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**SATELLITE NETWORKS: ARCHITECTURES,
APPLICATIONS, AND TECHNOLOGIES**

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SIMULATION OF A NASA LEO SATELLITE HYBRID NETWORK

by

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OBJECTIVE

**Investigate the performance of TCP/IP in a hybrid network consisting
of a global terrestrial network and a LEO satellite by simulation.**

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Satellite LEO - circular orbit at 650 km altitude
52 degrees inclination
FTP server
Transmission and reception at 9600 bps

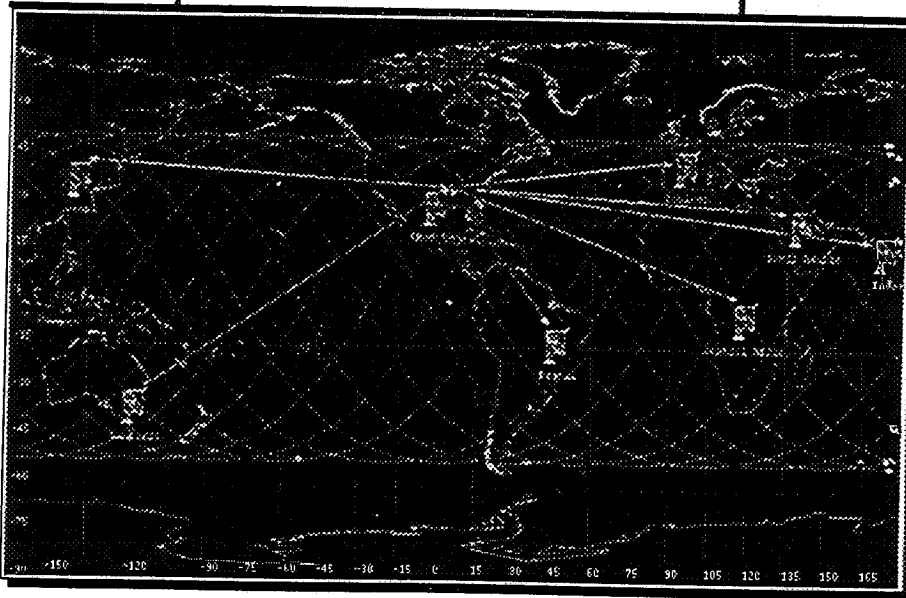
Houston, United States
Central node of a star topology
FTP client
Terrestrial transmission and reception at DS0 (64 kbps)
Radio transmission and reception at 9600 bps

Seoul, South Korea; Canberra, Australia; Toulouse, France;
India; Saudi Arabia; Central Africa; Brazil
Above terrestrial nodes connected to Houston
Terrestrial transmission and reception at DS0 (64 kbps)
Radio transmission and reception at 9600 bps

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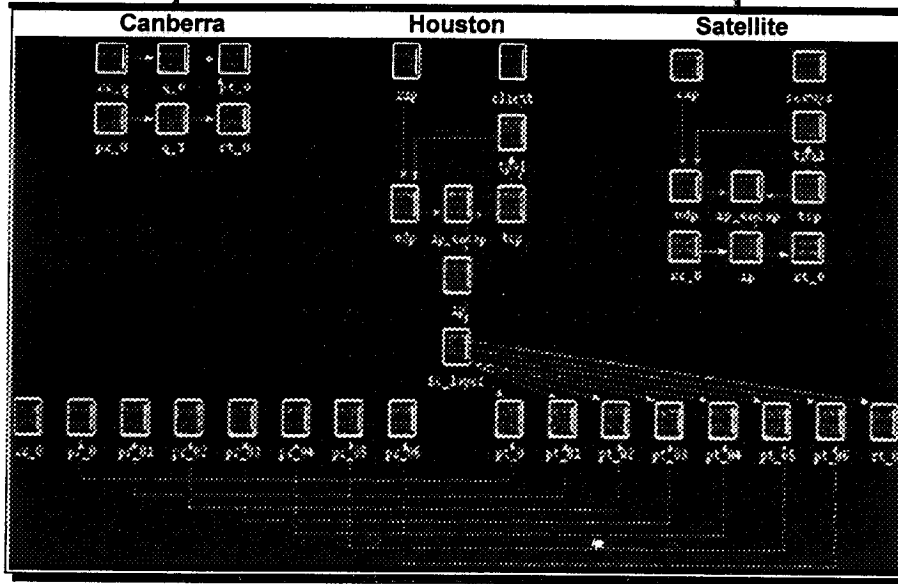
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TCP simulation includes

- Connection establishment and closing using three-way handshaking
- Flow control
- End-to-end reliability
- Reordering of the data at the receiver
- Slow-start congestion avoidance and control

FTP simulations

- Average size of the file modeled using a normal distribution
- Generation rate for sessions modeled using a Poisson process

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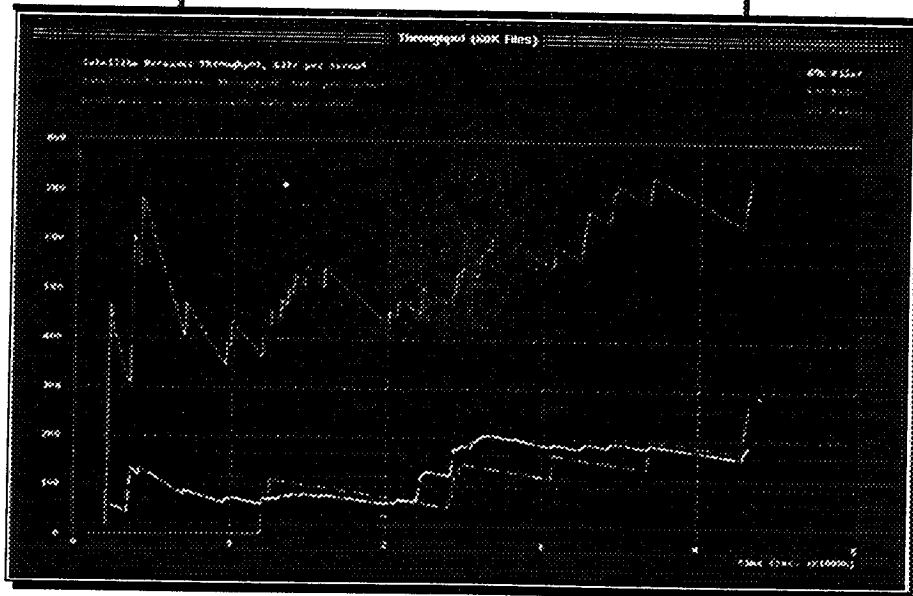
Simulation results for 60 KB, 300 KB, and 1500 KB files

- Throughput
- End-to-end delay
- Satellite transmitter queue size (7500 KB files)
- Canberra receiver queue size (7500 KB files)
- Client congestion windows
- Server congestion windows
- Client-server congestion windows

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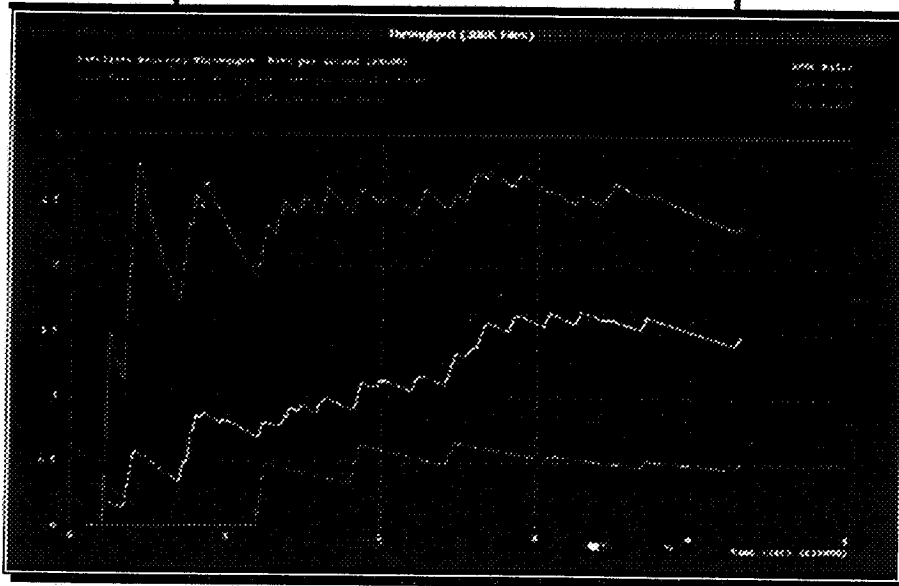
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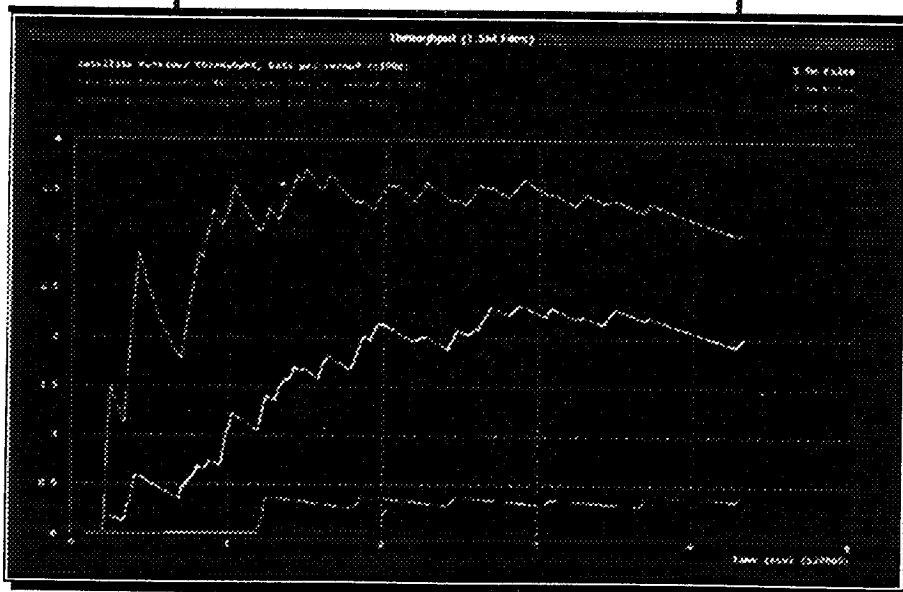
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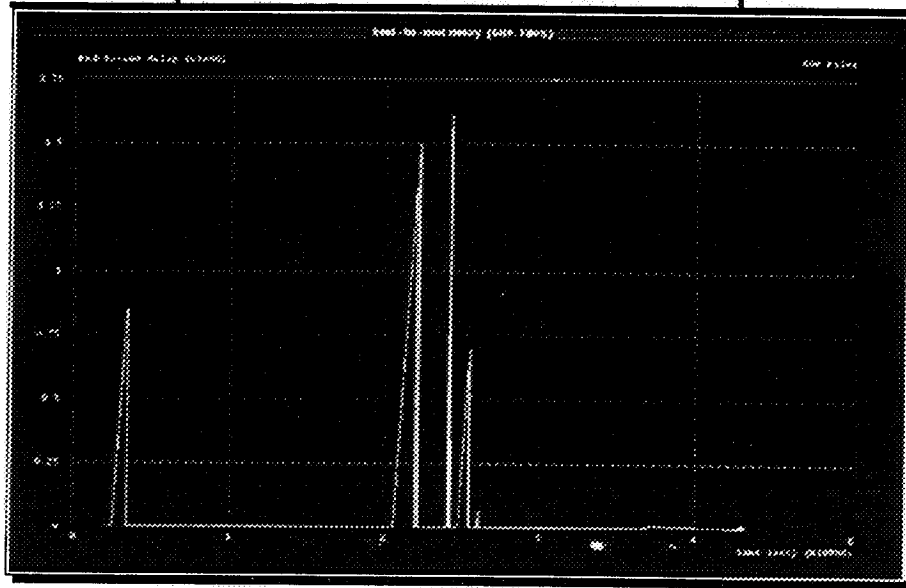
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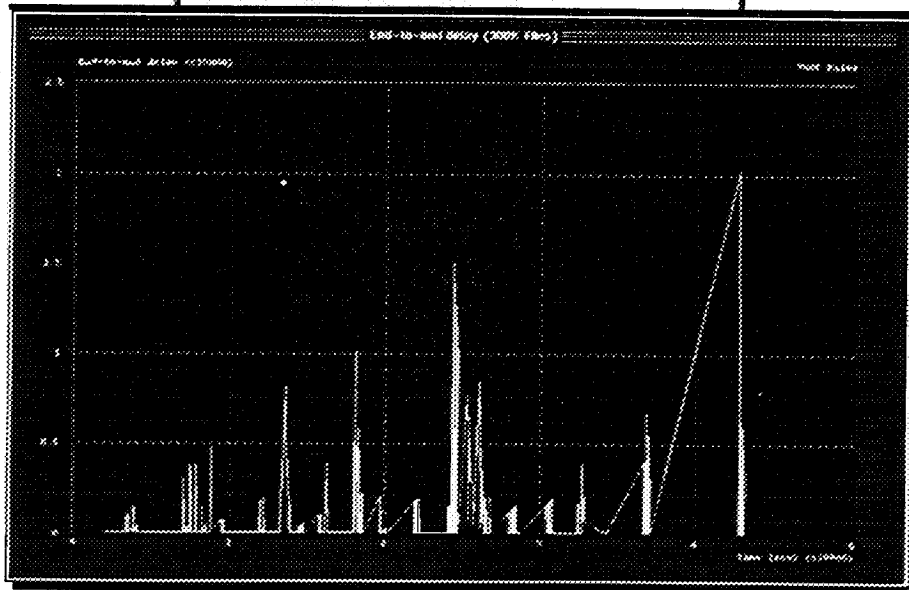
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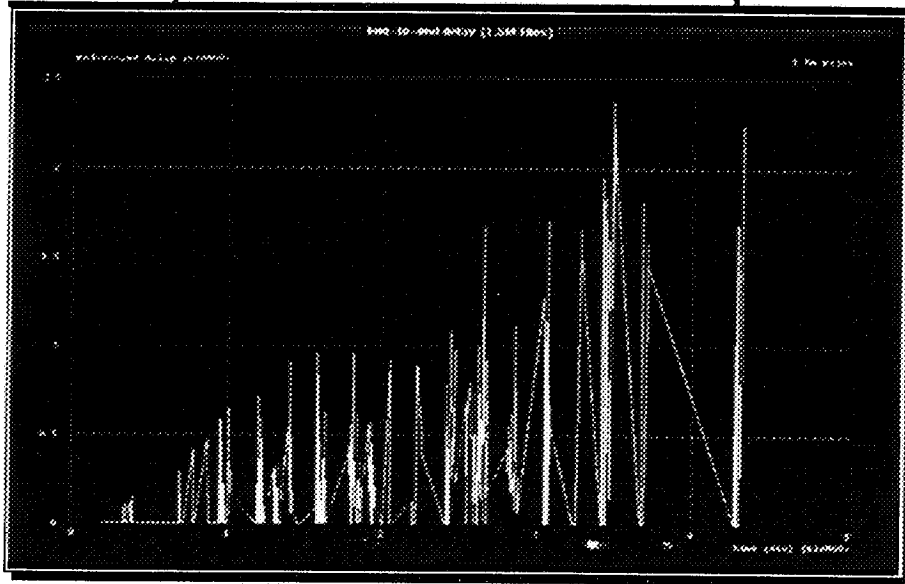
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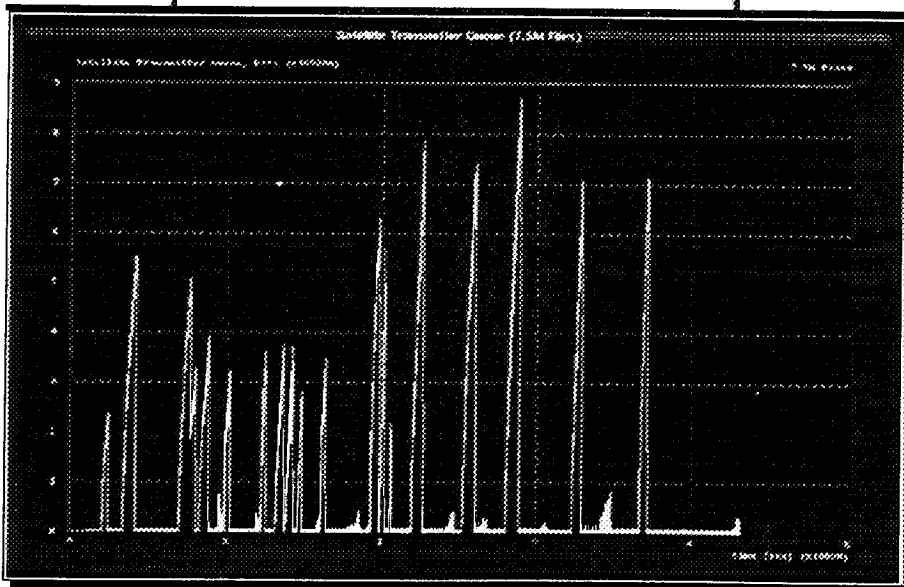
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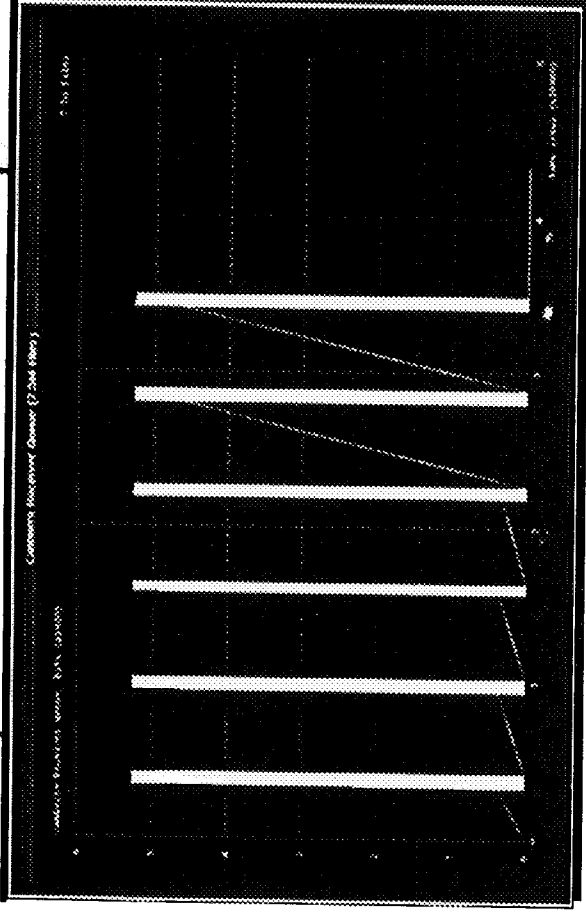
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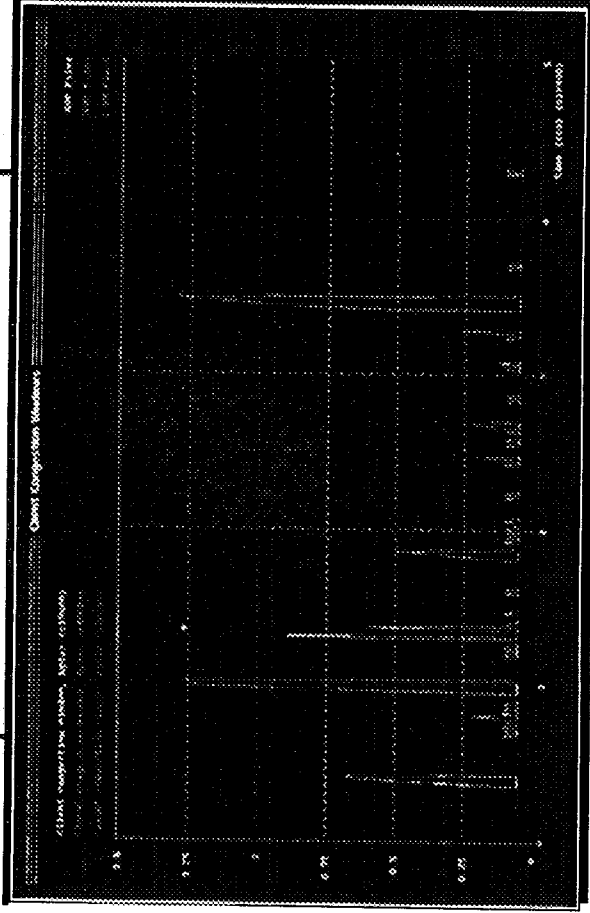
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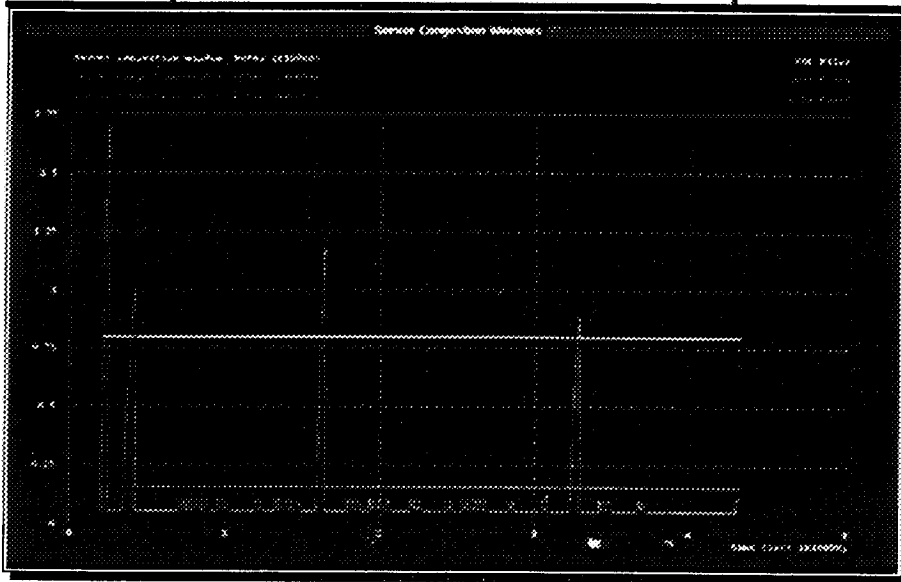
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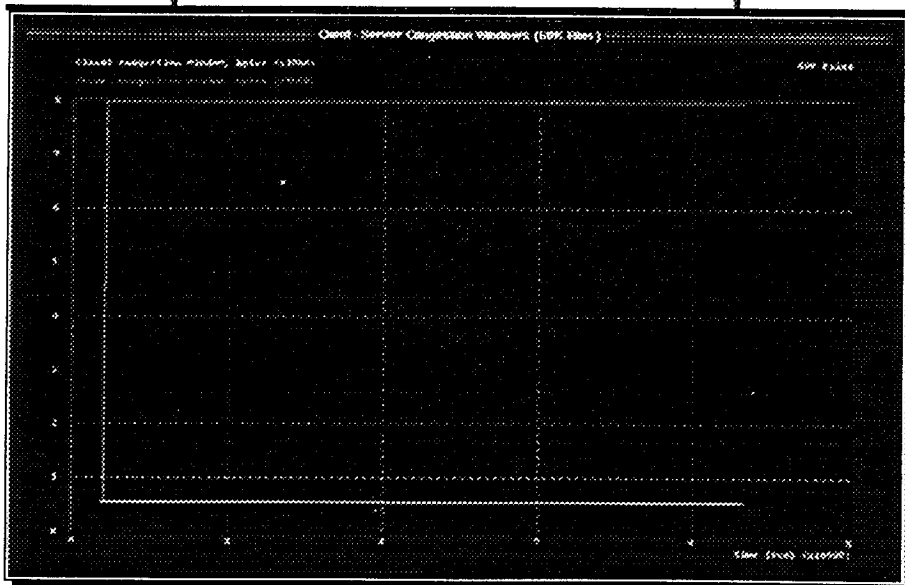
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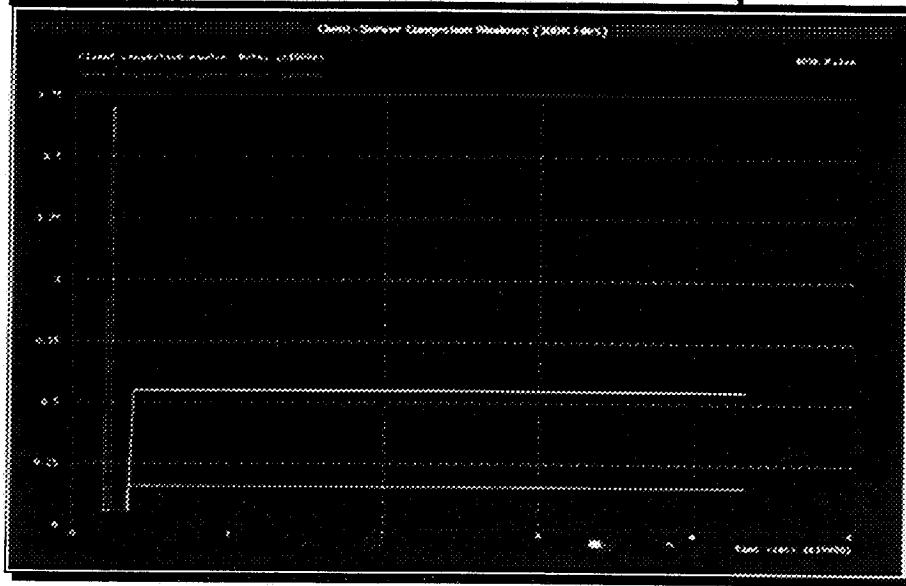
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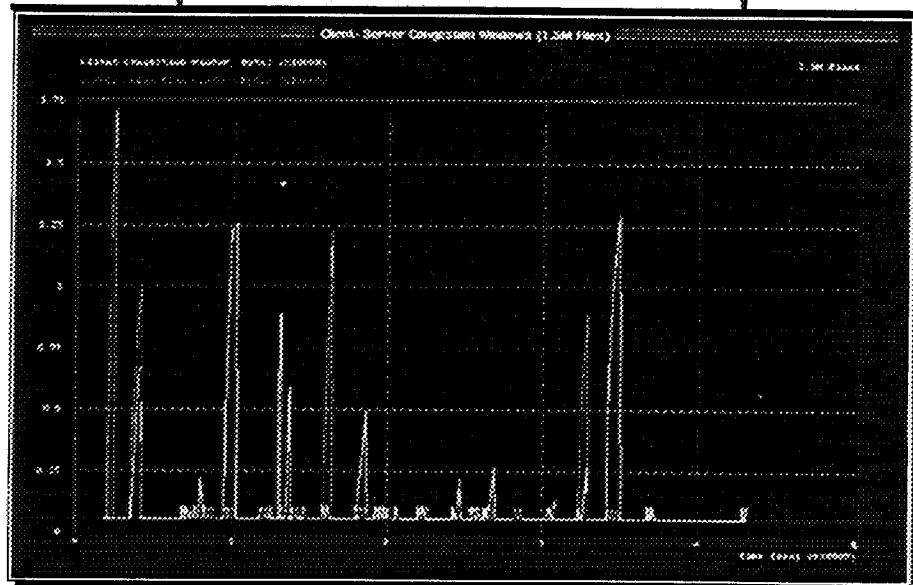
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CONCLUSIONS

- The satellite transmitter average throughput saturates for large files.
(~ 3500 bps)
- Houston receiver average throughput inconclusive.
(radio reception only)
- Frequent, large End-to-end delays for large files.
(small % increase for file size increase)
- Infrequent, small End-to-end delays for small files.
(large % increase for file size increase)
- Queueing delays at the terrestrial nodes are not significant.
- TCP slow-start algorithm degrades the performance for large files.