# VOIP over Space Networks

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# Overview

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

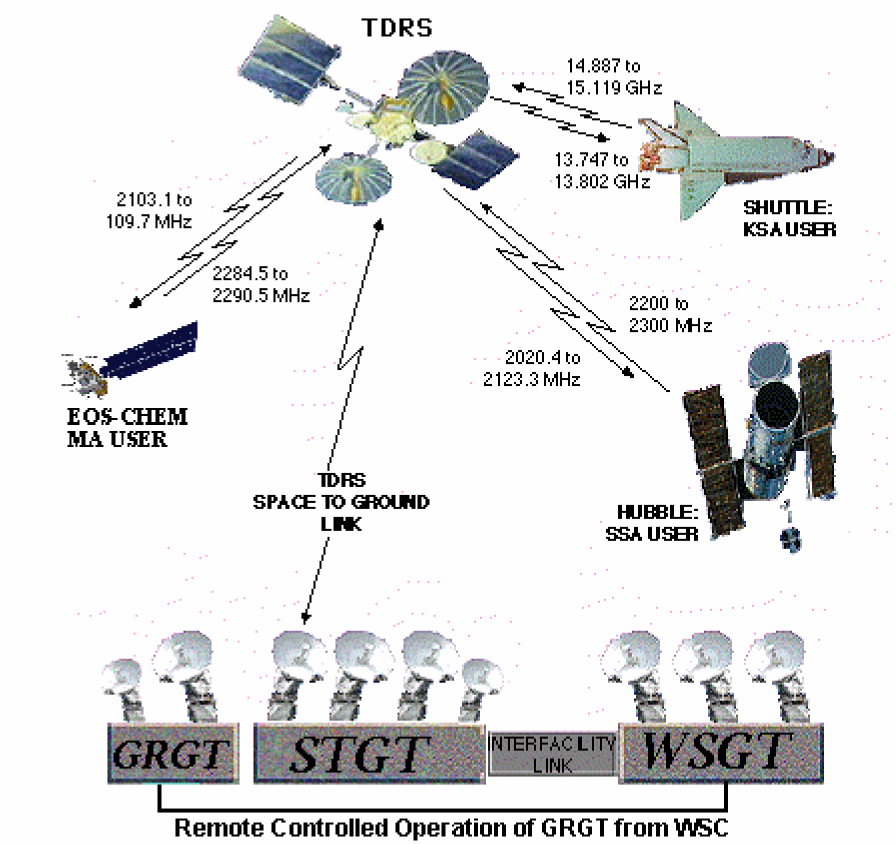
# Drivers for VOIP in Space

- 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 Space Communication and Navigation Architecture Recommendations for 2005-2030 (https://www.spacecomm.nasa.gov/doc_repository/architecture/SCAWG_Report.pdf)

# Challenges in the Space Networking Environment: Long Latencies

- Operations such as ISS through TDRSS relay and lunar-ground paths for envisioned future missions (Bush Vision statement) will involve substantial propagation delays in both directions of 2-way voice communications.



# Challenges in the Space Networking Environment: Path errors

- 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

# Challenges in the Space Networking Environment: Simplex paths

- Space operations must be able to 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.

# Challenges in the Space Networking Environment: Asymmetric paths

- Operations in space may involve communications in which the communications in opposite directions is subject to very distinct characteristics, such as bandwidth and BER.

# Challenges in the Space Networking Environment: QoS requirements

- The traffic requirements in space can be much different than those found in common commercial applications. There will be requirements on robustness, recognizability of the speaker.

# 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”

# Challenges in the Space Networking Environment: Overhead concerns

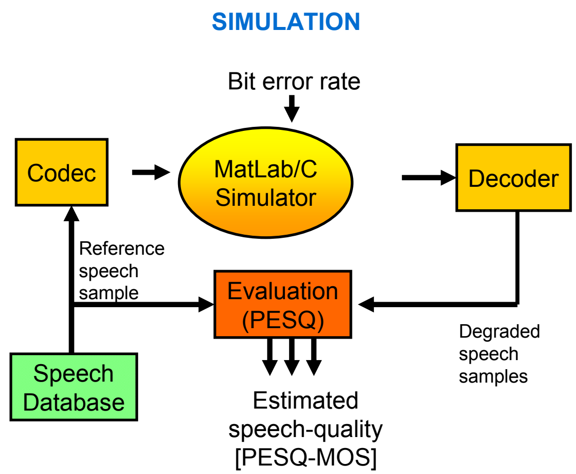
- **Cost considerations are paramount in the space environment, so incorporating a new voice technology like VOIP will be .**
- **The impact on voice connections is that rather than being point-to-point between two end users, they typically are formed using "voice loops"**

# Possible VOIPOSN approaches

- Possible solutions to each of the problems we raised:
- Latency, couple with Overhead concern:
  - Since already have big latency, can use big samples, or can pack multiple voice frames into one IP packet, to save overhead
  - Traditional voice frame encapsulation
    - 20 Bytes - IP header
    - 8 Bytes - UDP header
    - 12 Bytes - RTP header
- QOS for voice stream and mapping Advanced Orbiting Systems link layer's virtual channel from IP Diff Serv code.
- Studies on effects of BER due to coalescing multiple RTP voice frames into set-length AOS frames.

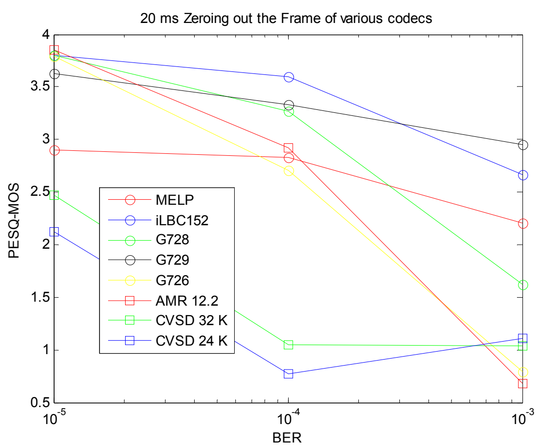
# Study of BER, code type and voice frame length on PESQ-MOS

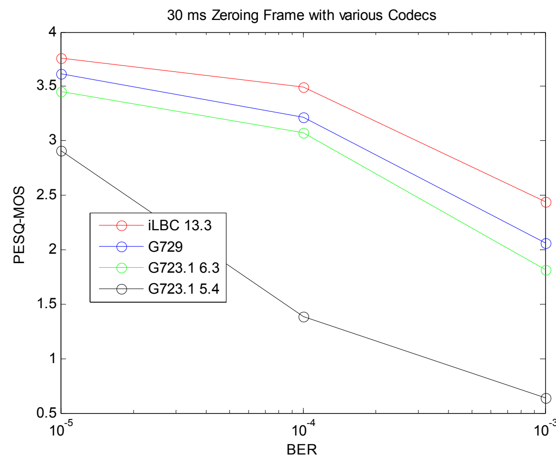
- Objective measure of speech quality
- ITU standard to use the Perceptual Evaluation of Speech Quality algorithm (“PESQ”, ITU-T P.862 standard)
- Compares original, unprocessed signal with degraded version at the output of the communication system
- Outputs Mean Opinion Score (MOS) ITU-T P.800.

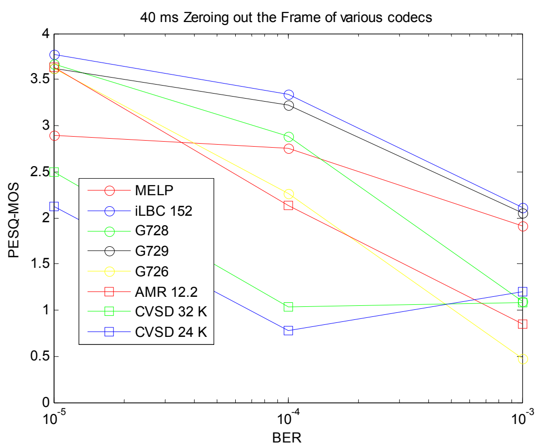


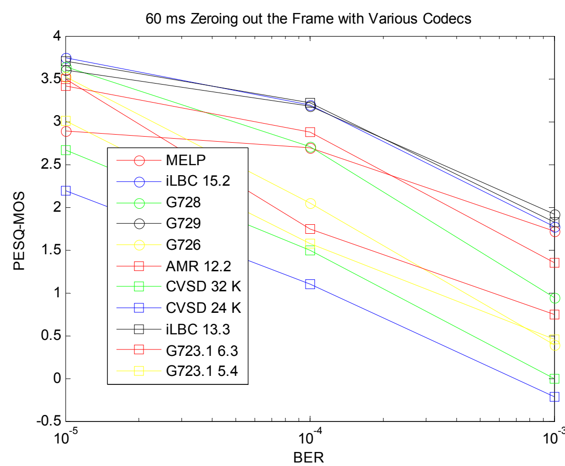
# Study of BER, code type and voice frame length on PESQ-MOS

- **BER arising from wireless links:**
  - **Study of BER, code type and voice frame length on PESQ-MOS**



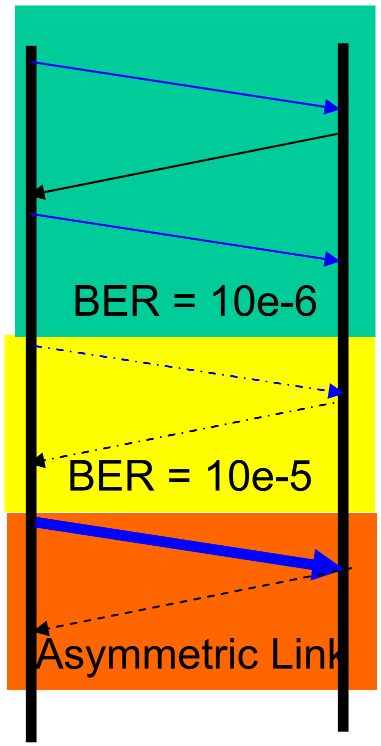



# Possible VOIPOSN approaches

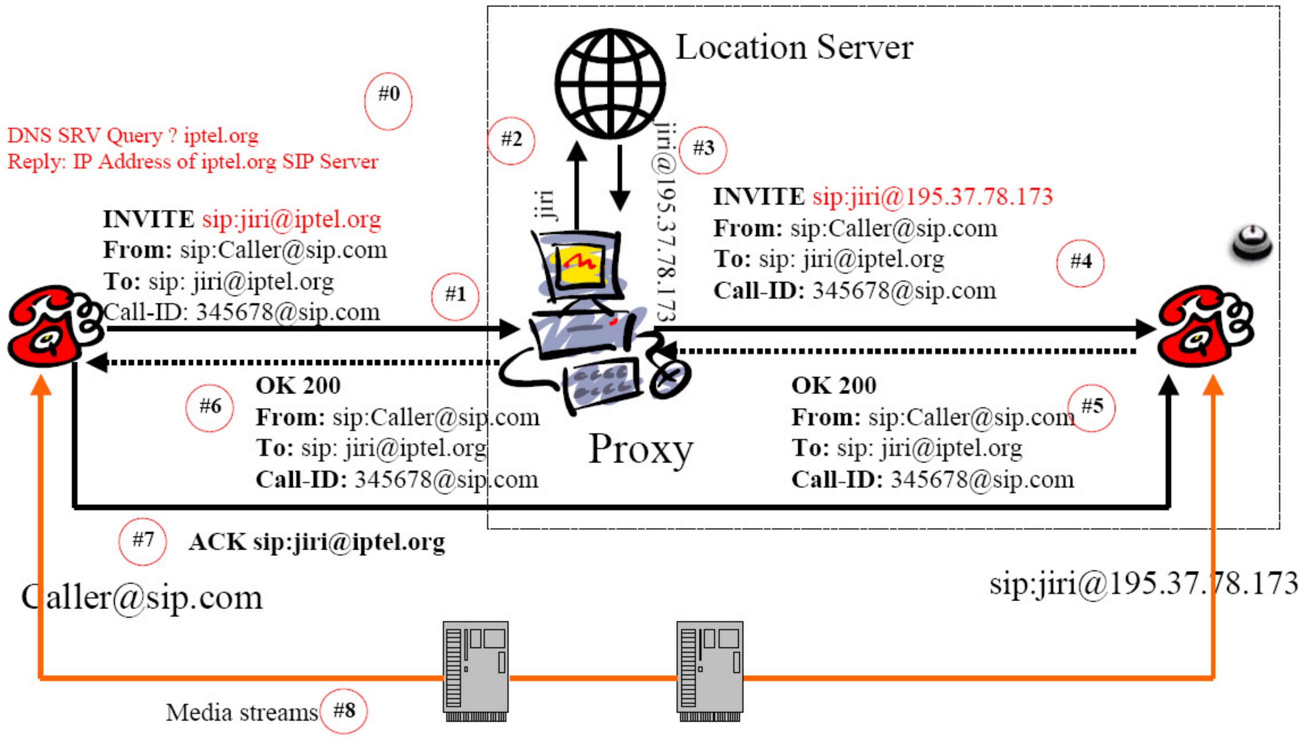
- **Varying BER during course of call:**
  - **Dynamically select codec**
  - **Implemented in soft VOIP client “linphone”**




1. **Initiated and established SIP call with PCMU G.711 Codec (64Kbits min. bandwidth)**
2. **BER rises and Codec switched to AMR-NB (12.2 Kbits/s min. bandwidth)**
3. **Codec use change also sensitive to changes in forward and return link bandwidth availability**

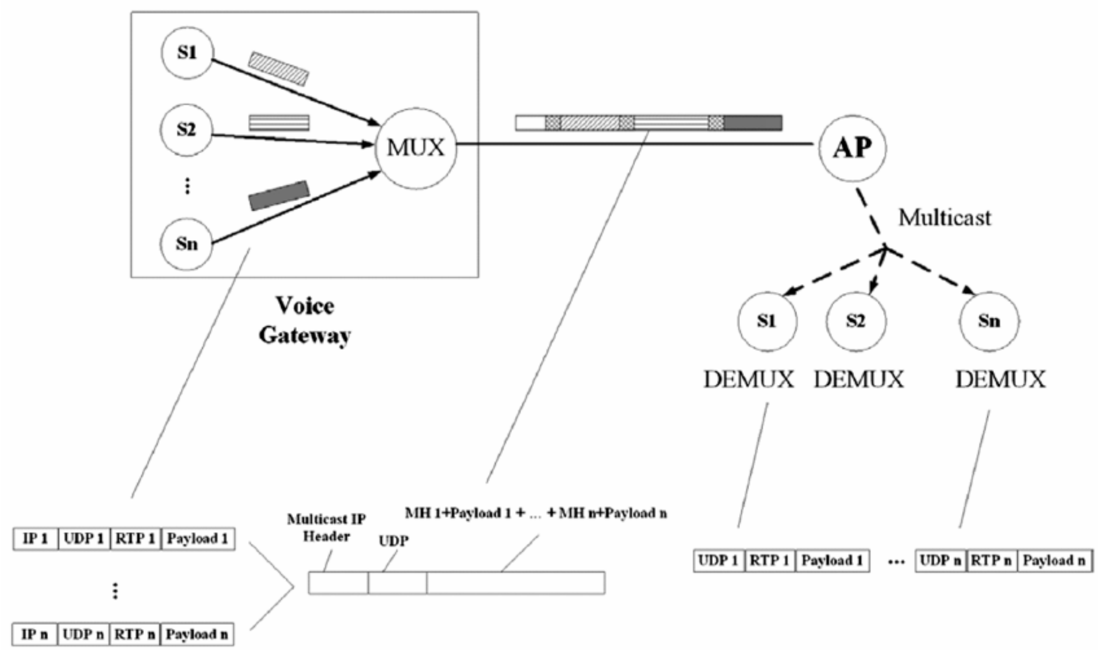
# Possible VOIPOSN approaches

- **Simplex Paths:**
  - **SIP Requires a duplex link. A New call initiation mechanism needed.**
- **Asymmetric Paths:**
  - **Use of different codecs at opposite endpoints**



# Possible VOIPOSN approaches

- Team Operations/Voice Loops
  - Use of IP Multicast with Client-side mixing
  - Figure source
    - "Wang w., et. al, "Solutions to Performance Problems in VOIP Over a 802.11 Wireless LAN"



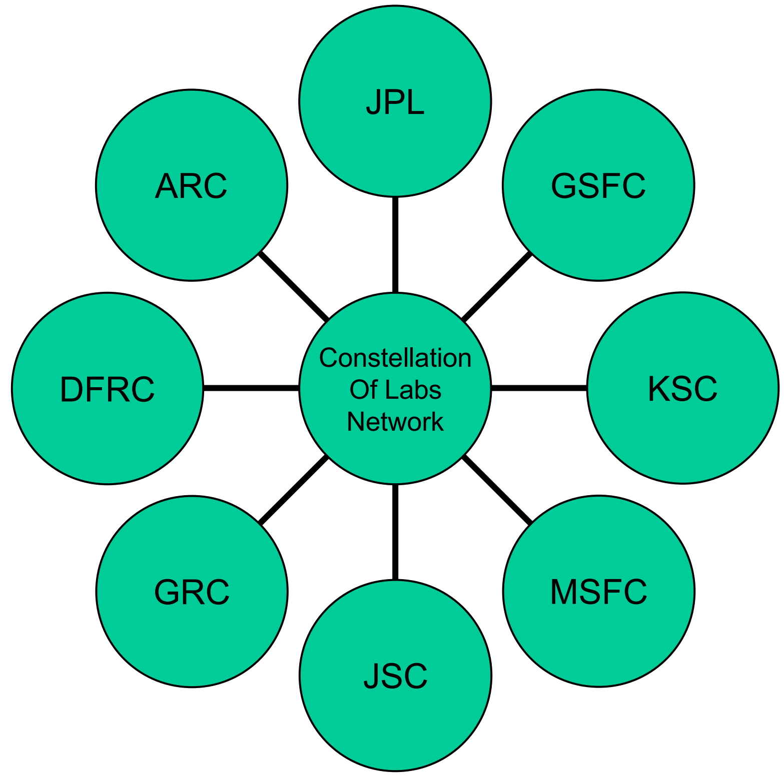
# Codec Latency Trade Space

- **High one way delay relative to traditional VOIP usage on earth**
- **Mouth-to-ear delay at Lunar distances (~ 300 ms):**
  - **One-way light time between Earth and moon (OWLT) (150ms)**
  - **Gateway and IPSec encryption delay (~105ms with AES)**
  - **Codec Delay at both ends (Varies between .75 to 30ms)**
- **Codec complexity vs. minimum bandwidth requirement**
- **More sophisticated codecs' processing delay may become insignificant due to large OWLT**

| CODEC | Raw CODEC Data Rate (Kbits/s) | Codec frame size / codec delay (ms) |
|---|---|---|
| ITU-T G.711 | 64 | 20, 30, 40, 60 ,80, 90, 100, 120 |
| GSM-AMR-EFR | 12.2 | 20, 40, 60, 80, 100, 120 |
| G.723 | 6.3, 5.6 | 37.5, 67.5, 97.5, 127.5 |
| G.726 | 32 | 20, 30, 40, 60 ,80, 90, 100, 120 |
| G.729 | 8 | 20, 30, 40, 60 ,80, 90, 100, 120 |
| Ilbc | 15.2, 13.3 | {30, 60, 90, 120}, {20, 40, 60, 80, 100, 120} |
| MELP | 2.4 | 22.5, 45, 67.5, 90, 112.5, 130 |
| G.728 | 16 | 20, 40, 60, 80, 100, 120 |
| CVSD | 16, 24, 36 | 20, 40, 60, 80, 100, 120 |

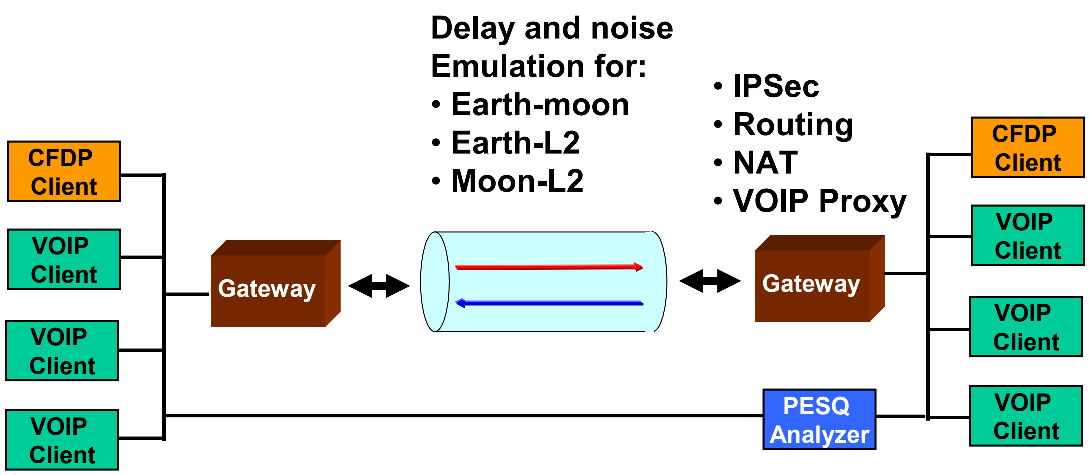
# Testbed

- Investigate the effects of using VOIP over IPSec in Lunar propagation delay and channel noise
- JPL is part of NASA-wide "Constellation of Labs"
- Labs in NASA centers connected using VPN concentrators



# Testbed

- Investigate the effects of using VOIP over IPSec in Lunar propagation delay and channel noise
- Measure PESQ on Voice streams
- Analyze the effectiveness of using dedicated AOS Link layer virtual channel to provide VOIP QOS



# Conclusions

- VOIP use in space poses new challenges in large delay, varying bandwidth availability and bit error on the link.
- Effective use of available bandwidth to provide intelligible VOIP service requires dynamic codec switching and merging multiple voice streams / codec frames to save packet overhead
- PESQ-MOS measure used to analyze voice degradation over space links
- VOIP test bed includes experiments to identify the effects of delay and BER from running voice traffic through IPSec using space-based link layer