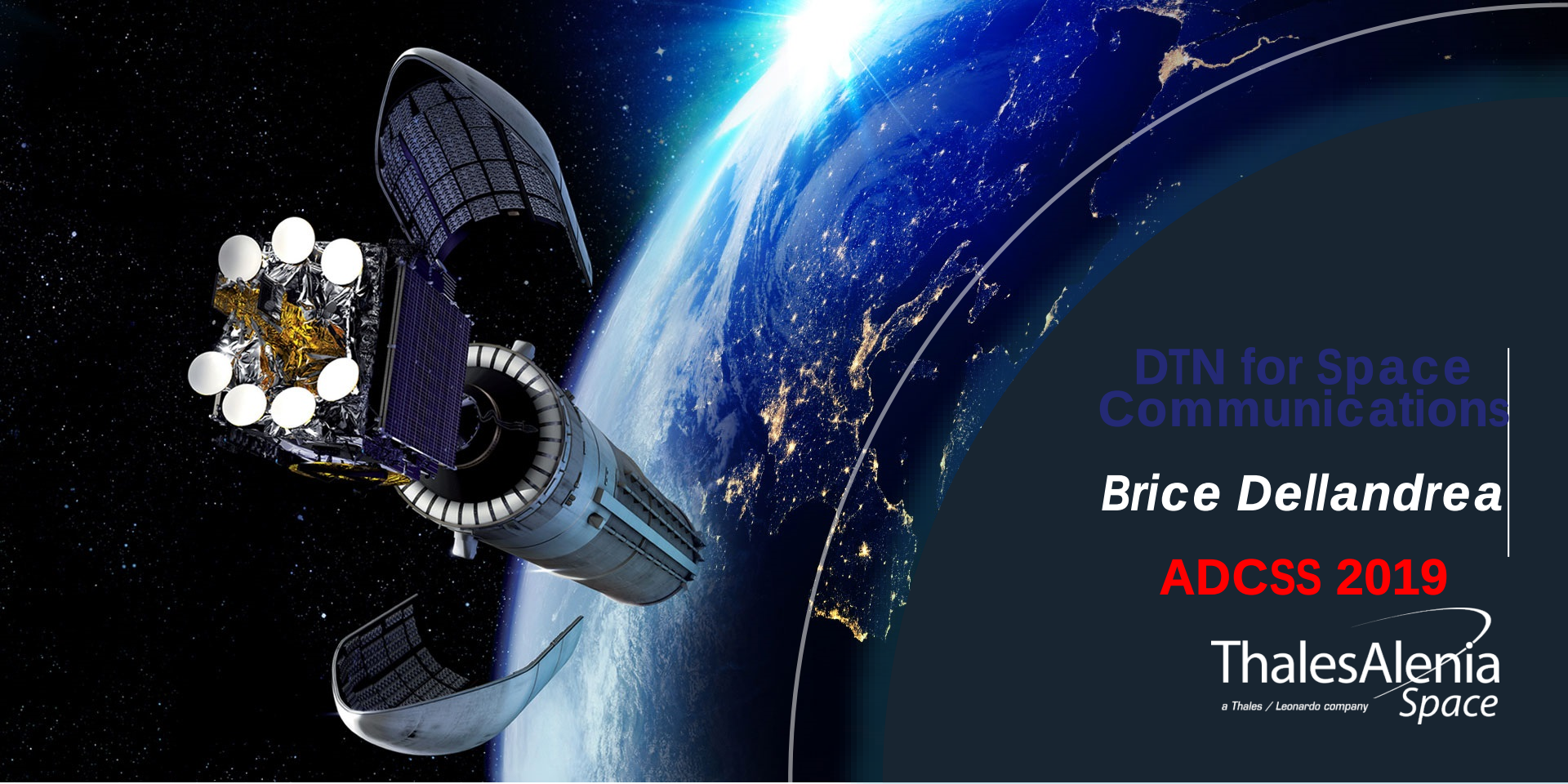

DTN for Space Communications

Brice Dellandrea

ADCSS 2019

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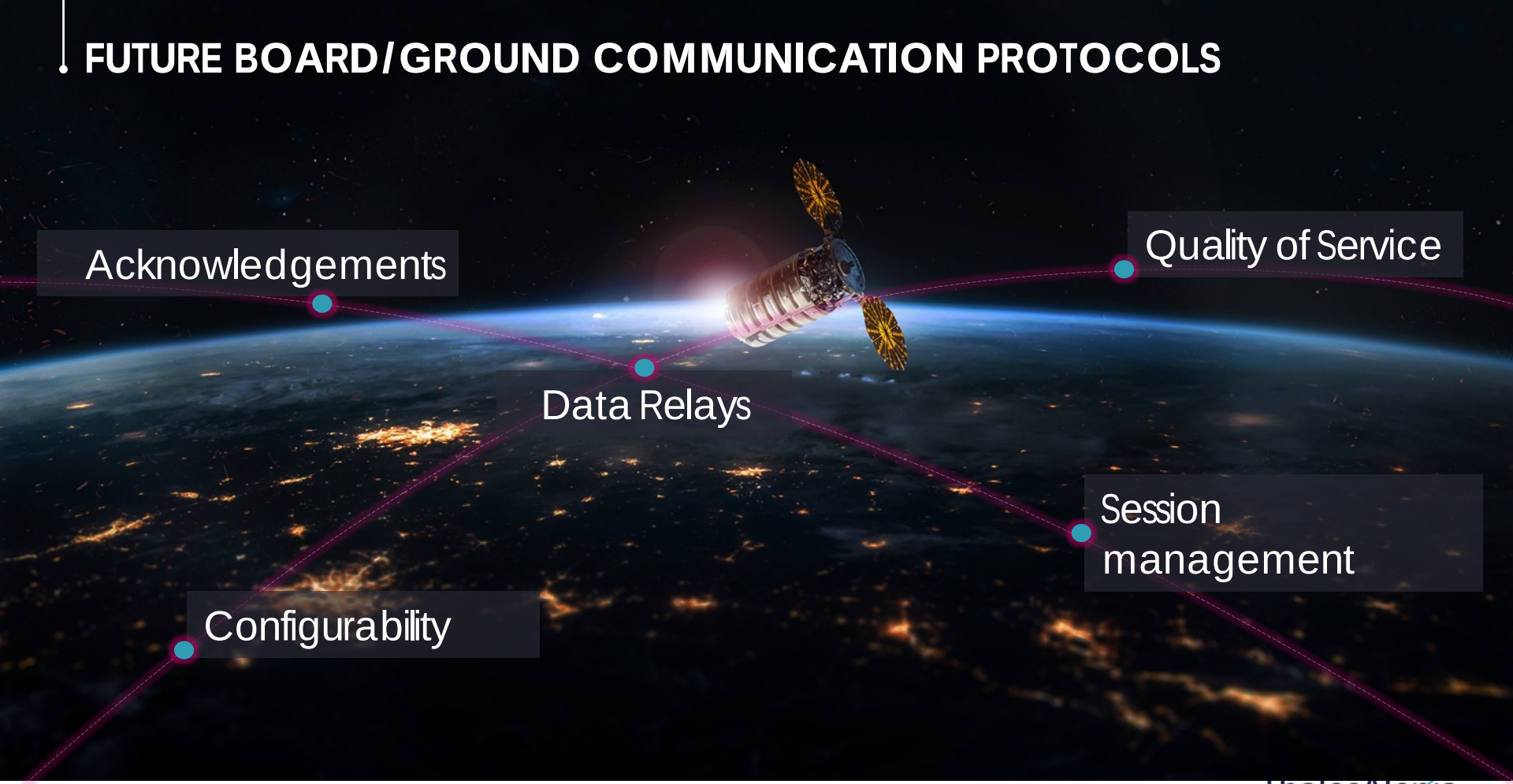
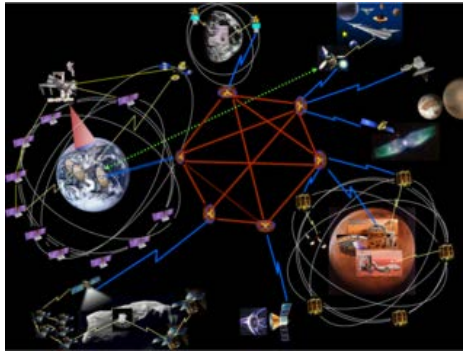
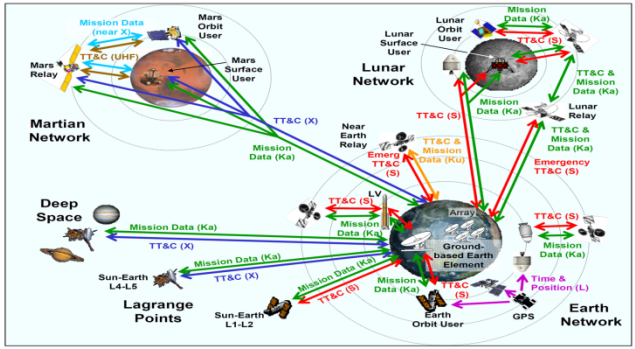
FUTURE BOARD/GROUND COMMUNICATION PROTOCOLS



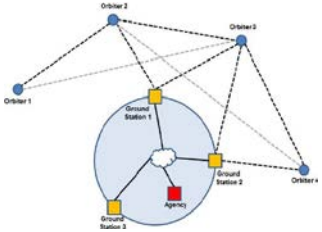
DTN in Space applications ?

- **DTN is reaching a high maturity**
  - NASA: experiments (Epoxy, DINET, ISS, LLCD, EO-1…), baselined for Mars 2020 & DRM 5 asteroid redirect – 2020 & 2022
  - Europe: R&T (ESTES, ESOC & CNES)
  - Interoperability to be verified (many concernes) – on-going activity with CNES
  - CCSDS 734.5-R-1 in review (security)

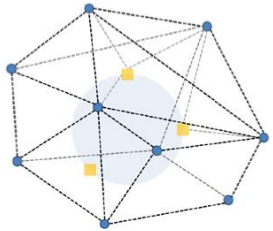




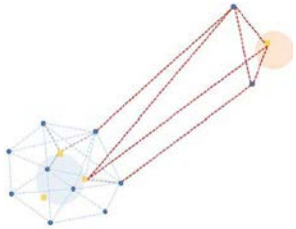
- **DTN is useful for complex dynamic topologies and/or links with heavy disruption (deep space/laser links)**



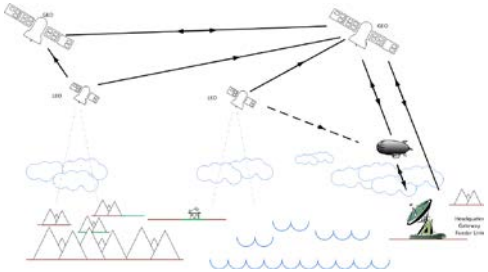
Single EO satellite interconnected with ground stations and relay satellites via DTN

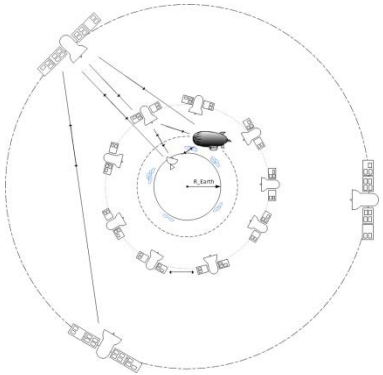


Globe-spanning DTN network of interconnected space and ground assets



Extension of DTN network to deep space mission





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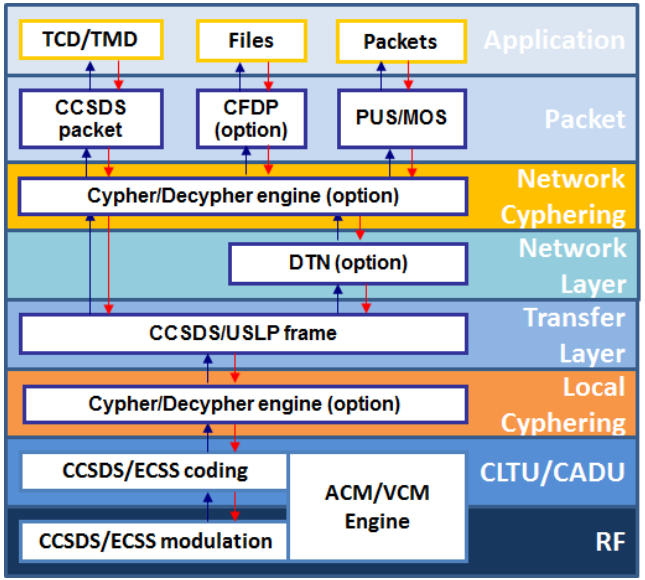
Why new protocols?

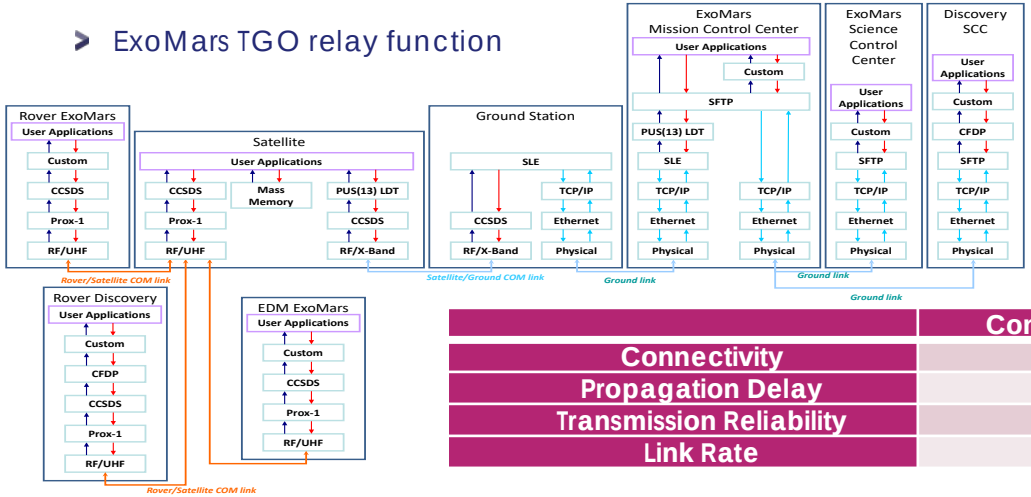
New services

- CFDP: **file transfer services** & proxy operations with acknowledgements **-** ***packet-level protocol***
- DTN: **solar-system internet** / overlay protocol for frame acknowledgements; store & forward and dynamic in-space routing on highly heterogenous networks **-** ***frame-level protocol***



CCSDS standards for improved inter-operability

- ExoMars TGO relay function



	Conventional Ground Networks	Space communications
Connectivity	Continuous	Frequent Disconnections
Propagation Delay	Short Time	Long Time
Transmission Reliability	High Reliability	Low Reliability
Link Rate	Symmetric	Asymmetric

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CFDP: CCSDS File Delivery Protocol?

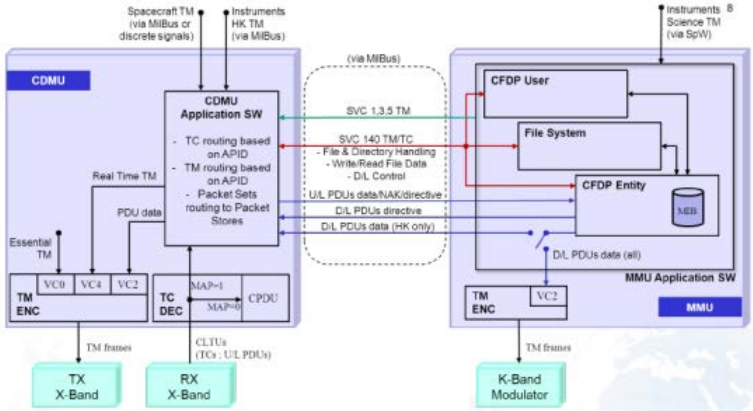
NASA missions

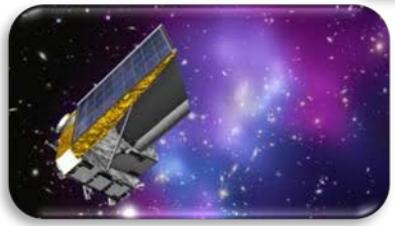
- For interplanetary missions (JWST)
- Implemented as flight software for the Messenger S/C

TAS missions: EUCLID, PLATO

- File transfer: Files can be transferred only one way, from the spacecraft to the Ground.
- File system operations, such as move and delete, are performed via native flight software commands as opposed to within CFDP.
- File transfers on the board side can be initiated automatically or through commanding outside of the CFDP framework.

- Robust to long data propagation delays and frequent losses of communication windows because it implements optional mechanisms of lost segments automatic repetition which ensures no loss of data.
- Enables instruments to store data to be send to ground on-board without having to check if the transmission is possible at that given time. This layer simplifies data handling on-board and data transfer scheduling hence absorbing part of both ground and on-board complexity in order to reduce costs for interplanetary missions.
- The CFDP protocol interfaces itself in between a File Management Service with well-defined primitives and a communication system with enough QoS without especially having an automatic system for repeating the data in case of errors.
- CFDP is also tolerant to random data transfer delays, its principle is store data then transfer data which can be compared to the way e-mails does with attachments.





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DTN: Delay Tolerant Network

In a nutshell

- DTN Protocol is in fact a suite of 2 stacked protocols : Bundle Protocol (BP) and Licklider Transmission Protocol (LTP)

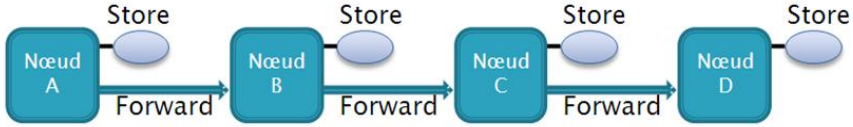
Missions?

- NASA mainly: ISS, Epoxy, NASA Lunar OISL, experiments with ESOC
- Baselined on the Gateway
- DTN engine available on NASA website

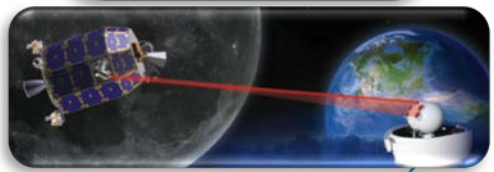
TAS?

- A complete version of a software DTN engine is available, compatible with NASA ION software
- Baselined in TAS-CH optical com terminal

Ready for USLP & ACM/VCM



- Long term storage. The nodes of the network have a dedicated storage capacity sufficient to keep the message until the node has the slot to transmit them. The storage duration is defined by the memory size and the priority of the messages it stores, the QoS requirements etc... The storage size may vary between nodes within a single network.
- The storage in DTN networks is managed at message level. A message is stored as a whole and it integrity is check locally. It is only when the message has been aggregated and checked that it can be forwarded.
- The messages are aggregated and checked at each node they go through during their routing.
- The DTN protocol is extremely powerful and enables managing at frame level issues usually addressed at higher level (packets). It introduces a QoS and routing capabilities absent from the current space frame-level protocols, but at the cost of a considerable complexity. Improvements of the protocol are possible to reduce its complexity while maintaining its benefits.



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DTN standards

- DTN is normalized through many standards and clarified through manuals:

Tutorial & starter kit:

- A comprehensive DTN tutorial: http://ipnsig.org/wp-content/uploads/2015/09/DTN_Tutorial_v3.2.pdf
- NASA's DTN Development Kit: https://www.mitre.org/download-nasas-dtn-development-kit (username: core; password: cvm): virtual machine & user guide

CCSDS:

- CCSDS 734.2-B-1 CCSDS Bundle Protocol Specification. Blue Book. Issue 1 (09/2015): https://public.ccsds.org/Pubs/734x2b1.pdf
- CCSDS 734.1-B-1 Licklider Transmission Protocol (LTP) for CCSDS. Blue Book Issue 1 (08/2015): https://public.ccsds.org/Pubs/734x1b1.pdf
- CCSSDS 734.5-R-1 CCSDS Streamlined Bundle Security Protocol Specification (03/2018): https://public.ccsds.org/Lists/CCSDS%207345R1/734x5r1.pdf
- CCSDS 730.0-G-1 Next Generation Space Internet (04/2003): https://public.ccsds.org/Pubs/730x0g1s.pdf
- CCSDS 730.1-G-0 Solar System Internetwork (SSI) Architecture (06/2014): https://public.ccsds.org/Pubs/730x1g1.pdf
- CCSDS 734.0-G-1-E-1 Rationale, Scenarios, and Requirements for DTN in Space (08/2010): https://public.ccsds.org/Pubs/734x0g1e1.pdf
- CCSDS 734.3-R-1 Schedule-Aware Bundle Routing (07/2018): https://public.ccsds.org/Lists/CCSDS%207343R1/734x3r1.pdf

RFC:

- Delay-Tolerant Networking Architecture: https://tools.ietf.org/html/rfc4838
- Bundle Protocol Specification: https://tools.ietf.org/html/rfc5050
- Licklider Transfer Protocol Specification: https://tools.ietf.org/html/rfc5326
- Compressed Bundle Header Encoding (CBHE): https://tools.ietf.org/html/rfc6260
- LTP, Licklider Transmission Protocol - Security Extensions: https://tools.ietf.org/html/rfc5327
- DTN IP Neighbor Discovery (IPND): https://tools.ietf.org/html/draft-irtf-dtnrg-ipnd-02

DTN full stack details (as per current datagrams)

DTN (SECU)

Layer	Definition	Header																				Data	Trailer	Doc Source
DTN (SECU)	Structure	CCSDS Streamlined bundle Security Protocol																						
	Type	*BIB Security Header: Integrity*										*BCB Security Header: Ciphering*										*Bundle Payload*		
	Subtype	Type	Control Flag	Security Target		Cipher suite ID	Cipher suite flags	Cipher Suite		Security result		Type	Control Flag	Security Target		Cipher suite ID	Cipher suite flags	Cipher Suite		Security result		Effective data		
				Number of parameters	Parameters data			Number of parameters	Parameters data	Length	Data			Number of parameters	Parameters data			Number of parameters	Parameters data	Length	Data			
	Note			SDNV	Compound	SDNV	SDNV	SDNV	Compound	SDNV	SDNV			SDNV	Compound	SDNV	SDNV	SDNV	Compound	SDNV	SDNV			
	Content	0x03										0x04										Data		
	Size(bits)	8	8	8	16	8	8	8	16	8	16	8	8	8	16	8	8	8	16	8	16			
	Size(bytes)	1	1	2	2	1	1	1	2	1	2	1	1	2	2	1	1	1	2	1	2	852		
	Total (bytes)	880																						CCSDS 734.5-R-1

DTN (BP)

Layer	Definition	Header																				Data	Trailer	Doc Source
DTN (BP)	Structure	Primary Bundle Block - CBHE (compressed) + ECOS extention																						
	Type	*Bundle Header*																				*Bundle Payload*	*Bundle Trailer*	
	Subtype	Version	Proc. Flags	Block length	Flag	Ordinal	Destination scheme offset	Destination SSP offset	Source scheme offset	Source SSP offset	Report-to scheme offset	Report-to-SSP offset	Custodian Scheme offset	Custodian SSP offset	Creation Timestamp time	Creation Timestamp sequence number	Lifetime	Dictionnary length	Dictionnay byte array	Fragment Offset	Total Application data unit length	Effective ciphered data	*Network security trailer*	
				Length of the rest of the primary block	Critical/ streaming/ ordinal	level of precedence	Destination Node ID	Destination Service ID	Source Node ID	Source Service ID	Report Node ID	Report Service ID	Custodian Node ID	Custodian service ID				None	None	Only if fragment flag is set in block's proc.	Only if fragment flag is set in block's proc.		Authentication Tail (optional)	
	Note												SDNV	SDNV	SDNV	SDNV	SDNV			**SDNV**	**SDNV**			
	Content				ECOS	ECOS																Data		
	Size(bits)	8 bits	24 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	32 bits	32 bits	32 bits	0 bits	0 bits	8 bits	8 bits		0 bits	
	Size(bytes)	1	3	1	1	1	1	1	1	1	1	1	1	1	4	4	4	0	0	1	1	880	0	
	Total (bytes)	909																						RFC-5050

DTN (BP)

Layer	Definition	Header					Data	Trailer	Doc Source
DTN (BP)	Structure	Extended Bundle Block - ECOS							
	Type	*Bundle Header*					*Bundle Payload*		
	Subtype	Block Type	Proc. Flags	Block Length	Flag	Ordinal	Effective data		
	Note		**= 1**	**SDNV**	Critical/ streaming/ ordinal	level of precedence			
	Content						Data		
	Size(bits)	8 bits	8 bits	16+8N bits	8 bits	8 bits			
	Size(bytes)	6					909		
	Total (bytes)								RFC-5050

DTN (LTP)

Layer	Definition	Header								Data	Trailer	Doc Source
DTN (LTP)	Structure	Licklider segment structure										
	Type	*LTP Header*						Header Security Extension		*LTP Segment Content*	LTP Security Trailer	
	Subtype	Version Number	Segment Type Flags	Session ID (Source+number)	Header Extension Cnt.	Trailer Extension Cnt.	Header Extensions	CipherSuite	LTP-auth header extension	Effective data (+ client service ID + Offset + length in SDNV)	AuthVal field	
	Note			**SDNV**			**SDNV**	**SDNV**	**SDNV**		**SDNV**	
	Content	= '0000'	CTRL, EXC, Flag 1, Flag					KeyID	1st segment only	Data		
	Size(bits)	4 bits	4 bits	8*N bits	4 bits	4 bits	8*N bits	8 bits	8*N bits		8*N bits	
	Size(bytes)	4								915	32	
	Total (bytes)	951										RFC-5050

!! A lot of SDNV fields !!!

DTN full stack details (as per current datagrams)

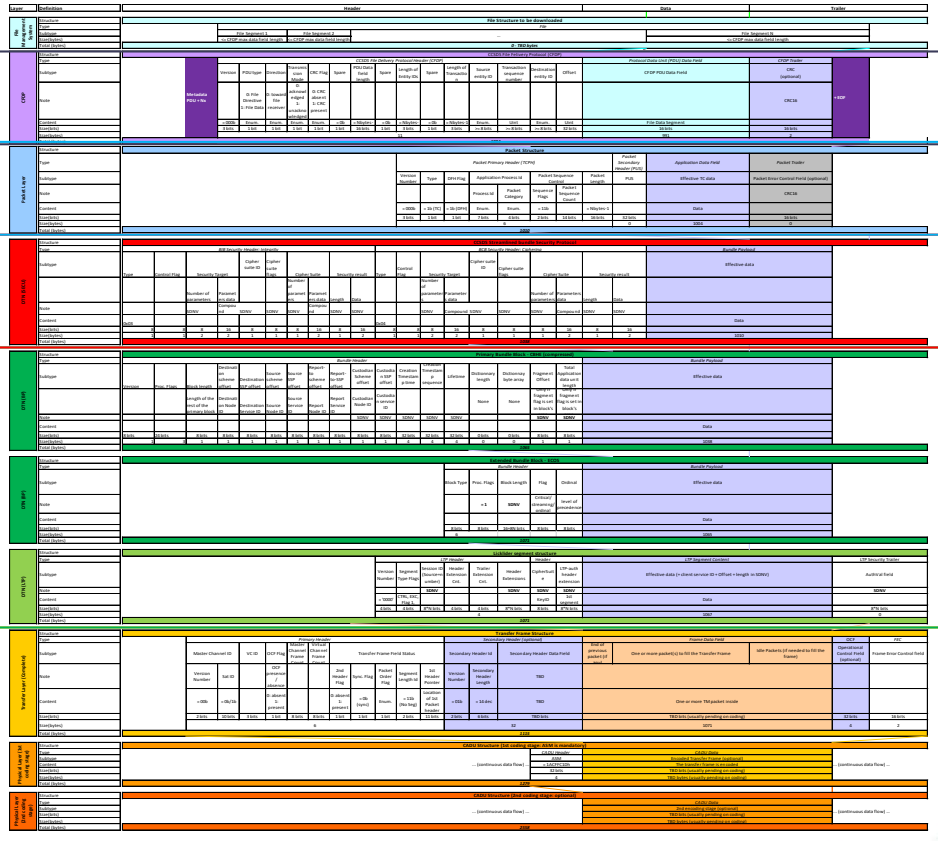
CCSDS CFDP

CCSDS Packet

DTN NET Security

DTN (BP, LTP & CLA)

Frames & Coding



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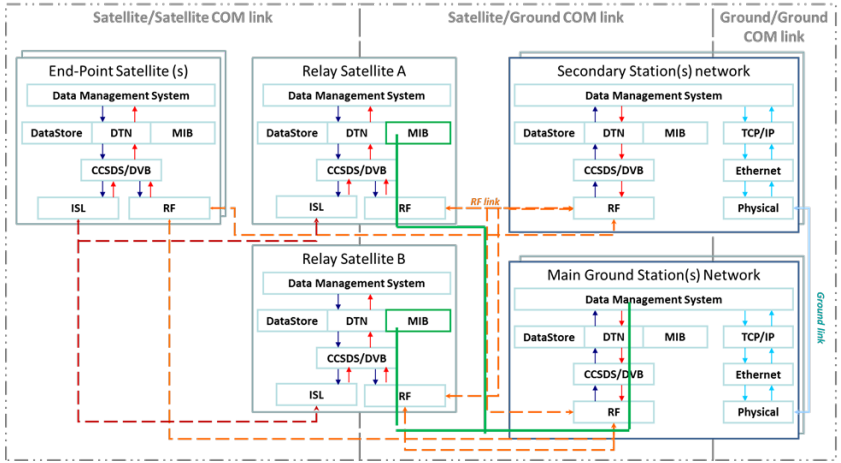
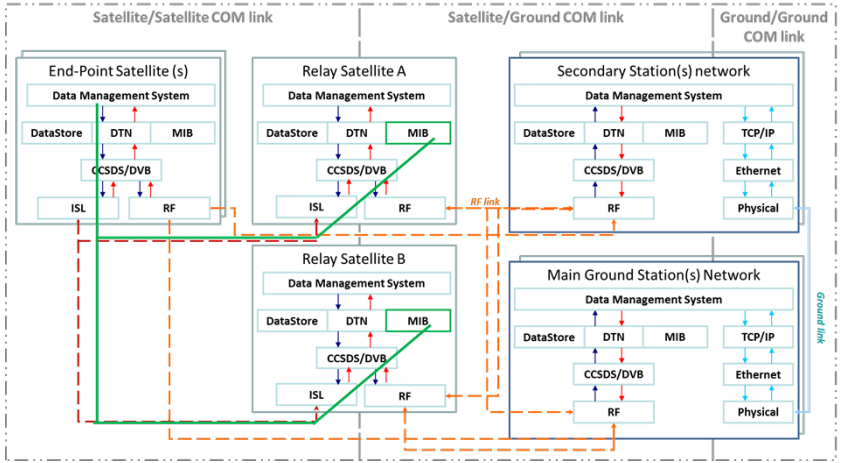
Architectures & topologies?

How to configure DTN in space ?

Each DTN layer has its own Mission Information Base (MIB), enabling to configure it. A change in DTN configuration requires a MIB patching through a mechanism not defined within DTN





Concept A: configuration by Super-user (Ground)

- Safe
- Issues in terms of scalability
- Not defined in current standard, yet usual way to configure spacecrafts

Concept B: configuration by the Network

- Scalable
- Security ?
- Not defined in current space standards, yet many Ground standards!

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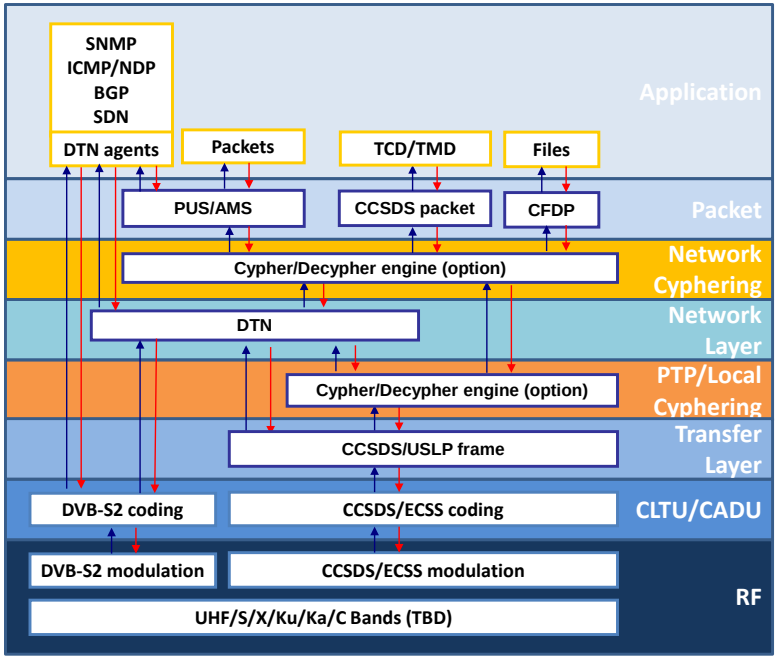
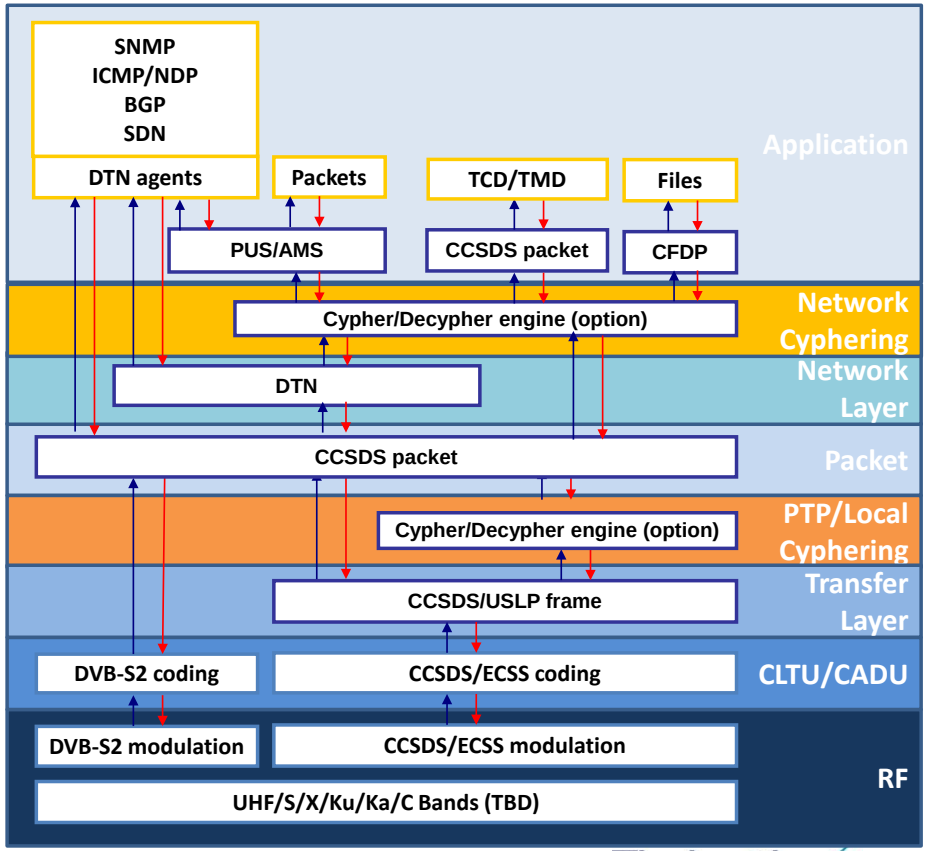
Implementation impacts – reference protocol stack

High level protocols & agents in the stack

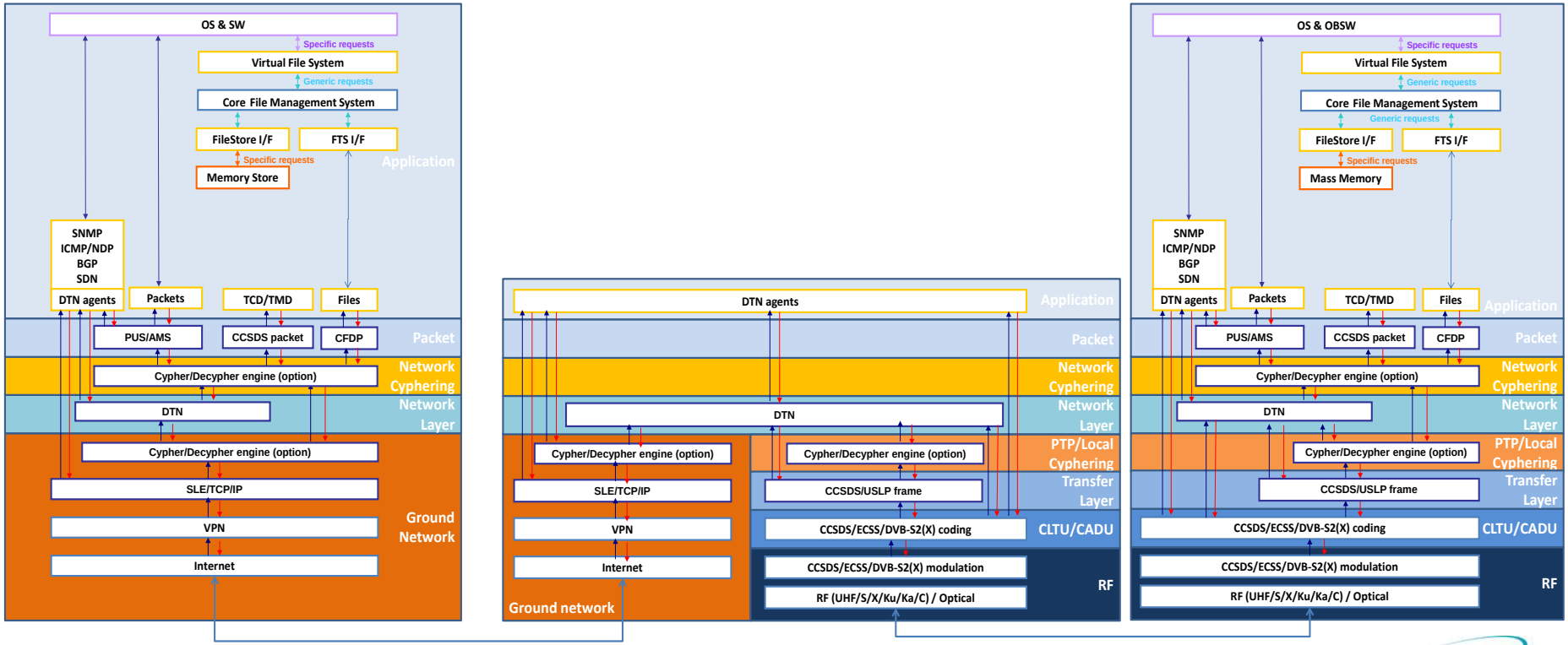
- Trade-off difficult to asses on packet layer position in the stack
- Pro & cons are related to the variable frame size handling & IDs management (see NDP after)





Implementation impacts – full network?

Including the Ground infrastructure, file transfer & PUS stacks



Conclusion & future works?

- **The DTN layers are about to converge to a fixed solution with the novel BPv7 stack, potentially with a LTP update**
- The DTN protocol introduces many features and come also with specific challenges to face:
  - Data retransmission without need for direct end-to-end visibilities,
  - Network security on-top of point-to-point encryption,
  - Long-range communication & sporadic links,
  - Reconfiguration/operational concepts for network handling:
    - Critical configuration points by a control center (visibilities, new-comers, authentication & crypto keys updates),
    - Adjustment parameters configurable by the end-users (visibility updates, bandwidth updates),
    - Automatic management of routing schemes within the secured zone.
- **If the three first issues can come with well identified solution within DTN, the latter is trickier even if not specific to the space segment. Many protocols have been developed for Internet yet relying on parallel stacks based on UDP or TCP. For Space, we then have the choice either to implement parallel stacks for network management or adapt those protocols to a DTN-based stack.**
- **DTN is already useful for:**
  - Data relay over space & ground networks
  - Frame transfer acknowledgement & retry process for noisy data links (high frequency/optical communications)
- **DTN needs CFDP to transfer files & perform the segmentation with file-specific services. Relying on DTN, CFDP class 1 can be sufficient (TBC for class 2)**

Q&A Discussion

Conclusion

Thank you for your attention !