White Paper on VDL Performance Monitoring

Abstract: This paper discusses techniques that may be employed by ANSPs to perform routine monitoring of VDL performance.
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### KEYWORDS


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1. INTRODUCTION

The LINK 2000+ ED-120 Interpretation Document [1] applies a statistical model of datalink performance to derive performance targets for the individual components of the end-to-end chain, including the Air/Ground Communication Service Provider (ACSP). These performance targets are reflected in the LINK 2000+ Generic ACSP Requirements Document [2].

Review of the latter document by Stakeholders has prompted queries from ANSPs on the methods that may be employed to perform routine monitoring of the performance achieved by ACSPs, and their compliance with the specified targets, and in particular the requirements on transit delay.

This paper seeks to discuss the relevant background and to propose techniques that may be applied to achieve this objective.

1.1 REFERENCES


2. BACKGROUND

The contractual boundaries of the service provided by ACSPs exist at the interface with the ANSP and at the aircraft antenna. Whilst the former is readily accessible to the ANSP, and is capable of being routinely monitored, the same is not true for the aircraft antenna. Realistically, the signals in space at the aircraft can be monitored only by a specially equipped trials aircraft, which is not a viable means for routine data collection.

Accordingly, an alternative surrogate measure of ACSP performance is needed, and it is proposed that routine measurement of Technical Round-Trip Delay can serve this purpose.

The statistical model described by [1] considers that three components, the ANSP, the ACSP and the avionics contribute to the round-trip technical delay across the end-to-end chain. The ACSP makes the dominant contribution. The model assumes that these components are statistically independent, and that each can be characterised by an exponential distribution. By allocating the delay budget to the components as follows (together with the delays specified for the Responder by ED-120), the model predicts that the ED-120 performance target for operational round trip delay can be met:

- ANSP Round-Trip Delay = 9 secs for 99%
- ACSP Round-Trip Delay = 16 secs for 99%
- Avionics Round-Trip Delay = 6 secs for 99%

By summing each of the three exponential distributions described above, the overall distribution of the round trip technical delay (which is not exponential) can be derived. This overall distribution is illustrated in the figure below, and is characterised in terms of percentile delays in the following table.
Expected Distribution of Technical Round Trip Delay

Expected Percentile Technical Round-Trip Delay

<table>
<thead>
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<tr>
<td>50.0</td>
<td>6</td>
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<tr>
<td>95.0</td>
<td>15</td>
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<td>99.0</td>
<td>21</td>
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<td>99.9</td>
<td>29</td>
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It should be noted however, as highlighted in [1], that the assumption of exponentially distributed component delays, although widely used by the academic literature, has not been validated by comparison with real-world data. This assumption will be kept under review as more data on LINK 2000+ operations is collected during the Pioneer Phase. In the light of such data, it may be necessary to revise the assumed statistical models of datalink performance.

3. MEASUREMENT OF TECHNICAL ROUND TRIP DELAY

Technical Round-Trip Delay can be readily measured by the ANSP, using data recorded at a Point of Control and Observation (PCO) within the ground End System (for example, at the DL-FEP in the Maastricht architecture, or at the Air Server in other systems). Uplink CPDLC messages requesting a LACK may be logged with their CPDLC time-stamp, and downlink LACKs from the aircraft can be logged at the same PCO with time of receipt recorded by reference to the same time source. The uplink messages may be associated with their corresponding LACKs as a post-process through use of
the CPDLC Message Reference Number, and the round trip delay calculated. This principle is illustrated in the figure below.

![Diagram of Technical Round-Trip Delay](image)

### Measurement of Technical Round-Trip Delay

LINK 2000+ has developed tools (i.e. the LISAT database) to perform such measurements based on data recorded by stakeholder ANSPs. Currently, data provided by UAC Maastricht is routinely imported into LISAT to provide monthly statistics, and support analysis such as that proposed here. At the time of writing, the measurements of Technical Round-Trip Delay are being validated, and will be reported to the LIT once the required confidence has been gained.

### 4. INTERPRETATION OF TECHNICAL ROUND TRIP DELAY

During routine monitoring of Technical Round-Trip Delay, it would be expected that measurements fall within the distribution and percentiles described in the previous section. Any significant deviation from the expected percentile delays would indicate that the technical components of the end-to-end chain were not performing as expected, and as a consequence, compliance with the ED-120 operational performance targets would be at risk.

As discussed earlier, although the contribution by the ACSP to Technical Round-Trip delays is expected to dominate, it is not the only contribution. Accordingly, in the event that significant anomalies in the measured delays were observed, further investigations would be necessary to identify the origin of the additional delay.

Potential causes of unexpected delays include the following, although this is not intended to provide an exhaustive list:
• **Delays in ground ES.** The ANSP would in principle be able to monitor this aspect of performance by establishing a PCO at the interface to the ACSP (e.g., at the ANSP’s Ground-Ground Router), to allow measurement of delays between generation/receipt of a CPDLC message and the time at which it is passed across the interface to the ACSP.

• **Delays in Avionics.** LINK 2000+ testing of Pioneer Phase avionics indicates that the delays in avionics are generally small in comparison with the allocated delay budget. Any anomalies in future systems could potentially be detected by statistical analysis of technical delay data to determine whether anomalies are confined to any particular avionic configuration.

• **Delays in single ACSP.** Here also, statistical analysis of technical delay data may identify whether anomalies in technical delays are confined to a particular ACSP. Such delays may arise from delays to PDUs on ground networks or in Routers for example.

• **Loss of PDUs.** Some occurrences of PDU loss have been observed during analyses of LINK 2000+ Trials Data. The ATN Transport layer will identify loss of PDUs and attempt to recover by re-transmission of affected messages. However, such recovery will involve additional delay, which is likely to distort the statistical performance of the link in the crucial tails of the distribution curve. For this reason, particularly stringent requirements are placed on ACSPs to minimise avoidable loss of PDUs. In the event that loss of PDUs is suspected, detailed logging throughout the end-to-end chain will be necessary to identify the origin of the loss.

• **VDL Channel Congestion.** Passive monitoring tools such as the EUROCONTROL MOON system will allow the performance of the VDL Link to be characterised, by parameters such as Channel Utilisation and AVLC re-try rates, both of which would allow congestion on the VDL channel to be recognised.

5. **CONCLUSIONS**

ANSPs foresee a need to monitor performance routinely of datalink systems, and particularly of the ACSP. One contractual boundary of the ACSP’s service is at the aircraft antenna, which is not a convenient point at which to monitor performance.

Therefore it is proposed that routine monitoring may be achieved by ANSPs through measurement of Technical Round Trip Delay. This requires logging and timestamping of uplink CPDLC messages at a PCO within the ANSP’s ES, and similarly for downlink LACKs from aircraft. A post process would then be able to determine the technical delays.

Comparison of the measured delay data with the expected statistical distribution would highlight any anomalies. Additional investigation would then be required to identify the origin of such anomalies.

LINK 2000+ has developed tools (i.e., the LISAT database) to determine the Technical Round-Trip Delay from ES data collected by UAC Maastricht and other ANSPs. At the time of writing, the delay data determined by this tool is being validated, and the results will be reported to the LIT in due course.