AERONAUTICAL TELECOMMUNICATION NETWORK PANEL

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ATN Simulation With Realistic Automatic Terminal Information Service (ATIS) Message Statistics

Prepared by: Yoon Hong

Presented by: Ron Cossa

SUMMARY

ATIS message length is a significant factor in ATIS end-to-end delay performance. CAASD's previous ATN simulations used a fixed ATIS message size of 270 bytes. Since real ATIS message sizes vary depending on time, weather conditions, and airport, using a fixed ATIS message size in simulation appears to be unrealistic except that it simplifies simulation. Anticipating that a real ATIS message distribution will do better than a fixed message size in predicting ATIS delay performance, the ATN simulation model has been modified to accommodate real ATIS messages' probabilistic behavior. This paper describes ATIS message statistics and their application to simulation, assuming the use of Mode S data link. Resulting performance data (mean uplink delays) for two airports—Baltimore-Washington International (BWI) and Pittsburgh (PIT) airports—meet the 15 seconds (uplink) requirement. It is possible that uplink delays for airports with heavy traffic or extreme weather conditions become longer than 15 seconds.

REVISION HISTORY

Section	Date	Issue	Reason for Change
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1. Introduction

1.1. Background

As part of its continuing effort to support development of the Aeronautical Telecommunication Network (ATN), the Center for Advanced Aviation Systems Development (CAASD) has been using its ATN simulation model to estimate the end-to-end delays in the Federal Aviation Administration (FAA) portion of the ATN using Mode S. The study results of [1] concluded that most delay requirements for Automatic Terminal Information Service (ATIS) as well as Controller-to-Pilot Data Link Communication (CPDLC) stated in [2] and [3] can be met for the expected application message rates. While it is known that ATIS message length is a significant factor in ATN end-to-end delay performance, what size should be used in simulation has been an issue. For example, ATIS message size estimates range from 400 bytes [4] to 300 bytes [5]. (A character is assumed to be equivalent to an 8-bit byte.) Assuming that a 10 percent reduction from 300 bytes is achievable with a compression algorithm, [1] used 270 bytes for the ATIS uplink message size in its simulation. As will be shown later, there is substantial performance difference between the 270 byte and 400 byte cases. This is due to the discrete nature of message delivery when used with Mode S scanning. The Mode S scan interval is 4.8 seconds for terminal sensors, which applies to the current simulation. Roughly speaking, the 400 byte size corresponds to 3 full scan times plus some additional time, whereas the 270 byte size corresponds to 2 full scan times and some additional time. The legitimate question is then what (fixed) value should be used for ATIS messages, which is not a trivial question to answer. Since real ATIS message sizes vary depending on time, weather conditions, and airport, and many messages are above 270 bytes with maximum values exceeding 400 bytes (for BWI and PIT), using a fixed ATIS message size in simulation is unrealistic except that it simplifies simulation. It appears that a real ATIS message distribution will do better than a fixed message size in predicting ATN delay performance.

1.2 Purpose

The purpose of this paper is to describe MITRE CAASD's simulation effort to determine the effects of realistic ATIS message distribution (as opposed to fixed sizes) on ATIS end-to-end delays assuming the use of Mode S data link. Real ATIS messages, message statistics, and their application to ATN simulation will be described in the following sections.

1.3 Summary of the Simulation Model

The simulation model used for this work is the same as that described in [1] except those features related to ATIS message statistics. These are synopsis of the simulation model excerpted from [1]: 1) The general simulation model includes a FAA ground topology of 22 routing domains, one for each Air Route Traffic Control Center (ARTCC). The current simulation included only those aircraft with connections to five ARTCC's—Kansas City (ZKC), Denver (ZDV), Albuquerque (ZAB), Fort Worth (ZFW), and Houston (ZHU). Each ARTCC was its own routing domain. The ground routers were interconnected by the National Airspace Data Interchange Network (NADIN) Packet Switched Network (PSN), the FAA's national X.25 network. (The time to send a packet across the PSN was uniformly distributed between 200 and 500 milliseconds.) 2) Two additional routers, Atlanta (ATL) and Memphis (ZME), acted as backbone routers for the FAA's ATN island. These routers were chosen to minimize the amount of routing updates in the overall network. Routes to aircraft were distributed using the Interdomain Routing Protocol (IDRP) [6, 7]. 3) Most of simulation run scenarios and parameter values were the same as those used in [1]. That is, aircraft flight times in an ARTCC's airspace were exponentially distributed with a mean of 27 minutes (consistent with current flight times in the U.S). The minimum time in an en route space is 60 seconds. Transport connections were set up as soon as an IDRP connection was established after an aircraft took off or entered the next center. The applications began generating messages when they were notified with a transport connect confirm (sent or received). End-to-end delays were measured from the time an application sent a packet until it was received by the destination application.

2. ATIS Messages of Fixed Sizes and Real Statistics

ATIS is currently sent as characters on the Airline Communications Addressing and Reporting System (ACARS). For ATN, more efficient use of ATIS has been proposed; however, considerable uncertainty exists in ATIS text formatting, encoding, and what processor these functions should be implemented [8]. Aside from these details, the present paper is just concerned about the effects of ATIS message length on ATN delay performance.

2.1 Fixed-size ATIS Messages

As mentioned in the introduction, the simulation model included two applications, ATIS and CPDLC. For CPDLC, either the ground or the aircraft could initiate a request/reply transaction. Fixed message sizes of 4 bytes (downlink) and 15 bytes (uplink) were used previously. The current simulation used the same CPDLC message sizes. Therefore, as far as CPDLC is concerned, results in [1] are still valid.

For ATIS, the aircraft periodically sent a request using a 7-byte message to a ground end system (aircraft destination). In previous simulations, the ground end system sent a response using a 270-byte fixed-size message. In current (modified) simulation, the fixed-size message was replaced with statistically varying messages as described in the next subsection.

2.2 ATIS Message Statistics

We obtained text versions of ATIS messages collected at two airports—Baltimore-Washington International (BWI) and Pittsburgh (PIT) airports. Figure 2-1 shows sample ATIS messages taken at these airports in October and November of 1992. Three messages are shown for BWI and two for PIT. The first line of each message is “surface observation” and not considered as ATIS message. (The National Weather Service (NWS) designates a surface observation report by SA. Terminals with ATIS will have a surface observation reported for them [9].) These ATIS messages are combined ones, that is they are used for both arrival and departure. (At some busy terminals two separate ATIS broadcasts are maintained—one for arrival and one for departure.) Notice also that these are experimental data in that they are mostly free text and do not involve elaborate formatting or encoding. Nevertheless, it is expected that using these data will give more realistic estimation of end-to-end delay performance.

For simulation purposes, these message were processed to extract useful information such as message sizes, i.e., number of characters (or equivalently bytes) for individual messages, and their probabilistic behaviors such as histogram, probability density function (PDF), and cumulative density function (CDF) (or distribution function). Figure 2-2 shows histogram and CDF of PIT ATIS messages. Statistics of interest are summarized for both BWI and PIT in Table 2-1. As shown, BWI ATIS data consist of 339 messages with message sizes ranging from 26 bytes to 418 bytes with mean value of 258.0. PIT ATIS data consists of 427 messages with message sizes of 26 bytes to 568 bytes with mean value of 274.5. The 26-byte messages simply indicate "digital ATIS not available," which occurs for various reasons including “system down.” Without these 26-byte messages, minimum message sizes will be 206 bytes and 207 bytes for PIT and BWI, respectively.

BWI Airport ATIS Messages:

BWI SA 0055 CLR 20 148/36/29/2104/996
BWI ATIS INFO T 0055Z. CLR 20 148/36/29/2304/996. VISUAL APCH RWY: 33L, 33R APCH in use. DEPG RWY: 28, 33R. SIMUL APCHS are being conducted to PARL RWYS. NOTAMS... PAPI RWY: 33R, REIL RWY: 33R OTS UFN. Readback all RWY hold short instructions. ...ADVS you have INFO T.

BWI SA 0153 250 -SCT 20 145/35/30/2105/995
BWI ATIS INFO U 0153Z. 250 -SCT 20 145/35/30/0000/995. VISUAL APCH RWY: 28, 33L, 33R APCH in use. DEPG RWY: 28, 33R. SOIR: 28, 33L. Visual APCH to intersecting RWYS. Visual APCH to PARL RWYS. SIMUL APCHS are being conducted to PARL RWYS. NOTAMS... PAPI RWY: 33R, REIL RWY: 33R OTS UFN. Readback all RWY hold short instructions. ...ADVS you have INFO U.

BWI SA 0252 250 -OVC 20 141/36/29/0000/994
DIGITAL ATIS NOT AVAILABLE

Pittsburg Airport ATIS Messages:

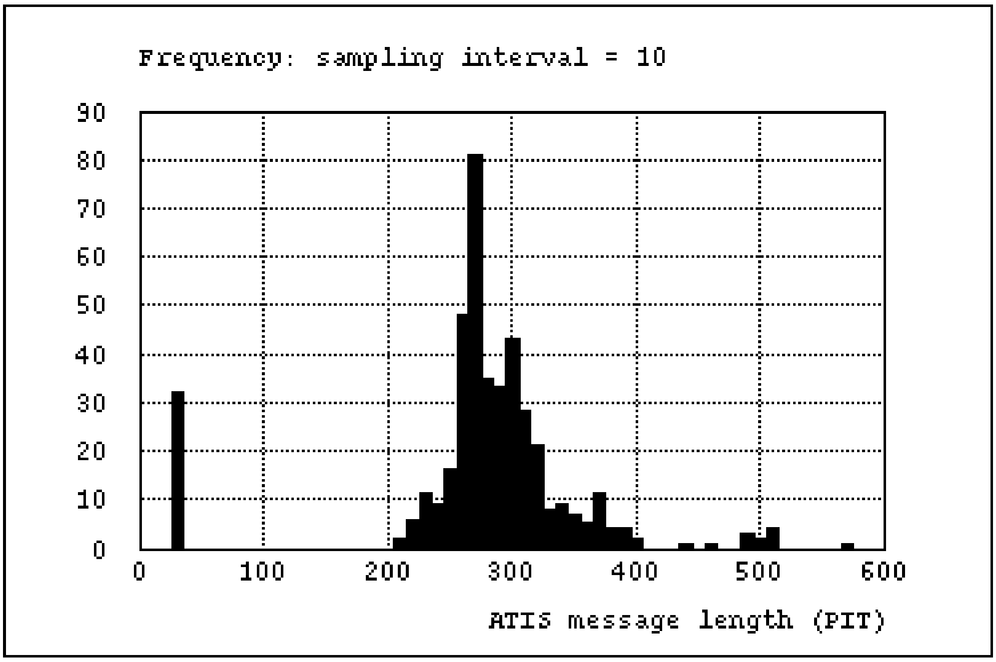
PIT SP 1004 7 SCT E45 OVC 3SW- 2204/987
PIT DEP INFO U 0951Z. E45 OVC 5SW- 124/33/32/2504/987. DEPG: RWY 28R, TWR FREQ will be 128.3. NOTAMS... RWY: 10C, 28C, 10R, 28L, 14, 32 CLSD UFN. TWY: T CLSD UFN. RCLS RWY: 28C, TWY LGTS: TWY J SOUTH OF RWY 28L OTS UFN. ALL RWYS AND TWYS WET. Readback all RWY hold short instructions. ...ADVS you have INFO U.

PIT SA 1051 7 SCT E42 OVC 3SW- 132/33/32/2205/989
PIT ARR INFO W 1051Z. 7 SCT E42 OVC 3SW- 132/33/32/2606/989. ILS RWY: 32 APCH in use. NOTAMS... RWY: 10C, 28C, 10R, 28L CLSD UFN. TWY: T CLSD UFN. RCLS RWY: 28C, TWY LGTS: TWY J SOUTH OF RWY 28L OTS UFN. ALL RWYS AND TWYS WET. Readback all RWY hold short instructions. ...ADVS you have INFO W.

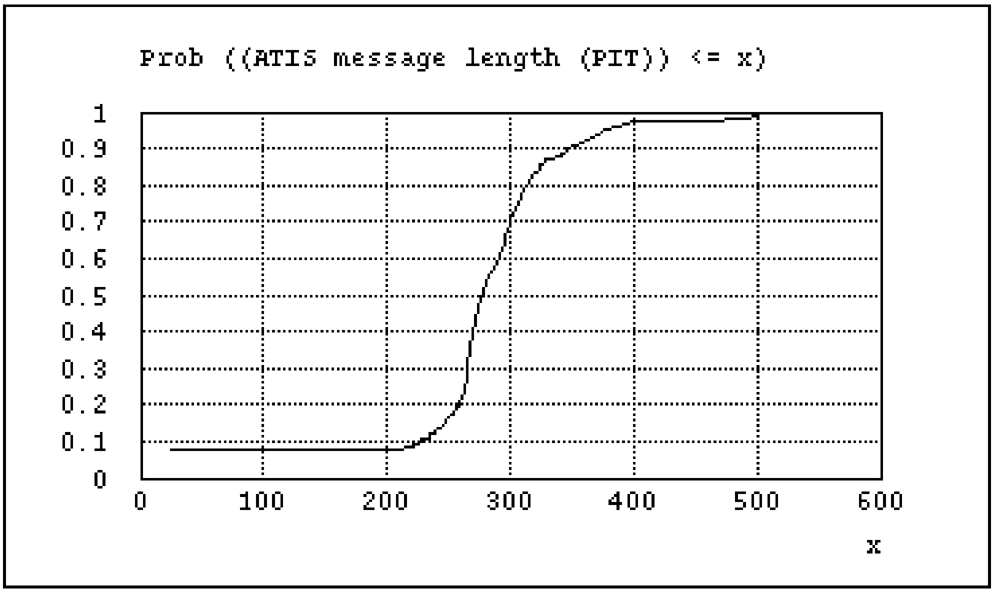
Figure 2-1. Sample ATIS Messages

2.3 ATN Simulation Methodology

The ATN simulation model has been modified to replace the fixed size with varying sizes using statistical quantities shown in Figure 2-2. The modification was straightforward though it required careful programming and validation of the simulation results. Incorporation of these statistics into ATN simulation was done as follows. First, the individual messages were treated as independent. In practice, this is not strictly true because some consecutive messages are correlated to some extent. However, these correlation statistics are hardly obtainable, and considering the large number (> 1,000) of messages involved in a simulation run, the independence assumption appears reasonable. Under this assumption, a random number between 0 and 1 was generated and this number was treated as CDF. Then simulation was run with that ATIS message size corresponding to this particular CDF value. The number of ATIS messages involved was 1338 over the typical simulation time of 18000 seconds (5 hours), which took about 1.3 hours real time. All other parameters involved in the simulation (except those related to ATIS message sizes) remained unchanged from those of the fixed size cases.



(a) Histogram (Frequency vs. Message Length)



(a) Cumulative Density Function

Figure 2-2. Probabilistic Behavior of ATIS messages (PIT Airport)

Table 2-1. Summary ATIS Message Statistics

	PIT (Nov. 5 -7, Nov. 23 - 25, 1992)	BWI (Oct. 14 - 16, Nov. 2 - 4.1992)
Number of messages	427	339
Minimum message size (bytes)	26*	26*
Minimum message size (bytes) excluding messages of 26 bytes	206	207
Maximum message size (bytes)	568	418
Mean value (bytes)	274.5	258.0
Standard deviation (bytes)	85.8	103.7

* The message of 26 bytes is “Digital ATIS Not Available.”

3. Simulation Results

3.1 Results for Fixed ATIS Message Sizes

To get a feel on the behavior of fixed-size messages, simulation was run for different (fixed) message sizes of 400, 350, 300, and 270 bytes. Results are shown in Table 3-1. Uplink delay increases gradually as the message size increases up to 350 bytes. Uplink delay then jumps from 13.2 seconds (for 350 bytes) to 18.6 seconds (for 400 bytes). Note that delay requirements specified in [2, 3] are 15 seconds for mean and 55 seconds for 95th percentile. Thus, uplink delays for up to 350 bytes messages meet the requirements, whereas the uplink delay for 400 bytes messages does not. Down link delays were not much affected (as expected) because a fixed (downlink) message size (7 bytes) was used for the cases shown here. (The one way delay statistics include all uplink and downlink samples. Uplink, downlink, and one way delays are all reported here because the requirements documents [2, 3] do not specify which of the three is meant by end-to-end delay.) Since the size of ATIS messages significantly affects ATIS delay performance and actual ATIS messages vary widely in length, using a fixed size in simulation is considered unrealistic.

Table 3-1. ATIS Delay Performance for Different (Fixed) Message Sizes.
(Mean values except those in parentheses with asterisk)

ATIS Message Size (Bytes)	Uplink Delay (sec)	Downlink Delay (sec)	One Way Delay (sec)
400	18.6	3.7	8.7
350	13.2	3.6	6.8
300	12.2 (24.0*)	3.7 (8.1*)	6.5 (14.7*)
270	12.0 (19.5*)	3.6 (8.2*)	6.4 (14.6*)

* 95th Percentile

3.2 Results for Realistic ATIS Message Statistics

Uplink delays using the modified simulation model (with BWI ATIS messages) as described in Subsection 2.3 are shown in Figure 3-1. Frequencies of uplink delays (i.e., histogram) are shown in Figure 3-2. As the histogram shows, uplink delays appear at near multiples of 4.8 seconds (mode S scan rate), which is expected. Means and 95th percentile values are summarized (for both PIT and BWI) in Table 3-2. As shown, delay values for both airports are very close. The BWI (mean) uplink delay of 13.7 seconds is 1.7 seconds longer than the 270 byte (fixed-size) case. Apparently, many ATIS messages, which are longer than 270 bytes (as seen in Figure 2-2), contribute to lengthening the mean (uplink) delay. Also, if the 26-byte messages, which do not carry any useful ATIS information, are replaced with real ATIS messages, resulting uplink delays may become longer than those values in the table. Despite this fact, it is fair to say that the (mean) uplink delays with real ATIS statistics (for both PIT and BWI) meet the 15 seconds requirement.

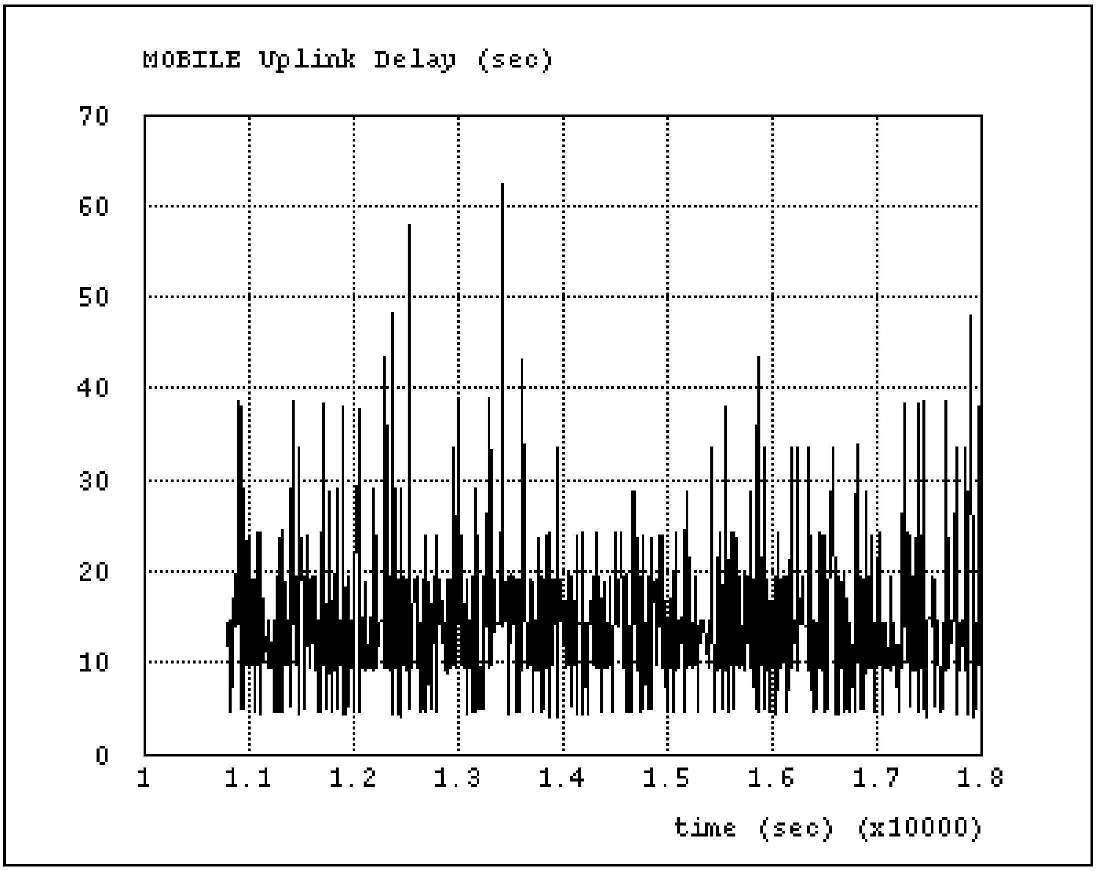


Figure 3-1. Uplink Delay vs. Simulation Time (BWI)

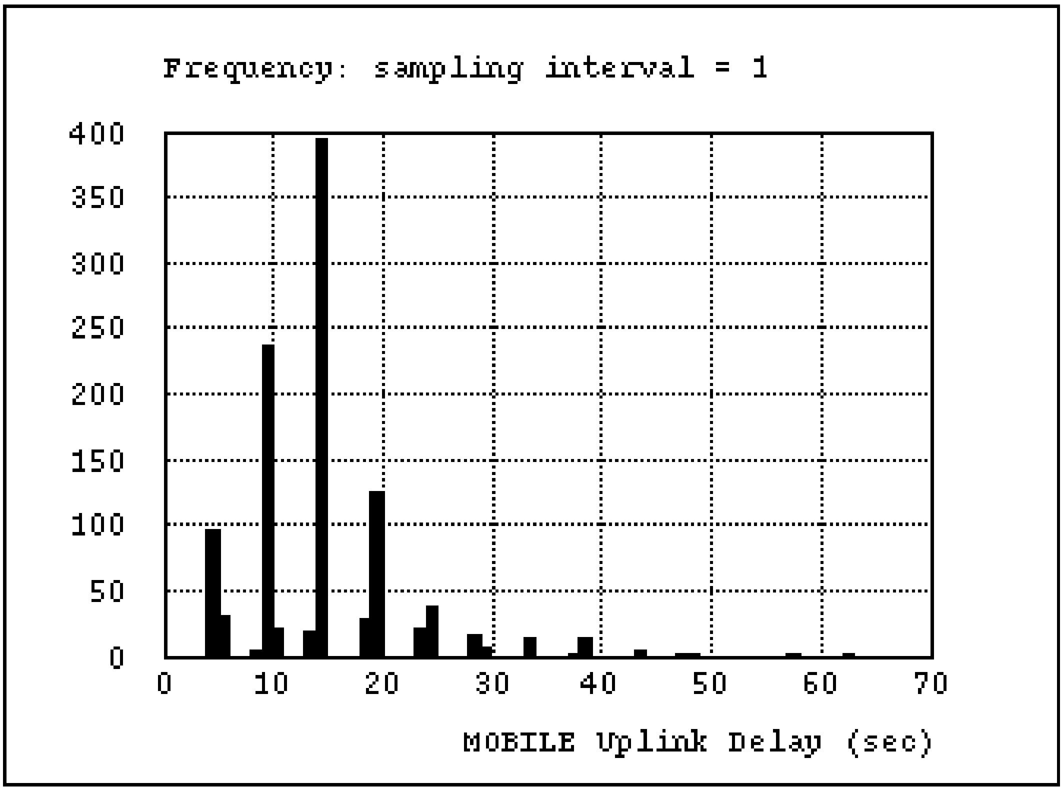


Figure 3-2. Frequency vs. Uplink Delay (Histogram) (BWI)

Table 3-2. Mean and 95th Percentile Delays (seconds) for PIT and BWI
(See Note below for end-to-end delay requirements.)

	PIT		BWI	
	Mean	95th Percentile	Mean	95th Percentile
Uplink	13.4	24.4	13.7	28.8
Downlink	3.6	7.6	3.7	8.8
One Way	6.8	19.1	7.0	19.3

Note:

Mean delay requirement: 15 seconds
95th percentile delay requirement: 55 seconds

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4. Conclusions

ATN simulation with realistic ATIS message distributions gives results that closely represent real operation. Both BWI and PIT performance data (mean uplink delays) meet the 15 seconds (uplink) requirement. It is possible that mean uplink delays for airports with heavy traffic or extreme weather conditions become longer than 15 seconds. System requirements may have to be relaxed in these cases.

5. Recommendations

Using a fixed ATIS message size in ATN simulation is unrealistic and may give a misleading result in predicting ATIS end-to-end delay performance. It is recommended that real ATIS message statistics as well as the analysis approach proposed in this paper be used in ATN simulation. More simulations are recommended for airports with heavy traffic or bad weather conditions. Requirement specifications may have to include worst-case requirements depending on the results of these extended simulations.

6. References

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7. Acknowledgments

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