time slots are utilized. Another TDMA system which uses eight such time slots is the Global System for Mobile Communications (GSM).

B. Code Division Multiple Access (CDMA)

Code Division Multiple Access (CDMA) is, alternatively, a "spread spectrum" digital technology. By spreading information contained in a particular signal over a much greater bandwidth than the original signal, it offers significant increases in coverage. Multiple signals can utilize the same frequency. The advantages of spread spectrum are security due to the difficulty in signal detection and interception by alien entities, protection against jamming, and the accommodation of multiple users in a single channel. It is also beneficial for ranging and radar applications. Signal capacity can be enlarged by up to eight to ten times that of TDMA and offer better reception quality with CDMA.

Typically cellular systems with 1200 channels for each cell exist with 1.25 MHz bandwidth for each channel. IS-95 which uses 64 bit codes is one such system.

C. Time Division with CDMA-encoding Multiple Access (TCeMA)

Integration of TCeMA and spatial multiplexing enables closing the link at varying rates, meeting QoS requirements while also maximizing spacecraft throughput. The primary reason for the superior performance of TCeMA is that TDMA only provides a fixed data rate while the TCeMA is able to provide variable data rates depending on the signal-to-noise ratio between two nodes. Thus, in many situations, TDMA is not able to establish a link at all, whereas TCeMA establishes one at a lower data rate. The nodes for 36 LEO satellites were created in OPNET as shown in Fig. 1.

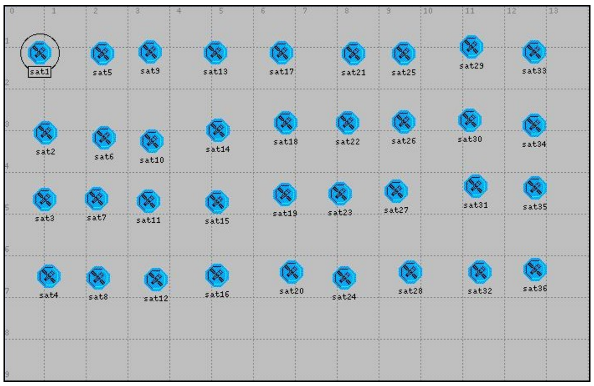

Figure 1. OPNET LEO satellite network model.

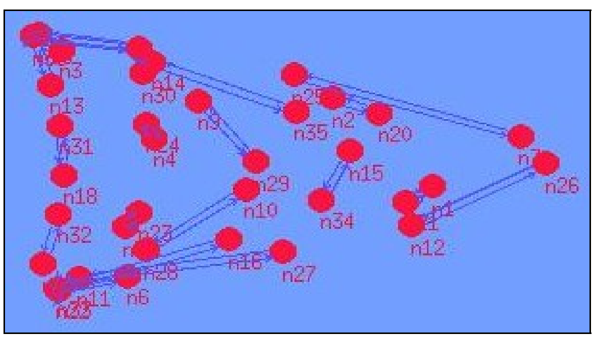

Figure 2. Simulated TDMA Connectivity Results

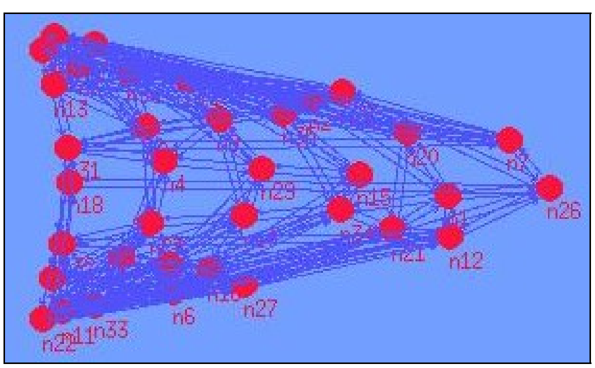

Figure 3. Simulated TCeMA Connectivity Results.

The OPNET simulation showing the results for connectivity are depicted using NetViz in Fig. 2 and Fig. 3 for TDMA and TCeMA, respectively. It was found through simulation that a TCeMA node outperforms a TDMA node by a factor of five and is able to achieve throughput at greater than three times that of a TDMA node.[3]

III. Data Link Layer Schemes

The Institute of Electrical and Electronics Engineers (IEEE) 802.11 Wireless Local Area Network (WLAN) standard was created in 1997.[*] This preliminary standard supported only a maximum bandwidth of 2 Mbps which is slow for most applications. Extensions to the 802.11 standard were subsequently added and are still being incorporated into the standard. The current standards being used in WLANs are IEEE 802.11a, 802.11b, 802.11g, and Bluetooth. Each of these technologies has relative advantages and disadvantages depending on the network specifications.

D. IEEE 802.11a

The IEEE 802.11a and IEEE 802.11b extensions were created at approximately the same time. The IEEE 802.11b gained in popularity much faster than did 802.11a, perhaps due to its lower cost or its lower frequency of operation at 2.4 GHz. IEEE 802.11a is predominately used in the business market, whereas 802.11b better serves the home market. IEEE 802.11a supports bandwidth up to 54 Mbps and signals in a regulated 5 GHz range. This higher frequency limits the range of 802.11a as compared to 802.11b. Also, the attenuation due to buildings and obstructions is higher at the 802.11a frequency.

Because 802.11a and 802.11b utilize different frequencies, the two technologies are incompatible with each other. Extant hybrid 802.11a/b network components are simply the implementation of the two standards side by side.

Some of the advantages in choosing 802.11a over the other technologies are the capability of the fastest maximum speed, supporting more simultaneous users, and the use of regulated frequencies to prevent signal interference from other devices. The disadvantages, again, are the highest cost and a shorter range for a signal that is more easily attenuated or obstructed.

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[*]Bradley Mitchell, http://compnetworking.about.com/cs/wirelessproducts/g/bldef_wlan.htm

E. IEEE 802.11b

The IEEE expanded on the original 802.11 standard in July 1999 and created the IEEE 802.11b specification. The IEEE 802.11b supports bandwidth up to 11 Mbps which is comparable to the traditional *Ethernet*. Also, the 802.11b uses the same radio signaling frequency, 2.4 GHz, as the original IEEE 802.11 standard. Since this is an unregulated frequency, 802.11b devices can incur interference from microwave ovens, cordless phones, and other appliances which use the same 2.4 GHz range. However, interference can easily be avoided by installing the 802.11b network devices a reasonable distance from other appliances.

Unregulated frequencies of operation for wireless communications networks are often preferred since no licensing is required and production costs for components are lowered. The important advantages in choosing 802.11b are the lowest cost and a higher range signal with less obstruction. The disadvantages are the slowest maximum speed, supports fewer simultaneous users, and the interference that is possible on the unregulated frequency band.

F. IEEE 802.11g

In 2002 and 2003, WLAN products supporting a new standard, the IEEE 802.11g, were being developed. The 802.11g attempts to combine the advantages of both 802.11a and 802.11b. The 802.11g supports bandwidth up to 54 Mbps and it uses the 2.4 GHz frequency for greater range. The 802.11g networks are compatible with 802.11b networks since both standards use the same frequency of operation, 2.4 GHz.

The advantages of 802.11g consist of having the fastest maximum speed, supporting more simultaneous users, and having a high signal range that is not easily obstructed. The disadvantages include a somewhat higher cost that 802.11b and the possible interference issue on the unregulated signal frequency.

G. IEEE 802.15.1 (Bluetooth)

Bluetooth is an alternative wireless network technology developed entirely different than the 802.11 family. Bluetooth supports a very short range of approximately ten meters and relatively low bandwidth (1 Mbps). It operates in the 2.4 GHz band with antenna power up to 20 dBm. Realistically, Bluetooth will network PDAs or cell phones with PCs but does not offer much value for general-purpose WLAN networking. The very low manufacturing cost of Bluetooth, however, is appealing. Bluetooth wireless network technology may offer distinct advantages for data communications in a space vehicle or lunar habitat. For the lunar surface network WLAN, the choice of technology depends on the lunar surface communications requirements and environmental issues for each aspect of the system.

H. IEEE 802.15.4 (ZigBee)

The ZigBee protocol is a wireless standard for communications which is inexpensive, bidirectional, and exhibits very low power consumption. It is of short range in application and can be adapted into a mesh network. This type of protocol would be ideal for lunar surface communications in or near a central habitat where astronauts must communicate with other astronauts in close proximity. ZigBee is an extension to the IEEE 802.15.4 standard which defines the protocol and interconnection of devices using radio communication in a personal area network (PAN). It is based on the standard Open Systems Interconnection (OSI) seven-layer model and provides the network layer and the framework for the application layer above IEEE 802.15.4. The application layer framework is comprised of the application support sub-layer, the ZigBee device objects, and the manufacturer-defined application objects.

The IEEE 802.15.4-2003 standard defines the two lower layers: the physical (PHY) layer and the medium access control (MAC) sub-layer. IEEE 802.15.4 has two PHY layers that operate in two separate frequency ranges: 868/915 MHz and 2.45 GHz. The standard also includes two optional physical layers (PHYs) in the lower frequency bands, yielding higher data rates. The following four PHYs are specified as an 868/915 MHz direct sequence spread spectrum (DSSS) PHY employing binary phase-shift keying (BPSK) modulation, an 868/915 MHz DSSS PHY employing offset quadrature phase-shift keying (O-QPSK) modulation, an 868/915 MHz parallel sequence spread spectrum (PSSS) PHY employing BPSK and amplitude shift keying (ASK) modulation, and a 2.450 GHz DSSS PHY employing O-QPSK modulation.

The lower frequency PHY layer covers both the 868 MHz European band and the 915 MHz band, used in countries such as the United States and Australia. The higher frequency PHY layer is used virtually worldwide.[4] The 868/915 MHz PHYs support wireless data rates of 20 kb/s, 40 kb/s, and optionally 100kb/s and 250kb/s. The 2450 MHz PHY supports a wireless data rate of 250 kb/s.

The IEEE 802.15.4 MAC sub-layer controls access to the radio channel using a carrier sense multiple access with collision avoidance (CSMA-CA) mechanism. Its responsibilities may also include transmitting beacon frames, synchronization and providing a reliable transmission mechanism.

The standard supports star as well as peer-to-peer topologies which would be present in a lunar surface environment. The media access is contention based; however, using the optional super frame structure, time slots can be allocated by the PAN coordinator to devices with time critical data. Connectivity to higher performance networks is provided through a PAN coordinator. This 2006 revision was initiated to incorporate additional features and enhancements as well as some simplifications to the 2003 edition of this standard.[5]

I. IEEE 802.16 (WiMAX)

Worldwide Interoperability for Microwave Access or WiMAX is a subset of the IEEE 802.16 specifications. It is envisioned to support wireless communications for many entities over a wide range of area. The IEEE 802.16d subset specifications provide for a fixed wireless communications network operating in the 2 GHz to 11 GHz frequency band while there is also a 10 GHz to 66 GHz frequency band for line-of-sight applications. Under the IEEE 802.16e subset specifications, Mobile WiMAX would operate in the 2 GHz to 6 GHz frequency band. WiMAX would also provide a 4 mile to 6 mile radius of non-line-of-sight communications from a base tower, similar to the current PCS range, and a 30 mile radius at somewhat less than 70 Mbps using outdoor line-of-sight. The modulation and the channel rate adapt to the link quality.[6]

The WiMAX protocol is designed to accommodate several different methods of data transmission, including the Voice over Internet Protocol (VoIP).[†] Anyone with a laptop computer on the lunar surface in the future could make a phone call using VoIP on a lunar WiMAX network. The most common WiMAX licensed frequency bands operate at 2.3 GHz, 2.5/2.6 GHz, 3.4/3.5 GHz, and 3.6 GHz. There are other licensed bands including one at 5 GHz. A 3.8 GHz band is under consideration for the lunar surface network. Emphasis on using WiMAX for lunar surface communications would not be valid until an extensive lunar colonization occurs.

IV. Protocol Technologies

J. Transport Control Protocol/Internet Protocol (TCP/IP)

The Transport Control Protocol (TCP) and the Internet Protocol (IP) are the *de facto* standards for terrestrial and, possibly, lunar communications. These protocols will find efficacy for reliable lunar surface communication for large networks. For communication between the Earth and the Moon, a better choice of protocols is required since the long time delay is detrimental to the TCP/IP efficiency. The TCP requires a three-way "handshake" in order to initiate a session. This can require nearly 1.8 seconds for terrestrial to lunar session initiation. Here, extensive coding can be applied.

K. Space Communications Protocol Standards (SCPS)

The Space Communications Protocol Standards (SCPS) are actually a suite of standard data handling protocols which provide connections appearing to be "transparent" or "seamless" from some user to a remote space vehicle which resembles just another "node on the Internet."[‡] A file handling protocol, the SCPS File Protocol or SCPS-FP, is included in this suite of protocols and is optimized towards the up-loading of spacecraft commands and software and the downloading of collections of telemetry data. The SCPS-FP is based on the well-known Internet File Transfer Protocol (FTP).

The SCPS also include an underlying retransmission control protocol, the SCPS Transport Protocol or SCPS-TP, which is optimized to provide reliable end-to-end delivery of spacecraft command and telemetry messages between computers that are communicating over a network containing one or more potentially unreliable space data transmission paths. The SCPS-TP is based on the well-known Internet Transmission Control Protocol (TCP). The SCPS-TP extensions to TCP will solve similar problems in other environments, such as those of the mobile/wireless and tactical communications communities. A data protection mechanism, the SCPS Security Protocol or SCPS-SP, provides the end-to-end security and integrity of such message exchange. The SCPS-SP is derived from the Secure Data Network (SDNS) "SP3" protocol, the ISO Network Layer Security Protocol (NLSP), the Integrated Network Layer Security Protocol (I-NLSP), the Internet Engineering Task Force (IETF) Internet Protocol Security (IPSEC) Encapsulating Security Payload (ESP) and Authentication Header (AH) protocols. There exists a networking protocol, the SCPS Network Protocol or SCPS-NP that supports both connectionless and connection-oriented routing of these messages through networks containing space or other wireless data links. The SCPS-NP is based on the standard Internet Protocol (IP) with modifications to support new space routing needs and increased communications efficiency.

[†] *How WiMAX Works* by Edward Grabianowski and Marshall Brain, URL: http://computer.howstuffworks.com/wimax.htm

[‡] URL: http://www.scps.org/, JPL

The Space Communications Protocol Standards (SCPS) exist as full ISO standards and as United States Military Standards. They serve as the final Recommendations of the International Consultative Committee for Space Data Systems.[§]

L. Simple Automatic File Exchange/User Datagram Protocol (SAFE/UDP)

Another protocol which appears to be efficient in the transfer of data files is the Simple Automatic File Exchange (SAFE) protocol. This is a recent file exchange method that was developed by Global Science and Technology for Goddard Space Flight Center (GSFC) in order to lower the cost of operation for scientific satellite missions. It achieves this objective by enabling reliable and automatic file exchange even when contact with a spacecraft is intermittent. It returns scientific data to the project without operator intervention and, moreover, can also load command files into the spacecraft automatically. The SAFE algorithm can operate with fewer staff and one mission can share network-interconnected resources with other missions.[7]

This protocol operates in the application layer and is comparable to the standard FTP/TCP operation. The User Datagram Protocol (UDP) or any other transport layer protocol such as the TCP can be used in conjunction with it. The SAFE protocol provides reliable transfer of data over an unreliable network. Data is automatically transferred so operator intervention is not required. The SAFE protocol also functions independently of the transport protocol. The advantage is that the SAFE protocol avoids associated problems with the TCP over satellite links. No time is spent establishing a TCP connection.
Also, the SAFE protocol can take advantage of other enhancements such as SCPS. A disadvantage is that reliability and flow control must be provided by the SAFE protocol in the higher application layer. The SAFE server hosts the source data called the primary file. The SAFE client creates a secondary file replica of the primary file. The client then sends requests while the server waits for requests to arrive. The client request initiates the file transfer.

The SAFE protocol exhibits through simulation, considerably larger throughput than FTP.[8] This is because the FTP requires a TCP connection which takes 1.5 round-trip times or approximately 3/4 second to establish or close. This is due to the considerable delay of the GEO satellite. The SAFE protocol, alternatively, uses the UDP which is connectionless and experiences approximately one quarter second, one third of the former, delay time. This is due to the fact that the TCP uses a delayed-ACK timer which must expire at the initiation of slow start before an ACK is sent for the first segment. The SAFE protocol, however, does not use a delayed-ACK mechanism.

The SAFE Protocol was modeled in OPNET software and compared to three variations of FTP simulation models for the South Pole TDRSS Relay (SPTR) system illustrated in Fig. 4: FTP with a 8760 byte receive window and SACK (Selective Acknowledgments) disabled, FTP with a 64 kilobyte receive window and SACK disabled, and FTP with a 64 kilobyte receive window and SACK enabled, as implemented in Windows 95/98 which also includes the Fast Retransmit/Recovery algorithms and the window scaling option. The SAFE protocol exhibits a lower throughput for small average file sizes in comparison to throughput for large average file sizes since more percentage of time is spent in slow start. Time is required for the congestion window to increase. The SAFE/UDP also provides a higher throughput and a greater number of complete files received than all three variations of the FTP/TCP for file sizes from 1 MB to 50 MB in the SPTR System. Network bandwidth is better utilized with the SAFE protocol. The SAFE/UDP displays superiority to the three variations of the FTP/TCP.[9]

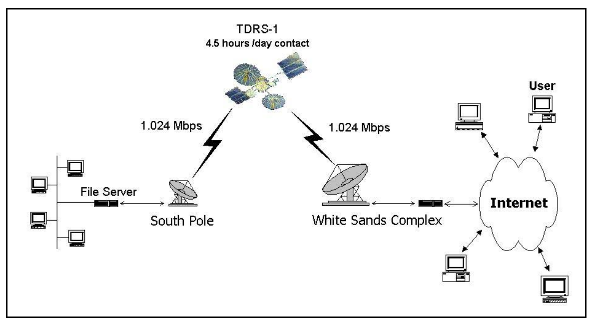

Figure 4. The SPTR communications system.

V. Conclusion

An ordered approach is needed to design lunar surface communications architectures. The task complexity dictates the requirements. The approach must be inherently an iterative process to optimize the network performance since no unique architecture exists. In order to design and develop protocol architectures consistently, a general methodology, which is beyond the scope of this paper, is discussed in specific detail in the literature.[10 11]

[§]URL: http://www.ccsds.org/, International Consultative Committee for Space Data Systems

An application assessment should be the initial step in the design process to identify the specific performance, functional, and application objectives. An assessment of the media should, then, follow to determine the homogeneity or heterogeneity of the environment. This will impact the types of extant hardware, software, and protocols in need of accommodation. Once these requirements and characteristics are known, an analysis of the possible transmission paths should be conducted to select the proper transmission facility. This, in turn, will lead to the selection process for the switching technology to be employed. The choices for the correct protocols, subsequently, will depend on the analysis of the protocol requirements, compatibility, and functionality.

VI. Future Prognosis

The future lunar surface network architecture designs will probably be based on the proven designs for terrestrial communications networks using specific lunar surface communication requirements. The framework for this will, most likely, be associated with the International Organization for Standardization (ISO) seven-layer Open Systems Interconnection (OSI) protocol reference model. Upon completion of this analysis, the process of synthesizing the conceptual protocol architecture can commence. This process will involve further analysis and comparison modeling. Certain protocol issues which for the most part are well known in the field will lead to various generic solutions to extirpate these issues for the amelioration of the protocol architecture design. A "trade-off" analysis will improve further the architecture design to satisfy the performance criteria.[12] This type of analysis is discussed in detail in the literature.

References

[1]New Vision for Space Exploration Program: Remarks by the President on U.S. Space Policy, NASA Headquarters, Washington, DC, Jan. 14, 2004.

[2]Preuss, R., and Bergamo, M., BBN, Inc., "Data Communications System and Hybrid Time-Code Multiplexing," U.S. Patent No. 6,590,889 B1, Jul. 8, 2003.

[3]Hain, Regina R., Ramanathan, Ram, Bergamo, Marcos, and Wallett, Thomas M., "Comparison of TCeMA and TDMA for Inter-Satellite Communications using OPNET Simulation," *Proceedings of the 2003 OPNETWORK Conference,* Washington, DC, August 25-29, 2003.

[4] ZigBee Specification, Document 053474r13, ZigBee Alliance, 1 December 2006.

[5] IEEE Std 802.15.4™-2006 (Revision of IEEE Std 802.15.4-2003), IEEE, 3 Park Avenue, New York, NY 10016-5997, USA, 8 September 2006.

[6] Mike Cauley, private discussion on 10 April 2008 about the WiMAX World 2007 Conference, 25-27 September 2007, McCormick Place Convention Center, Chicago, Illinois.

[7]Baker, Paul, "Guide to the Protocol for Simple Automatic File Exchange (SAFE)," *Report to NASA Goddard Space Flight Center,"* Global Science and Technology, Greenbelt, Maryland 20770, Jun. 8, 1999.

[8] Knoblock, Eric J., Konangi, Vijaya K., and Wallett, Thomas M., "Simulation and Evaluation of the SAFE Protocol," *OPNETWORKS'2000 Conference*, Washington, DC, Aug. 31, 2000.

[9]Knoblock, Eric J., Konangi, Vijaya K., and Wallett, Thomas M., "Comparison of SAFE and FTP for the South Pole TDRS Relay System," 18th *AIAA International Communications Satellite Systems Conference,"* Oakland, CA, Apr. 13, 2000.

[10]Dhas, Chris, "Protocol Architecture Model Report," NASA/CR—2000-209781, Computer Networks and Software, Springfield, VA, Jan. 2000.

[11]Dhas, Chris, "Architectural Methodology Report," NASA/CR—2000-209783, Computer Networks and Software, Springfield, VA, Jan. 2000.

[12]Dhas, Chris, "Trade-off Analysis Report," NASA/CR—2000-209785, Computer Networks and Software, Springfield, VA, Jan. 2000.

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14. ABSTRACT
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