Satellite/Terrestrial Networks:

End-to-End Communication
Interoperability
Quality-Of-Service Experiments

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Quality of Service

VOICE
FAX
MEDICAL IMAGING
TELECONFERENCING
COMPRESSED VIDEO
"REAL-TIME" DATA MANIPULATION
Goals

• Determine Quality-of-Service Parameters that Satellites must provide to remain competitive in the Global Information Infrastructure.

• Evaluate the effect of transmission link quality and characteristics on overall QoS for various applications and protocols.

Strategy

• Evaluate ATM over noisy link.
  – ATM was designed for “near” error free channels such as fiber. We need to understand the effect that various error characteristics have on the ATM QoS.

• Evaluate Digital Video over Satellites
  – Digital Video (particularly compressed video such as MPEG-II) is expected to require stringent QoS.

• Evaluate effect of layer protocols
  – Errors that occur in the lower layer of the protocol stacks tend to get magnified as one propagate through the upper layers.
ATM Performance Characteristics

- **CER**  Cell Error Ratio
  - One or more errors in the payload
- **CLR**  Cell Loss Ratio
  - *Generally* 2 or more errors in the header
- **SECBR**  Severely Errored Cell Block Ratio
- **CMR**  Cell Misinsertion Rate
- **CTD**  Cell Transfer Delay
- **CDV**  Cell Delay Variation

![Diagram of ATM Performance Characteristics](image)

MPEG-2 Transport Stream Mapping to AAL-5

![Diagram of MPEG-2 Transport Stream Mapping to AAL-5](image)
Compressed Video Tests Over ATM

- MPEG-2 Transport Stream With Errors
  - Baseline without ATM
- MPEG-2 Over ATM With Binomial Errors
  - Digital Errors
- MPEG-2 Over ATM Over Emulated Satellite
  - Analog Errors
- Dual Decoder Test
  - Variations due to decoder implementation
- MPEG-2 over ATM Channel Characteristics
  - QoS dependence independently on CER and CLR
Observations and Discussion

• MPEG-2 requires a link quality of $10^{-10}$ BER or better regardless of underlying protocol.
• Block errors are far easier to tolerate than decoder resynchronization
• Higher encoding rates require slightly higher quality links
• Further study is necessary in order to determine the relationship between the video quality and the ATM QoS parameters - in particular between the visible errors per second and the CLR and CER as well as the affect different CER and CLR distributions have on the video

Status Digital Video over Satellites

• Work was completed in September 1997 and reported to ITU-R Working Party 4B and T1A1.3
  – Paper is available via anonymous FTP
    • Site: ftp.tl.org
    • Directory: /pub/t1a1/t1a1.3
    • T1BBS FILE: 7a130840.doc
• ITU-T Rec. I.356 Class I, stringent class, objectives for CLR, CER should be at least 1.0E-8 and 1.0E-7 respectively in order to acceptably carry such services as MPEG-2 compressed video and may require even better performance.
### Test Results

<table>
<thead>
<tr>
<th>Cell Interval (Milliseconds)</th>
<th>E-BER</th>
<th>BERH</th>
<th>CLR</th>
<th>BERH</th>
<th>Comments</th>
<th>Voice</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>39.3</td>
<td>-</td>
<td>3.8E-11</td>
<td>0</td>
<td>Excellent</td>
<td>Video and Audio OK</td>
<td>Excellent</td>
</tr>
<tr>
<td>14</td>
<td>9.4</td>
<td>-</td>
<td>5.7E-10</td>
<td>0</td>
<td>no change</td>
<td>no change</td>
<td>no change</td>
</tr>
<tr>
<td>8</td>
<td>8.7</td>
<td>-</td>
<td>6.0E-7</td>
<td>0</td>
<td>no change</td>
<td>no change</td>
<td>no change</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>5.6E-7</td>
<td>2.8E-2</td>
<td>no change</td>
<td>OK</td>
<td>no change</td>
<td>no change</td>
</tr>
<tr>
<td>3</td>
<td>4.5</td>
<td>2.9E-3</td>
<td>1.2E-3</td>
<td>motionless breaking up slight at times.</td>
<td>Few black streaks, errors, voice anomalies.</td>
<td>Motionless breaking up slight at times.</td>
<td>Motionless breaking up slight at times.</td>
</tr>
</tbody>
</table>

**NOTES**

Bit Error Ratio measured by the satellite modem.

CLR is the Uncorrected or Discarded Cell Ratio (DCR) i.e. all cells with two or more errors in the header.

Notice that at low BERs there is not enough statistical confidence on the CLR measurement.

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**SATELLITE LINK CONFIGURATIONS**

![Diagram](image)

- **EF-DATA SDM-9000**
- **ADTECH 8X/14 Data Channel Simulator**
- **HP 3705A Notes Test Set**
- **HP 3x219 Network Impairment Simulator**

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MPEG-2 Over ATM With Binomial Errors

- **Purpose**
  - Determine dependence on CLR and CER
  - Determine dependence on encode rate

- **Conclusions**
  - BER of 1.0E-8 or higher is definitely unacceptable
  - Higher encode rates are slightly less susceptible to errors

MPEG-2 over ATM Channel Characteristics

- **Purpose**
  - Determine video degradation relative to CLR only and CER only

- **Conclusion**
  - CLR has far more affect on the video than CER
Purpose
- Evaluate video quality when errors are inserted at the RF link (different CLR and CER distribution)

Conclusion
- Unacceptable link quality at BER 1.0E-8, CLR 1.0E-7 and CER 1.0E-6

Purpose
- Baseline MPEG-2 Video
- Determine dependence on encode rate (compression)

Conclusions:
- BER of 1.0E-8 or higher is definitely unacceptable
- Higher encode rates are slightly less susceptible to errors
Dual Decoder Test

Purpose
- Determine if different decoder react similarly to errors

Conclusion
- The two decoders tested degrade at the same point