VOIP over Space Networks

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Overview

- Drivers for VOIP in Space Networking
- Challenges in the Space Networking Environment
  - Long latencies
  - Packet Loss
  - Simplex paths
  - Asymmetric paths
  - QoS requirements
  - Team-based operations
  - Overhead concerns, including that from IPSEC
- Possible VOIPOSN approaches
- Testbed efforts
- Conclusions

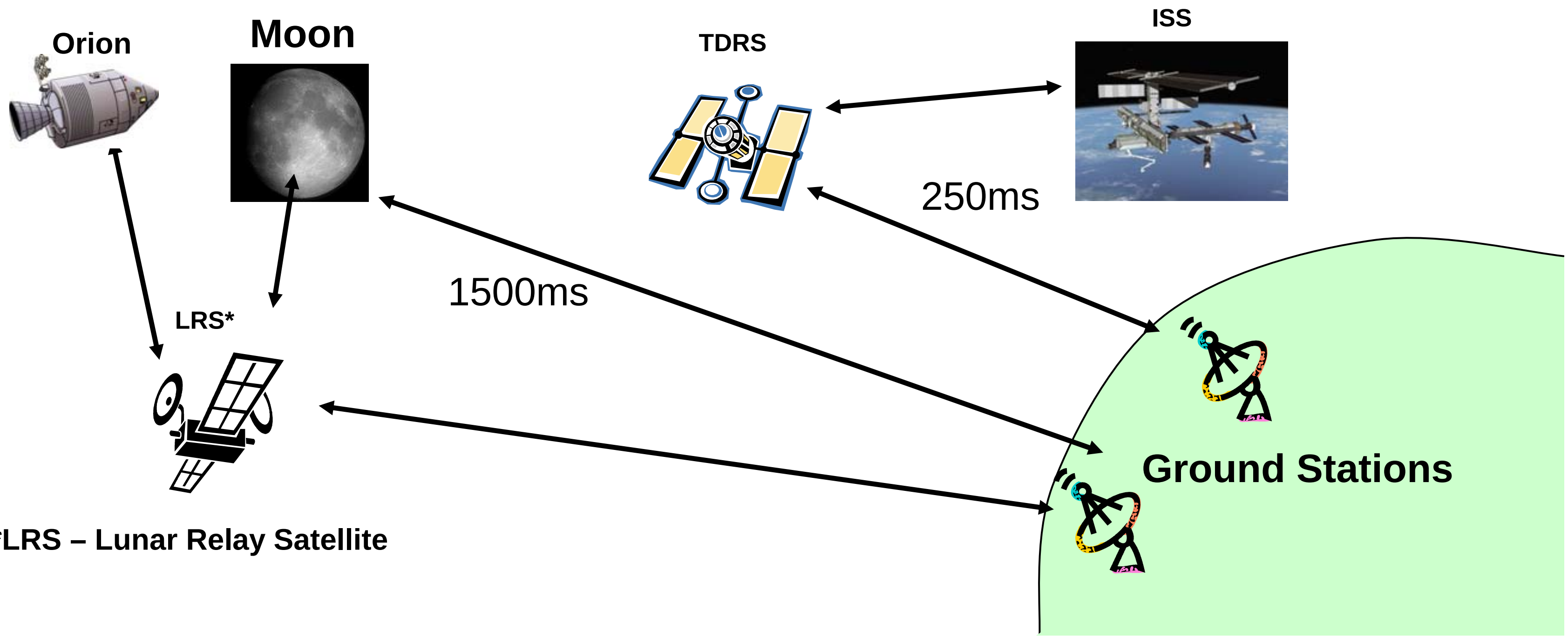
Drivers for VOIP in Space

- **The NASA Space Communication Architecture Working Group (SCAWG) generated a report* that recommends standardization of the network layer based on IP (although some enhancements, such as via DTN, are recognized as being necessary)**
- **Voice communications will be handled in a "converged" network, multiplexed with other traffic sources of telemetry etc., for increased efficiency**
- **NASA has verified use of VOIP in LEO operations using the Orbital Communications Adaptor (OCA)****

- **NASA Space Communication and Navigation Architecture Recommendations for 2005-2030 (https://www.spacecomm.nasa.gov/doc_repository/architecture/SCAWG_Report.pdf)**
- ****http://www.gcn.com/print/vol20_no5/3777-1.html**

Challenges in the Space Networking Environment: Long Latencies

- Operations in LEO through TDRSS relay poses noticeable two-way path latencies
- NASA is progressing toward President Bush's vision to "gain a new foothold on the moon and to prepare for new journeys to the worlds beyond our own." The lunar environment will introduce very substantial propagation delays in VOIP control and transport.



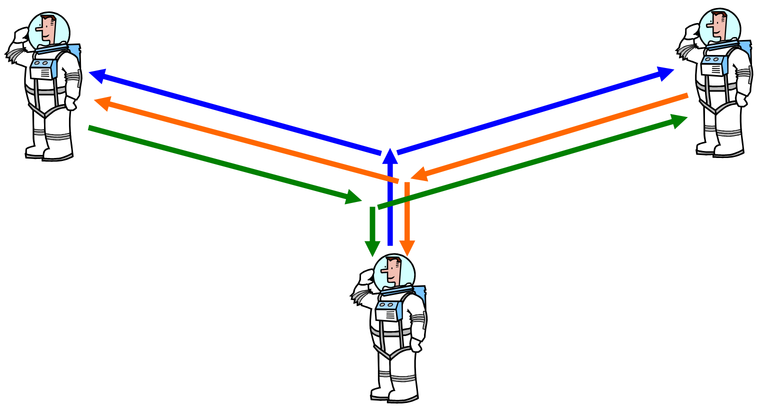
*LRS – Lunar Relay Satellite

Challenges in the Space Networking Environment: Packet Loss

- **Space communications will use wireless links that may be subject to significant bit error rates**
- **While there are emerging advancements in VOIP in terrestrial wireless applications (e.g. WLANs, WiMax), these must be considered in the space in conjunction with other aspects such as long distance links**
- **In addition, the BER can change during the course of a call. Potential solutions include**
  - **automated codec changes**
  - **voice/channel quality detection algorithm**
    - **e.g. RTP sequence number skip**

Challenges in the Space Networking Environment: Team-based operations

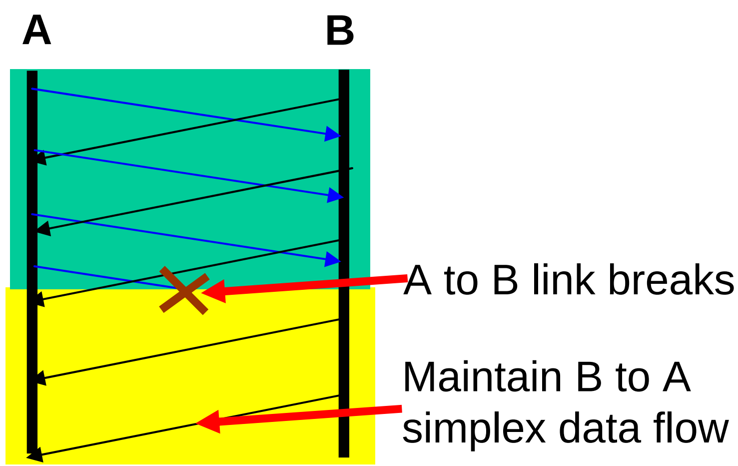
- **Space operations generally work in teams***
- **The impact on voice connections is that rather than being point-to-point between two end users, they typically are formed using "voice loops"**
- **Voice loops could be achieved via multicast or use of centralized conference call server or hybrid. Factors to be considered include:**
  - **Traffic loading pattern**
  - **Placement of conference call server**
  - **Mixing method (client-side vs. central server)**
  - **Efficiency of long-haul and short-range link use**

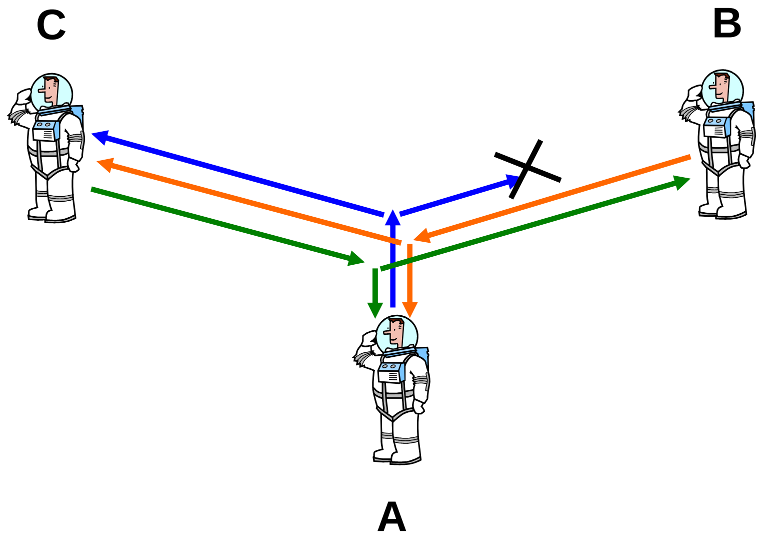


*** Watts J., et. al., "Voice Loops as Cooperative Aids in Space Shuttle Mission Control", Proceedings of the 1996 ACM conference on Computer supported cooperative work.**

Challenges in the Space Networking Environment: Simplex paths

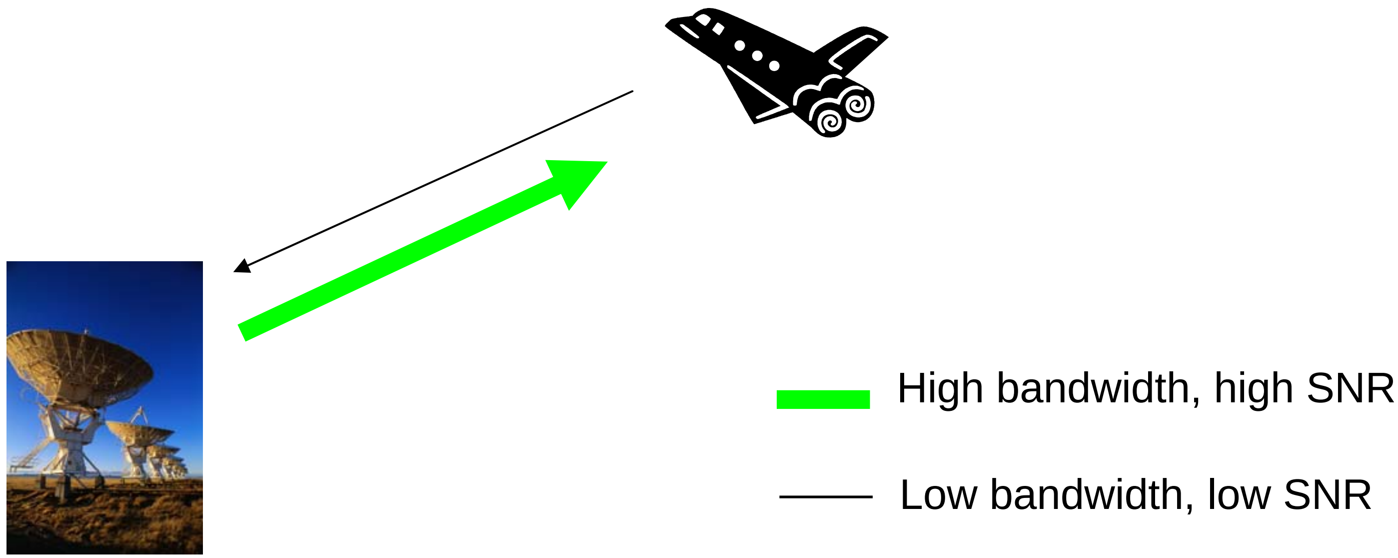
- **Space operations must be able to use simplex (one-way) channels**
- **In addition, if a two-way channel is operating, and a failure occurs in one direction, then the voice in the direction where communications is still feasible must be maintained. This type of operation may not be possible with COTS technologies which operate under different assumptions than the space environment.**





Challenges in the Space Networking Environment: Asymmetric paths

- **Operations in space may involve the communications in opposite directions are subject to very distinct characteristics, such as bandwidth and BER**
- **Asymmetry of link layer capacity/reliability may benefit by use of different codecs for each direction within a single call, which may not be supported by current COTS products**



Challenges in the Space Networking Environment: Overhead concerns

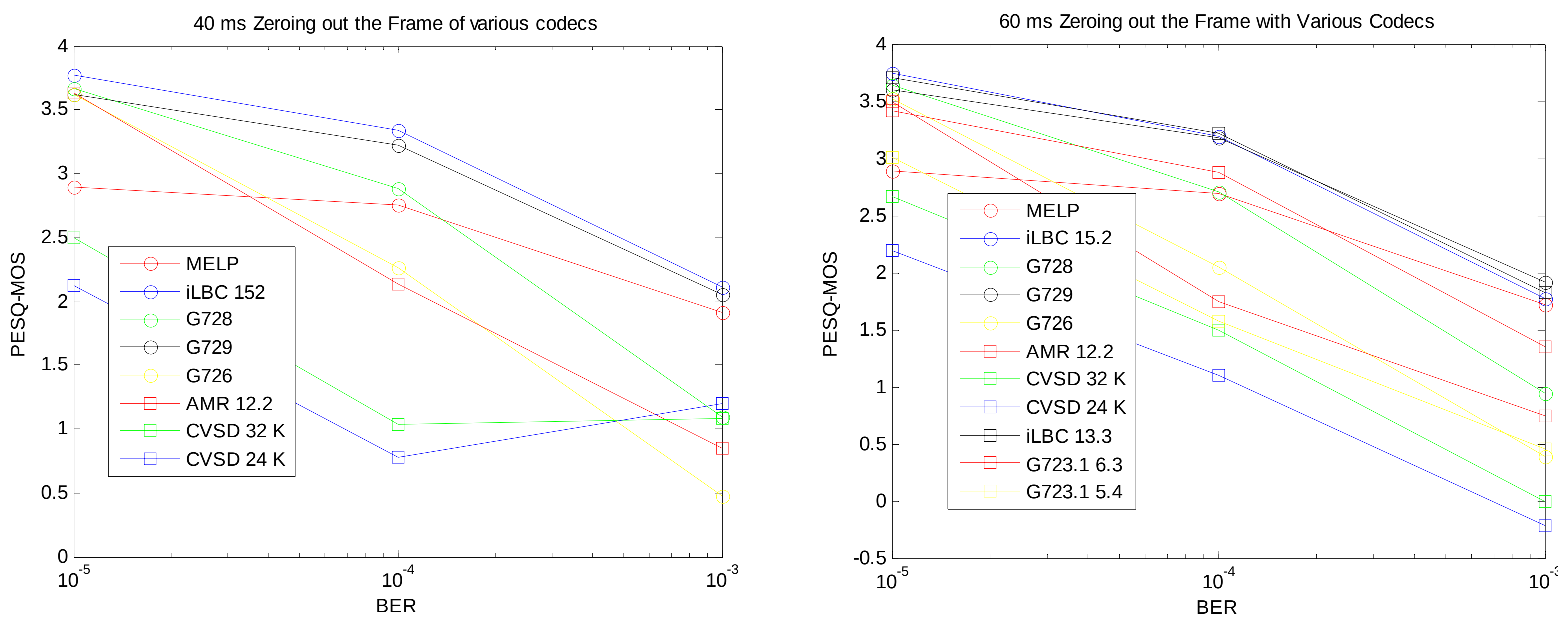
- **VoIP may introduce a significant amount of overhead**
- **The amount of overhead will depend on:**
  - **Amount of header compression used**
  - **If multiple voice packets are combined per IP packet**
  - **Size of voice sample**
  - **If IPv4 or IPv6 is used**
  - **If IPSec is used**

Total Overhead (Bytes)							
48			AOS (8)	IPv4 (20)	UDP (8)	RTP (12)	Voice
72			AOS (8)	IPSec ESP (24)	IPv4 (20)	UDP (8)	RTP (12)	Voice
76		AOS (8)	Encapsulation Packet Hdr (8)	IPv6 (40)	UDP (8)	RTP (12)	Voice
100	AOS (8)	Encapsulation Packet Hdr (8)	IPSec ESP (24)	IPv6 (40)	UDP (8)	RTP (12)	Voice

Example using AOS VCP Service for link layer

Possible VOIPOSN approaches: Codec Comparisons

- **Study of BER, codec type and voice frame length on PESQ-MOS**
- **Identify the optimal (based on PESQ-MOS metric) codec under a given channel condition**



Possible VOIPOSN approaches: Codec Comparisons

- Space environment may introduce a high one way delay relative to traditional VOIP usage on Earth
- Mouth-to-ear delay at Lunar distances (~ 1630 ms):
  - One-way light time (OWLT) between Earth and moon (1500ms)
  - Gateway and IPSec encryption delay (~105ms with AES)
  - Codec delay at both ends (varies between .75 to 30ms)
- Codec MOE depends on complexity and minimum bandwidth requirement
- More sophisticated codecs' processing delay may become insignificant due to large OWLT

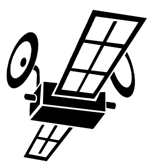
CODEC	Data Rate (Kbits/s)	Enc Complexity*	Dec Complexity*	Codec frame size / codec delay (ms)
ITU-T G.711	64	1	1	20, 30, 40, 60 ,80, 90, 100, 120
GSM-AMR-EFR	12.2	60.3	12.3	20, 40, 60, 80, 100, 120
G.723	6.3, 5.6	109.2	5.7	37.5, 67.5, 97.5, 127.5
G.726	32	20.7	12.6	20, 30, 40, 60 ,80, 90, 100, 120
G.729	8	.581	.34	20, 30, 40, 60 ,80, 90, 100, 120
Ilbc	15.2, 13.3	36.8	9.2	{30, 60, 90, 120}, {20, 40, 60, 80, 100, 120}
MELP	2.4	20.9	10.9	22.5, 45, 67.5, 90, 112.5, 130
G.728	16	53.28	31.8	20, 40, 60, 80, 100, 120
CVSD	16, 24, 36	.53	.43	20, 40, 60, 80, 100, 120

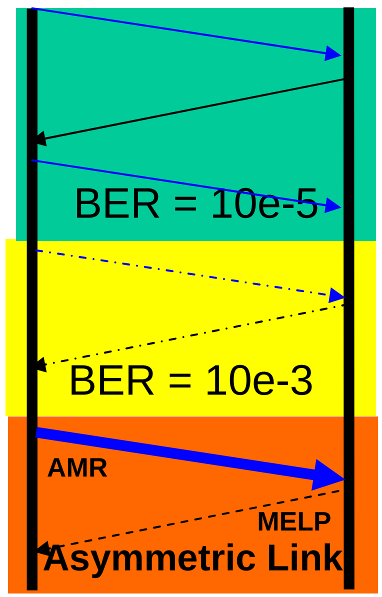
*Complexity metric is the relative encoding and decoding time required to process a 53-second long ITU-T provided voice sample file using a PC with 2.0 GHz Pentium 4 CPU and 2GB RAM running Cygwin OS.

Possible VOIPOSN approaches: Dynamic Codec Selection

- **To mitigate voice quality fluctuation when BER varies during course of call:**
  - **Dynamically select codec to meet the bandwidth availability to obtain the optimal voice quality**

LRS



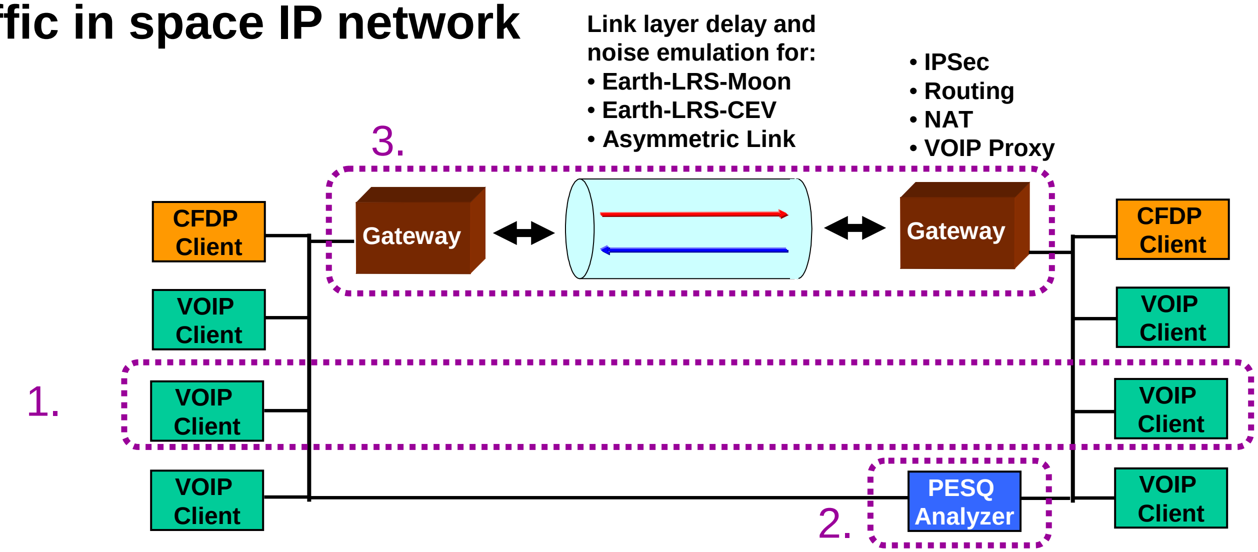


- **Initiated and established call with GSM-AMR-EFR codec (12.2 Kbits/s minimum required bandwidth)**
- **BER rises and codec switched to MELP (2.4 Kbits/s minimum required bandwidth)**
- **Codec use change also sensitive to changes in forward and return link bandwidth availability**

- **To accommodate asymmetry – may use different codecs at opposite ends of the duplex link**

Testbed Efforts

- Developing VOIP over space testbed
  1. Completed open source implementation of VOIP with simplex links, packet loss emulation, and dynamic codec reconfiguration
  2. Completed codec PESQ-MOS simulation analysis environment tool
  3. Completed secure VOIP gateway implementation
- Investigating the effects of using VOIP over IPSec in Lunar propagation delay and channel noise
- Experimenting with channel quality detection mechanisms to trigger the dynamic codec switching algorithm
- Analyzes the performance of multiplexing VOIP traffic with other traffic in space IP network



Conclusions

- **VOIP use in space poses new challenges arising from large delays, varying bandwidth availability and bit errors**
- **Identified specific user requirements in the space exploration domain**
- **Possible methods to improve the effective use of available bandwidth to provide intelligible VOIP service include dynamic codec switching and merging multiple voice frames to save packet overhead**
- **PESQ-MOS measure used to analyze voice degradation over space links tested for variety of codecs**
- **VOIP over space network testbed developed to enable experimentation in the context of general traffic and physical links anticipated for emerging missions**