Global Grid Architecture Concept[1]

Leonard J. Schiavone
The MITRE Corporation
202 Burlington Road
Bedford, MA, 01730 USA

Abstract- Military operations are becoming increasingly reliant on a communications and information infrastructure that provides seamless, interoperable connectivity between all forces, anytime and everywhere. This operational emphasis is changing the manner in which command and control (C2) systems are defined, developed and fielded. Communication systems can no longer be 'application-centric'. Instead, we must define a communications infrastructure to support a variety of applications and missions. In particular, communications systems must be interconnected to create a network accessible by all applications and users. This 'network-centric' communications infrastructure has been coined the 'Global Grid'. In many ways, the tremendous technology advances over the past ten years in the commercial world are making the Global Grid realizable.

I. INTRODUCTION

To facilitate the migration of our current communications infrastructure within the USAF to a more 'Global Grid'-like capability, we are developing an architecture framework. This architecture framework serves as a focal point for the many contractors and government organizations involved in communication systems design and development. Using this Global Grid architecture as a framework, we are able to develop roadmaps for ongoing acquisition programs and identify technology investment needs. The architecture framework also presents a useful construct for 'customers' of the Global Grid as they develop and define end-user applications and services.

One of the most significant challenges in executing the Global Grid architecture for the USAF is in extending this framework to the aircraft environment. A number of factors contribute to this situation. Most aircraft require very long lead times for integrating new equipment. Avionics systems into which the communications systems must integrate are typically non-standard proprietary domains. Radio communications systems typically impose extensive physical and electromagnetic impacts on the aircraft.

In this paper, we will present an architecture framework developed for the USAF Global Grid and its application to our program planning activities. We will discuss some of the more significant architectural challenges and review some methods for overcoming these challenges.

II. EMERGENCE OF THE GLOBAL GRID CONCEPT

The era of distributed computing environments was ushered in with the advent of the Internet and its related technologies. Various policy initiatives have been created to harness this capability in the form of 'information infrastructures'. The United States National Telecommunications and Information Administration (NTIA) has outlined the National Information Infrastructure (NII) as the nation's 'Information Superhighway'. Similarly, the International Telecommunications Union is in the process of defining standard for a Global Information Infrastructure (GII). Within the United States Department of Defense, the military sector has defined a Defense Information Infrastructure (DII).

The underlying component to each of these information infrastructures is a communications network. The public Internet is the communications network upon which the NII and GII are built. For the military's DII, a more secure version of Internet model has been applied within certain operating domains. The DII internet communication services are one segment of the Defense Integrated Service Network (DISN).

In concert with the development of these 'information infrastructures,' the military has recognized a need to migrate towards a more integrated approach for its command and control systems. Historically, military Command and Control (C2) systems have been developed as a collection of disparate and unique equipment, which accomplished very specific functionality. A number of influential concept studies within the United States Department of Defense have underscored the need to migrate towards an integrated C2 system to achieve higher levels of force effectiveness. In each study, the underpinning of such a C2 system is common communications infrastructure, usually referred to as a 'Global Grid'.

One of the first studies to outline the Global Grid in this C2 context was sponsored by the Office of the Secretary of Defense (OSD) and the Joint Chiefs of Staff (JCS) in 1995

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[1]. In this study, a notional system construct, called the Advanced Battlefield Information System (ABIS), was comprised of three major components. The 'Battle Management' and 'Sensor-to-Shooter' functional components were supported by a communications and information infrastructure referred to as the 'Global Grid'. The ABIS concept was used as the basis for investment planning in advanced military research and development within the United States Department of Defense.

In 1996, the United States Air Force (USAF) Scientific Advisory Board (SAB) followed this DARPA/JCS study with a complementary study recommending migration towards an integrated command and control system (IC2S) for Air Force systems [2]. In subsequent years, the USAF SAB has repeatedly embraced the goals of an integrated command and control system and the Global Grid as a key enabler. Importantly, this goal has applied throughout the USAF to include its aircraft. In the major 1997 study on converting the Air Force to an Aerospace Expeditionary Force (AEF), this broad scope for Global Grid was emphasized in the following excerpt:

'Every platform that can potentially participate in an AEF must have some means of assured connectivity. This applies to not only Air Force platforms but those of Joint and Coalition forces as well.' [3]

III. AN ARCHITECTURAL APPROACH FOR GLOBAL GRID

Because of the complexities involved in system-of-system design, an architecture-based approach towards realizing the Global Grid capability has been pursued. Emphasis has been on developing a vision that captures the desired future functionality in terms of architecture principles. A process for developing architecture from fundamental architectural principles is described in the Technical Architecture Framework for Information Management (TAFIM) [4]. While the TAFIM is applied to US DOD programs, The Open Group's Architecture Framework defines a similar architecture development method for the information system industry [5]. In the context of either of these processes, definition of the basic architectural principles is a necessary first step.

A first step in defining this architecture is to establish the scope of the Global Grid's functionality. For this effort, the Global Grid is constrained to a communications utility function. Other endeavors have applied a broader meaning to Global Grid, having it encompass information services such as data storage, information management tools and message translation. However, risk apparent in such definitions is that communications infrastructures will evolve to meet the specific capabilities and demands of the information it carries. An important characteristic of the Global Grid, as a communications utility, is its transparency to the information it moves.

In reviewing trends and needs from the aforementioned studies and abiding to the defined functional scope, architecture principles for the Global Grid can be established. These principles are summarized below:

- ⇨ Employ a common network infrastructure
- ⇨ Transport any traffic type
- ⇨ Seamlessly integrate various transport media
- ⇨ Adapt to change
- ⇨ Provide assurance of service

Each of these architecture principles address constraints within the military's current communication infrastructure. Certainly, the greatest impediment in developing a unified communications infrastructure is the many mission-specific communications systems in use today. In a very general sense, completely different infrastructures are apparent for support of the strategic forces, ground theater forces and airborne systems.

While the military currently deploys a plethora of communications systems, the systems are not typically interconnected. When systems are interconnected, it is usually accomplished via information gateways. As a result, communications between two nodes on different systems is either not possible or only possible within the bounds of the translation mechanisms established at the information gateway. The movement towards 'network-centric' warfare is contingent upon a richly connected communications infrastructure. Migration towards a common network infrastructure will provide the Global Grid with this desired connectivity.

The emergence of the Internet Protocol as a unifying element in the commercial market is viewed as the likely technology enabler for many of the architecture principles. The Internet Protocol (IP) provides a 'point of convergence' on the protocol stack accommodating all types of service required by the application layer and compatible with any available transport medium at the link layer.

As Quality of Service (QoS) mechanisms are resolved in the commercial market, the tendency will be for the Internet Protocol to carry all traffic types (voice, video, data and imagery). Early capabilities are evidenced by the emergence of Voice-over-IP (VOIP) technologies and H.323 video-teleconference technologies.

While IP was designed for 'wired' links, wireless transport mechanisms, such as satellite communications and personal wireless systems, are becoming increasingly more efficient carrying IP traffic. As these QoS mechanisms and wireless IP approaches mature, the architecture principles prescribing an ability carrying any mix of traffic over any mix of transport media can realized.

The ability to adapt to change can be best realized by applying a layered architecture construct. The layers should be defined using a functional decomposition and encapsulation method. All interfaces between the layers should be standardized [6]. In an appropriately layered architecture, two distinct benefits can be achieved. First, the communications infrastructure can adapt to incremental advances in technology by replacing only affected layers. For example, link layer changes could be made without modifying the network layer (for example, replacing Ku-band satellite communications with line-of-sight tactical radio). A second benefit is that functional layers can be recomposed to create a system, which meets an unanticipated need. Efforts to apply this concept at even lower levels of system functionality at the wireless link layer are underway [7].

Finally, the Global Grid should provide assurance of service. In this respect, assurance of service comprises a range of desirable capabilities to include traditional wireless protection mechanisms for military systems (e.g., interference resistance, low probability of exploitation, scintillation resistance, data security) as well as newer mechanisms for networked communications (e.g., perimeter controls, intrusion detection systems). Assurance of service also encompasses functionality needed to provide a high degree of reliability within the infrastructure. Most importantly, the ability to manage and control the network infrastructure in an autonomous fashion is an objective end-state.

IV. Applying architecture to airborne systems

As described in the previous section, we can expect to realize the architectural principles through the following mechanisms:

- ⇨ Migrate towards an IP-based infrastructure
- ⇨ Apply layered architecture methodology
- ⇨ Extensively leverage commercial communications and networking technologies

For much of the ground-based infrastructure, both fixed and deployable, following the commercial market is a reasonable strategy. For aircraft systems, their lengthy development cycles and unique platform environments impose special challenges.

Some concepts which are being considered include exploiting information gateways, developing high capacity digital waveforms that leverage legacy voice radio RF characteristic, and layered radio systems.

V. Summary

Technology trends toward ‘information infrastructures’ and operational trends toward integrated command and control systems are predicated on an ‘internet-like’ communications infrastructure called the Global Grid. To start defining the Global Grid architecture, some of its basic principles have been described. The aircraft environment presents some difficult challenges for accommodating the Global Grid architectural principles. Some initial approaches were identified; however, a considerable amount of work remains to ensure the airborne nodes of the Global Grid are as capable as the ground segment.

References

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