DEVELOPMENT OF THE FUTURE AERONAUTICAL SUBNETWORKS TRAFFIC EVALUATOR (FASTE) FOR CNS SYSTEMS

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Summary

The FASTE-CNS project is the first phase of a software-based set of tools to assist in the complex task of estimating and modeling aeronautical traffic for future operational environments; including general aviation, business aviation and commercial air transport. Traffic estimating involves two major activities: determination of transactional loads and determination of aircraft densities for the region of interest. Transactional analysis involves understanding the applications using aeronautical communications. Examples of these applications include owner operational control, weather, air traffic control, surveillance, navigation and passenger related activities. The services supported by these applications cause air-to-ground communication transactions to occur throughout the duration of the flight. This creates traffic loads on the communication media systems that are used to form the communications channels of the aeronautical subnetwork. These media channels are often shared mechanisms, and thus, the aircraft density within a given airspace region is the other important factor in performing communication traffic forecasts. FASTE-CNS provides a web-based means for the system engineering community to collaborate on producing traffic forecasts. The system provides a means to model the resource use of the media channels. This collaboration yields benefits in providing a shared understanding of system resource use and reduces the cost of recurring traffic forecast analysis.

Background

Need

Either through necessity or renewed confidence, air travelers are returning to the nation's skies. As air traffic begins to recover from recent tragic events, the air transportation system will soon return to the situation it faced prior to September 2001 – that is, on the verge of gridlock. Delays are mounting, and as recent trends indicate, they'll continue to increase at an alarming pace. The question is, as passengers return to the air, will the National Airspace System (NAS) be any better prepared to respond to near air traffic gridlock?

The use of advanced technology is one of the ways to mitigate this alarming trend. Technology improvements, within the air transportation system, are faced with many constraining factors (hurdles). They include: the inability to further reduce separation between aircraft; limitations of the present nearly 50-year-old technology to adapt to growth; present high concentration of air traffic through a select few sectors of the airspace; and sorting through the available information to optimize controller productivity and traffic flow.

Many new ideas for controlling the NAS have emerged. However, these constraints are hard to overcome, especially without confidence about what lies beyond the barrier. Confidence comes from confirmation that technology choices have a positive impact. With potential positive examples to present to the NAS decision-makers, confidence in the technology grows to the point of acceptance -- showing by demonstration that improvements can be realized given the right mix of technology and operational techniques. The need to perform conceptual trade-off evaluations, to provide detailed evaluations considering many viewpoints of changes to the system, and to conduct real-time and non-real-time system-wide performance analyses is driving the need for dynamic and high fidelity modeling and simulation capabilities.

Advanced research towards improved aviation system technologies (i.e., AvSTAR) is in the planning stages. AvSTAR envisions developing technologies that will satisfy the growth projection in passengers, address their newly identified security requirements, and provide a technology foundation for the future.

As a precursor to this research, the need to develop and assess advanced, system-level, air transportation concepts, validate these concepts, and develop airspace simulation technologies beyond what is presently available is the work of the Virtual Airspace Modeling and Simulation (VAMS) project.

A great deal of effort has gone into modern modeling and simulation technologies and confidence in the results presented by these technologies is increasing resulting in their gaining broad acceptance throughout the industry.

The Virtual Airspace Modeling and Simulation Task will provide the VAMS Project with a national simulation and modeling capability for design and tradeoff studies of system level concepts within the national air transportation system. An effective modeling and simulation capability will be achieved by improvements to existing models, by model integration, and by development of extensive new modeling capabilities. Identification of particular modeling deficiencies will be guided by several well-defined, advanced operational concepts specified within the VAMS Project.

The assembly of models must address a variety of questions that include system-level policy assessments, regional/sector traffic flow performance, economic impact of new technologies, and infrastructure constraints.

The ability to accurately and realistically portray communications, navigation and surveillance (CNS) functions is vital to the fidelity of analysis conducted using these modeling and simulation tools. The NASA Glenn Research Center is leading the effort for the development of CNS models and simulation elements to be integrated into the Virtual Airspace Simulation Technologies (VAST) toolbox, and development of communications traffic models needed for CNS model assessment and subsystem and system simulations. This effort is highly dependent upon the ability to model today's collection of isolated systems consisting of analog communications links, ground based primary radar surveillance, and ground-based navigation aids. Thus, today's model must then be modeled with the model of the modern digital information network that provides the high capacity, reliability, availability, integrity and security that is needed to implement advanced airspace management concepts. Critical to these modeling efforts is an accurate means of depicting air traffic and generating CNS transactions that are tied to accurate traffic profiles. The FASTE-CNS concept was developed to satisfy this critical need.

Traffic Analysis and Forecast Studies

NASA GRC is conducting a number of aviation communications related tests, evaluations, and experiments to aid in understanding aviation wireless subnetworks. The objectives of these activities are to foster an analytical and empirical engineering knowledge of the complex wireless media that is planned to support the NAS and to provide for integration of the many disciplines that comprise the "Free Flight" objectives of users of the NAS. The tracing of the system applications resulting from the emerging operation concepts into their respective communications traffic loading is a complex task that requires consensus among distributed industry experts. At present, there is no single, common source of loading models used to evaluate the existing and planned communications channels. However, consensus and accuracy in the traffic load models is a very important input to the decisions being made on the acceptability of communication techniques to fulfill the aeronautical requirements.

The NASA Glenn Research Center has conducted traffic forecasts as part of the SAIC Task Order 24 Contract [1], the Communications Technology GAP Analysis [2], and the Small Aircraft Transportation SATS study on the Airborne Internet [3]. Each of these required significant labor-intensive activity to develop very similar results. The FASTE-CNS system provides the means to reduce the time in performing loading studies as well as the means to achieve and archive a recurring consensus for use in future studies.

FASTE Overview

The scope of the FASTE-CNS project is the development of a dynamic communications estimating tool that is accessible through the performance of web-based functions. The system concept is depicted in Figure 1.

The project has two phases. Phase I involves the development work activities of System Specification, System Design Drawings, Software Requirements Specifications, Software Coding and Test, and System Acceptance. Phase II involves demonstrating the FASTE-CNS to non-GRC organizations. This will occur by providing web-based access to NASA, FAA and other aviation industry organizations. Feedback will be collected from the users to ascertain the effectiveness of FASTE-CNS as a communications estimating tool. Comments will be solicited on improvements. The FASTE-CNS will be revised to add desired improvements.

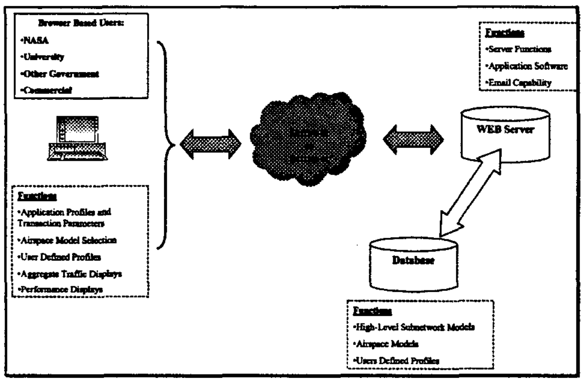

Figure 1. FASTE System Concept

System Capabilities

FASTE-CNS is accessible through the Internet using a browser such as Internet Explorer or Netscape. It provides a means to model the data communications traffic load associated with existing and new applications. (Phase 1 FASTE-CNS does not support the analysis of voice communications requirements.) FASTE-CNS will ultimately reside within GRC's multi-fidelity simulation environment and be an integrated component of GRC's modeling and simulation capability.

FASTE-CNS allows a user to dynamically define application message sets and configure communications traffic profiles composed of those message sets. The user also can define a geographical region and assign a number of aircraft to the region. The combination of traffic profiles assigned to regions provides a researcher with an understanding of the quantity and type of air/ground and air/air data link communications that occur in the region. FASTE-CNS also calculates the number of frequencies needed to support communications within the region. Some of the features of FASTE-CNS are:

Internet-Based

- FASTE-CNS is an Internet-based aeronautical communications calculation capability that will support geographically dispersed NASA, FAA, university, and contractor communications evaluations for the future aeronautical environment of the 48 contiguous states in the Continental United States (CONUS).
- Authorized users access the system using common web browsers such as Internet Explorer and Netscape.

User Accounts

- FASTE-CNS provides a mechanism to establish user accounts.
- Account holders can establish their own user identification (ID) and password.

Application Message Sets

A user can:

- Define the communicated messages associated with an application.
- Select and use an application from a library of public applications, or save it as a private application for his/her use.
- Print desired application message sets.

Communications Traffic Profiles (Per Aircraft Communications Applications)

A user can:

- Define a communications traffic profile, which is a series of applications and their associated media.
- Select and use a profile from a library of public profiles, or can save it as a private profile for his/her use.
- Print desired profiles.

Aircraft Density Profiles (Fleet Placement)

A user can:

- Define a geographic region composed of contiguous sub-regions and assign a number of aircraft to each sub-region to define an aircraft density profile. The largest profile supported covers the entire CONUS.
- Select and use a profile from a library of public profiles, or save a new profile as a private profile for his/her use.
- Print desired profiles.

Communications Forecast Data Model

- A communications forecast data model combines a user-selected group of communications traffic profiles and an aircraft density profile to describe the total communications traffic of interest in a geographical region.
- A user can assign separate communications traffic profiles to subsets of the total number of aircraft within a sub-region. For example: For a region with 100 aircraft, a user can assign profile #1 to 40 aircraft, profile #2 to 35 aircraft, and profile #3 to 25 aircraft. Profile #1 might represent the communications traffic of commercial airliners, profile #2 general aviation, and profile #3 military aircraft.
- The communications traffic loads for each type of media within a region (and its sub-regions) can be printed to provide researchers with an understanding of the data link communications requirements within the region.

Frequency Requirements

- FASTE-CNS calculates the frequency requirements needed to support the geographical region defined in the density profile.
- Results can be displayed in textual or graphical format.

System Functionality and Workflow

FASTE provides a complete set of interactive displays to guide users through the communication forecasting process. The workflow steps to accomplish the forecast are shown in Figure 2. The services necessary to support the workflow are described in the following paragraphs.

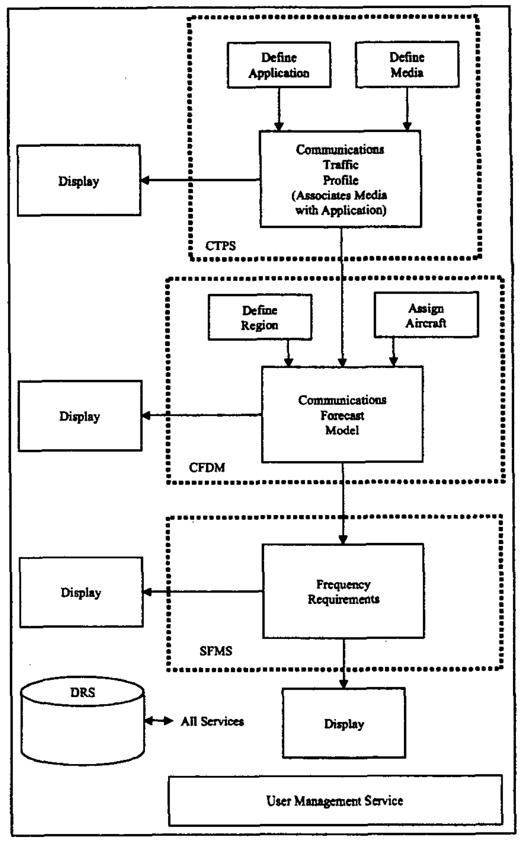

Figure 2. FASTE System Concept

User Management Service (UMS)

The User Management Service provides a mechanism to establish and delete user accounts. This service allows the user to establish a user name and password. The UMS uses the user name and password to manage access to the system. The UMS is responsible for releasing system resources once the user leaves the system.

Communications Traffic Profile Service (CTPS)

This service allows the user to generate Application Message Sets (AMS) for each application, name it and add it either to the public or private AMS library. CTPS allows a user to select and use an AMS from a library of public AMSs, modify it and save it as a private AMS or as a new AMS under the public domain. The system supports the capability to specify an AMS for a new application.

An AMS consists of application messages and their characteristics, which include message size, frequency of transmission, phase of flight, uplink/downlink (from the aircraft perspective) and message mode (human or system generated). The web interface for entering AMS data is shown in Figure 3.

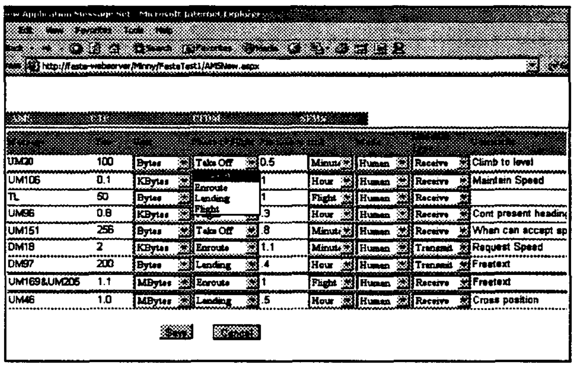

Figure 3. AMS Definition Screen

Examples of AMSs are shown in Table 1. Note that the FASTE-CNS allows the user to establish generically titled AMSs. For each of these the user may define an unlimited number of messages as indicated in Figure 3.

Table 1. Examples of AMSs

No.	AMS
1	Flight Plan Service
2	ATC Separation Service
3	ATC Advisory Service
4	Traffic Management – Synchronization Service
5	Traffic Management – Strategic Flow Service
6	Emergency and Alerting Service
7	Navigation Service
8	Airspace Management Service
9	Infrastructure/Information Management Service
10	Aircraft/Airline Operational Service
11	Passenger Onboard Service

This service also supports user definition of a media and the creation of a media library. (Figure 4) Examples of a media are VDL Mode 2, VDL Mode 3, SATCOM, UAT, 1090 MHz, and VDL Mode SATS. A user can define new media. A user can name a media and add it to either a public or private library of media. CTPS allows a user to select and use a media from a library of public media, modify it and save it as a private media or as a new media under the public domain.

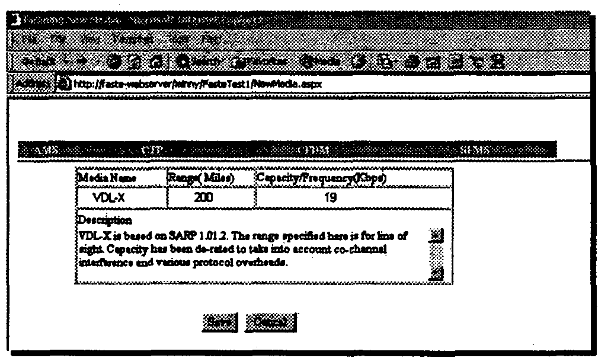

Figure 4. Media Definition Screen

The next step is the generation of the Communications Traffic Profile (CTP). A CTP is formed from selecting a set of AMSs and associating a media with each AMS. The CTP is aircraft-centric and represents the per aircraft communications profile. A CTP can be thought of as representing all of the data communications traffic associated with an aircraft. Once the profiles are generated, CTPS provide the capability to print and display the graphical representation of the CTP. (Figure 5)

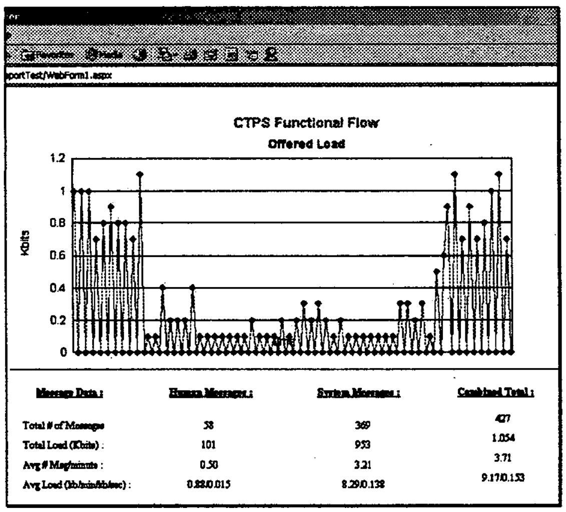

Figure 5. Single Aircraft Traffic Load

Communications Forecast Data Model Service (CFDS)

The Communications Forecast Data Model Service (CFDS) allows the user to generate a Communications Forecast Data Model (CFDM). It supports the capability to define a geographic region composed of one or more contiguous sub-regions. (Figure 6) CFDS allows the user to allocate a number of aircraft to each sub-region. The largest profile supported will cover the 48 contiguous states in the Continental United States (CONUS). CFDS allows the user to select and use a CFDM from a library of public models, or the user can create and save a private model. CFDS supports the capability to display and print desired region and model results.

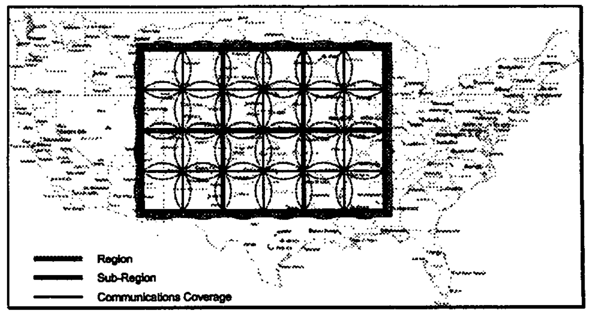

Figure 6. Defined Region

CFDS allows the user to create a data model by assigning CTPs to aircraft within the sub-regions of the user selected geographic region. The aircraft within the sub-regions can be grouped and assigned different CTPs. For example, a CTP could be assigned to the number of aircraft representing commercial aircraft, another CTP for the military aircraft, and a third CTP for general aviation aircraft. A CFDM describes the communication load generated by aircraft flying their associated traffic profiles in user-defined region. CFDS provides the capability to display as well as to print the communications forecast data model.

Subnetwork Frequency Modeling Service (SFMS)

The Subnetwork Frequency Modeling Service is the repository of various algorithms to model different media (subnetwork protocols). The media can be existing or conceptual. SFMS allows the user to calculate the number of frequencies required to support a geographical region and its sub-regions using various subnetwork protocols (e.g., VDL Mode 2, VDL Mode 3, SATCOM, user defined media).

SFMS provides capabilities to display the results in textual or graphical format.

Data Repository Service (DRS)

The Data Repository Service provides the capability to store all the FASTE-CNS environment data in a relational Database Management System.

Communications Between Users

FASTE-CNS is intended to be a communications traffic estimation tool that supports collaboration between researchers. It is anticipated that email would be one of the collaboration means used. To support collaboration, FASTE-CNS provides a means to display an account holder's user name associated with his/her email address.

System Environment

Components

The FASTE-CNS software is hosted on a server using the Microsoft 2000 (server) operating system. A user can access the FASTE-CNS features via the Internet using either Internet Explorer version 5.1 or Netscape 4.7. The system environment is shown in Figure 7.

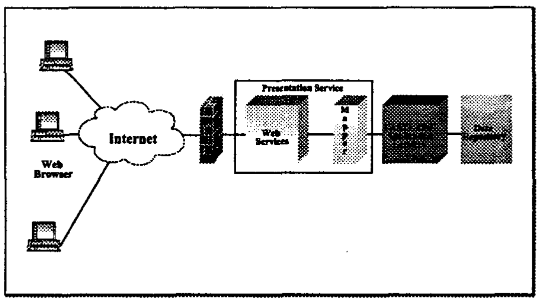

Figure 7. System Environment

System Architecture

Figure 8 presents the logical architecture of the FASTE-CNS system. It consists of a number of logical services needed to meet the FASTE-CNS environment. The first service is the Presentation Service, which consists of the Web Services and the Mapper Service. The end user interfaces to the Presentation Service through the Internet using a browser such as Internet Explorer or Netscape. The Mapper Service translates user requests into an appropriate Application Service request.

The second service is called the FASTE-CNS Application Services. The Application Services consist of the following:

- User Management Service (UMS)
- Communications Traffic Profiles Service (CTPS)
- Communications Forecast Data Model Service (CFDS)
- Subnetwork Frequency Modeling Service (SFMS)
- Data Repository Service (DRS)

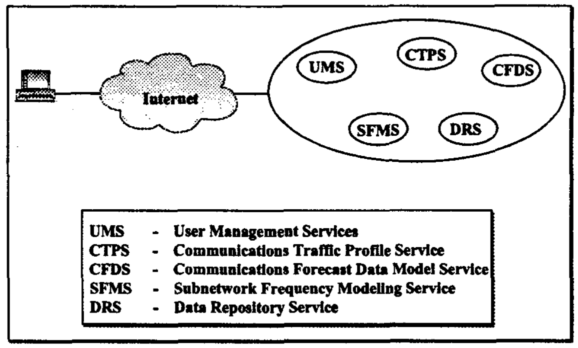

Figure 8. System Logical Architecture

Development Status

Phase 1

The first Phase of FASTE-CNS will be completed in November 2002. It is expected that detailed examples of the tools available within the FASTE-CNS will be shown during the presentation of this paper at the 21st DASC.

Phase 2

The second Phase of FASTE-CNS will involve obtaining user feedback and the linking to or the inclusion of additional subnetwork models. The connection to additional models will improve the feedback of information to systems engineers on the operational impacts of increased automated applications. Through a cooperative agreement with Cleveland State University (CSU), NASA Glenn Research Center has acquired unpublished models for VDL Modes 2, 3, and 4. It appears that with some modification, simulations involving the three modes above can be performed using these models. Each of these regional simulations involves a snapshot of multiple aircraft converging at a moment in time on an air traffic control tower. Presently, they generate communications traffic according to probability distributions using specified means and variances for inter-arrival times and packet sizes. GRC also possesses a simulation of national scope involving a comparison between an untried data link and VDL

Mode 2 (and potentially VDL Modes 3 and 4). It also uses the same method of communications traffic generation as the CSU models. This simulation and its successor cover a 24-hour period and involve upwards of 34 of the busiest US airports, and thousands of mobile aircraft with realistic trajectories. These models and others are candidates for inclusion in Phase 2 of the FASTE-CNS effort.

Conclusion

FASTE-CNS allows a user to dynamically define application message sets and configure communications traffic profiles composed of those message sets. The user also can define a geographical region and assign a number of aircraft to the region. The combination of traffic profiles assigned to sub-regions provides a researcher with an understanding of the quantity and type of air/ground and air/air data link communications that occur in the region. FASTE-CNS also calculates the number of frequencies needed to support communications within the region.

The NAS decision makers are in need of tools to aid them in decision-making. Modeling and simulation is viewed as just such a tool. Analysis of the concepts requires varying degrees of accuracy and fidelity and confidence in the solutions. Without the CNS elements any performance conclusions are suspect and open to criticism.

References

[1] Science Applications International Corporation (SAIC) et al., July1999, *Communications System Architecture Development For Air Traffic Management & Aviation Weather Information Dissemination* (NASA Glenn Research Center Under Contract NAS2-98002).

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[3] Computer Networks & Software, Inc., 2001, *SATS Airborne Internet Requirements,* Springfield, VA.