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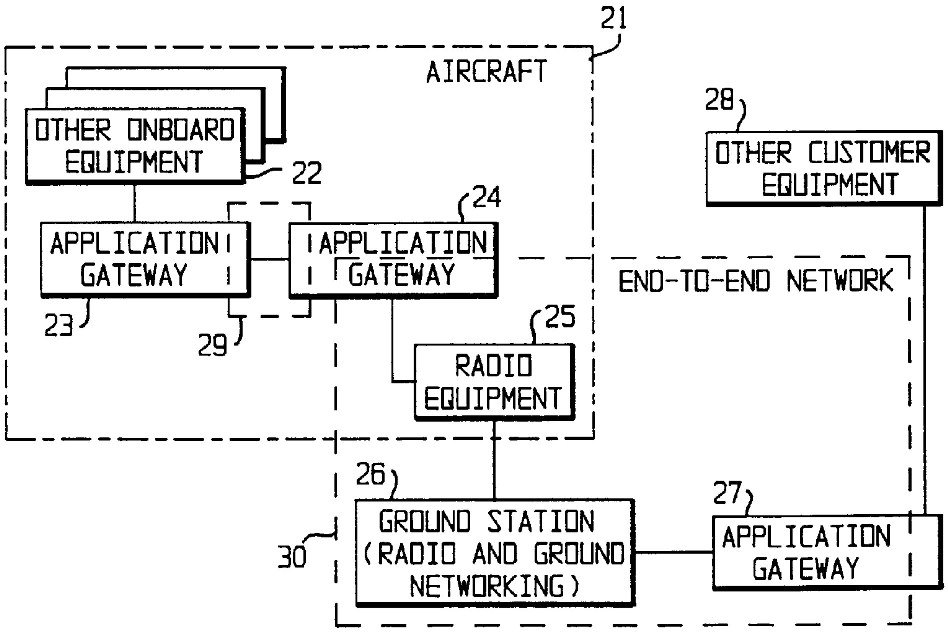
(54) **Title:** END-TOO-END AERONAUTICAL DATA NETWORK ARCHITECTURE AND METHOD AND APPARATUS FOR TRANSITIONING THERETO



(57) **Abstract:** A networking architecture for air/ground data communications implements a single network-layer protocol between a customer aircraft network interface and a customer ground system network interface, routes data between customer aircraft and associated customer ground systems, and eliminates the need for network-layer protocol conversion by service provider ground systems. To provide a transition to the new networking architecture, a transition method and a hybrid radio are provided.

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END-TO-END AERONAUTICAL DATA NETWORK ARCHITECTURE AND METHOD AND APPARATUS FOR TRANSITIONING THERETO

Reference to Related Applications

The present application claims the benefit of U.S. Provisional Application Nos. 60/202,117, 60/202,118 and 60/202,119, all filed May 5, 2000, whose disclosures are hereby incorporated by reference in their entireties into the present disclosure.

Field of the Invention

The present invention is directed to a network architecture for the processing and routing of air/ground data communications between aircraft and ground systems. The present invention is further directed to a transition to such a network architecture from present network architectures.

Description of Related Art

Commercial aircraft commonly transmit and receive air/ground digital information via radio equipment operating in the Very High Frequency (VHF) portion of the radio spectrum, on 25 kHz channels, using a system known generically as the Aircraft Communications Addressing and Reporting System (ACARS). There are several variations of ACARS in use today, including extensions to satellite relay media and High Frequency (HF) radio. Communications services using these systems are provided to customers by commercial enterprises on a for-fee basis, using networks of fixed ground stations (and optionally satellites) which support compatible protocols and hardware. The airborne equipment, ground station equipment and extended ground network all cooperate to support the end-to-end transmission and reception of digital information between a customer's aeronautical mobile station (an aircraft) and ground-based end-system (e.g., an airline operations center). In the currently-deployed and operational systems, onboard end-system equipment (e.g., an FMC or printer) communicates individually with an ACARS Management Unit (MU) according to the rules of ARINC Specification 619. The ACARS MU acts as an application gateway between these onboard systems and the air/ground network which includes the RF link and extends to a service-provider application gateway. The ground/ground data exchange between a service-provider application gateway and a customer-premises application gateway is viewed as comprising a separate network with different and incompatible protocols relative to the air/ground network. It is the responsibility of the service provider to manage the air/ground exchange of data and provide routing and protocol conversions as needed to interface with the intended users' ground-based end-systems. Routing and format translation functions are described in ARINC Specification 620. The ACARS air/ground environment is described in ARINC Specification 618. The capabilities of onboard equipment are defined in ARINC Characteristics 597, 724 and 724B. The ACARS ground/ground environment is described in ARINC Specification 620. The routing and protocol conversion functions are provided in one or more application gateway(s) maintained by the service provider(s). The(se) application gateway(s) represent critical points of failure, and must be highly reliable in order to ensure the desired quality of service.

In the currently-deployed and operational systems, both the air/ground protocol (e.g., ARINC 618) and the ground/ground protocol (e.g., ARINC 620) require significant tailoring on a per-customer basis (i.e., some messages are airline-specific and so must be interpreted differently for each airline), a per-aircraft basis (different aircraft operated by the same airline may support different equipment which requires special protocol conversions on the air or on the ground), and sometimes even a location basis (some destination addresses must be decoded differently based on the current location of the aircraft). This leads to a complex service provider application gateway. Therefore, another consequence of the present system is ongoing protocol configuration tailoring which in turn leads to high maintenance cost, impaired network performance (many failures are attributed to software error) and impaired network robustness (due to the criticality of the centralized conversion).

The aviation community has developed a new networking standard, known as the Aeronautical Telecommunications Network (ATN), which replaces the entire current system with new avionics and ground equipment providing end-to-end routing without need for protocol conversion by the service provider. This enhances ground network reliability but requires all new hardware on customer aircraft and at customer ground sites. The transition, from the current system architecture comprising two incompatible networks to the future system architecture comprising a single end-to-end network, is planned to occur in several stages comprising, among others,

a) transition to a new air/ground radio subnetwork with higher throughput than is currently available (but the air/ground network protocols will remain substantially unchanged);

b) service providers will install appropriate ground equipment and networks to support the ATN, operating in parallel with existing services; and

c) eventually, the application gateways on customer aircraft and at customer-premises ground facilities will be replaced or modified to support the ATN.

In FIG. **1**, the current air/ground networking architecture is illustrated. Consider a downlink message i.e. one generated by an aircraft **11** intended for delivery to a customerpremise end system **20** on the ground. The message may be generated with our without human intervention by onboard equipment **12** or the application gateway **13**, for example an ACARS MU. The aircraft application gateway **13** is part of the air/ground communications network **15** which typically implements a standardized set of protocols tailored for RF communications between the airborne radio equipment **14** and the ground station radio equipment **16**. The set of protocols would typically comprise physical, link layer and subnetwork layer protocols for RF communications between airborne radio **14** and ground radio **16**, and network layer protocols for data communications between the airborne application gateway **13** and the service provider's application gateway **17**. The network access points for the air/ground network **15** are the airborne application gateway **13** and the service provider's application gateway **17**. One example of a network layer protocol is the ARINC Specification 618 which implements ACARS.

The user's message information is passed through the radio equipment **14**, the ground station **16**, and thence to the service provider's application gateway **17**, for example AFEPS in the ARINC ACARS network. The detailed formatting of the message may depend on aircraft ID and ground station location, as noted above, but must conform with the protocol standard for the air/ground network as a whole (for example, ARINC Specification 618). Several message interchanges may exist between each pair of hardware elements, and the path between the ground station **16** and the application gateway **17** may traverse many networking nodes, but the important feature is that information encoded in the air/ground networking protocol standard (e.g., ARINC Specification 618) is only decoded and processed at the application gateway **17**.

After reading the downlink message and understanding its source and intended destination, the application gateway **17** reformats the message to comply with a separate ground/ground networking protocol (for example, ARINC Specification 620) and delivers the message through a ground/ground network **18** to the intended destination customer premises application gateway **19** (which may then pass the information to other customer equipment **20**). Again, the path from the service provider's application gateway **17** to the customer premises application gateway **19** could traverse many networking nodes and several messages may be exchanged on each leg of the path. The network access points for the ground/ground network **18** are the service provider's application gateway **17** and the customer premises application gateway **19**.

Uplink information passes from ground-based customer equipment to an aircraft by following a path substantially in reverse order to that described for a downlink message.

The principal feature of the system of FIG. **1** is that an application gateway provides the interface between the air/ground network **15** and the ground/ground network **18**. The service provider's application gateway cannot be bypassed since, for example, the source and destination information used on the air/ground network **15** is not able to be interpreted by the protocol elements of the ground/ground network **18**.

The ATN provides a single network without any need for the service provider to maintain an application gateway, but requires the replacement of the airborne application gateway **13** and the customer premises application gateway **19**.

The problem of communicating information across incompatible networks is well-known in the prior art. Yanosy, Jr., et. al. (US Patent 4,677,611) discloses a method for executing communication protocol conversions among a plurality of protocols, thereby allowing data communications among devices operating on incompatible networks, by converting all protocols to a common uniform protocol. Horney, II, et. al. (US Patent 5,581,558) discloses a bridging apparatus which facilitates communication between processors across networks having incompatible protocols, the bridging apparatus comprising a LAN/WAN bridge with packet assembly/disassembly and bridging functionality. Wiedeman (US Patent 5,640,386) discloses a method for bidirectionally coupling a first satellite communication system to a second satellite communication system, using a ground-based protocol conversion unit. Kulkarni, et. al. (US Patent 5,862,481) discloses an inter-technology roaming proxy which has elements in the mobile equipment and the fixed ground equipment. This system relies on coordination between the two incompatible systems. Gallagher, et. al. (US patent 5,933,784) also discloses a signaling gateway and method for two incompatible cellular systems which relies in part on communications between the two systems. Alexander, Jr., et. al. (US Patent 5,946,311) discloses a method for allowing more efficient communication in an environment wherein multiple protocols are utilized, essentially by overlaying a base protocol with additional protocols. Brivet, et. al. (US Patent 6,011,842) discloses a telecommunications network with heterogeneous operation codings, essentially comprising a network node which allows compatible communications to pass in a transparent manner, and which appropriately changes the format of incompatible messages so that they may be handled by the remainder of the network. Vo, et. al. (US patent 6,044,274) discloses a method for handling of mobile originated intelligent network calls from a non-intelligent capable mobile switching center.

In most prior systems for exchanging digital information, a user equipped to operate within a given system was unable to operate in other systems. This is illustrated in FIG. **5** where a user equipped for system A can operate in region of coverage for Network A **51**, while a user equipped for system B can operate in the region of coverage for Network B **52**. A user's route structure **53** would typically span only one network. A user wishing to operate in both networks (for example, to support an extended route structure spanning two networks **54**), would traditionally require equipage for both system A and system B. Not shown in this figure, are the network(s) of ground stations and internetworking facilities designed to support operations in the defined service areas, and route information to/from desired end-systems. These internetworking facilities could allow a mobile user to communicate with a single ground-based end-system (e.g., a user's control facility) via either of the networks illustrated.

FIG. **6** illustrates typical sets of hardware elements and associated processing functions within a mobile station. The Human Interface and Management Unit (HIMU) comprises input and output functionality for the exchange of digital information as well as control functionality for the mobile radio. The radio comprises the modulation and demodulation functions (among others). These hardware elements may or may not be located within a single chassis. As an example, the ACARS functionality on an aircraft may be implemented with a VHF transceiver, an ACARS Management Unit (MU), and a separate control/display unit (either dedicated or multi-purpose). The detailed allocation of functions to hardware elements depends on the design of the systems involved, and may vary considerably. However, for the traditional implementation illustrated in this figure, a user requires two separate "strings" of hardware and a switching device (or method) in order to operate in two separate networks. For example, HIMU A **61** and radio A **62** for communication over Network A may represent one string of equipment while HIMU B **63** and radio B **64** for communication over Network B may represent a second string of equipment. Each unit may be connected to a source of power and have interfaces to other equipment, and the radio(s) are typically connected to an antenna for the radiation and collection of radio-frequency energy. All elements for communication over Network A and Network B may be combined in a single device as shown by HIMU A **65**, radio A **66**, HIMU B **67** and radio B **68**, but the fundamental character of the separate equipment strings is typically preserved. A single equipment string may also be flexible or reconfigurable in order to support communications over two or more networks. In this case either the human user may select a preferred mode of operation, or the equipment itself may automatically select a preferred mode of operation based on software rules and RF signals detected via the radio equipment. When a single reconfigurable equipment string is used, two equipment strings may be considered to exist in a "virtual state" with only one or the other having operational effectiveness at a given instant of time. Examples of the traditional implementation are disclosed in Phillips, et. al. (US Patent 5 020 092), wherein a dual bandwidth cellular telephone is disclosed, and Pirch (US Patent 5 020 093) relating to a similar system. Kivari, et. al. (US Patent 5 396 653) disclose a cellular telephone signaling circuit operable with different cellular telephone systems, wherein the switching function is DSP or microprocessor controlled. Freeburg (US patent 5 327 572) describes a networked satellite and terrestrial cellular radiotelephone system. Grube, et. al. (US patent 5 371 898) describes a method for a communications unit to operate in either a trunking or a cellular communications system using full equipment strings and automatic switching. Tsuji, et. al. (US patent 5 590 174) describes an apparatus and method for mobile communications networking, using dual transceivers and a switching device, which ensures that a user who is out of a service area can receive an incoming call from another service area. Byrne, et. al.

(US patent 5 659 598) describes a dual mode subscriber terminal and a handover procedure of the dual mode subscriber terminal in a mobile telecommunications network, which also uses dual equipment strings, standard communications protocols and a selection capability.

The existence of multiple equipment strings, whether actual or virtual, may affect overall mobile station cost, weight, power and thermal management accommodations, as well as the user's perceived cost associated with logistics and training, the complexity of operational procedures, etc. There may also exist a need to retain certain features of one system even while using the communications capability of another system. This might include, for example, the human interface located in the cockpit of an aircraft and also the analog voice capability provided by at least one (but not all) of the systems involved. If the human interface and radio equipment are located in separate chassis, the reuse of the human interface and interactive control protocols for additional networks may lead to reduced equipment costs and reduced training costs in certain situations.

An enhancement to ACARS known as VHF Digital Link Mode 2 (VDL/2) has been introduced. A disadvantage of ACARS and VDL/2 is the inability to deliver time-critical information in a reliable manner. An alternative protocol, known as VHF Digital Link Mode 4 (VDL/4), can reliably handle time-critical information but is not widely implemented in the field. This protocol uses a different modulation technique and a different media access protocol than either ACARS or VDL/2. VDL/4 users can exchange information among themselves without requiring the presence or active participation of fixed base stations or ground stations. However, fixed base stations or ground stations may be present in order to support internetworking with other users and networks (these networks may provide a communications path to a selected ground-based end system). All VDL/4 stations, including fixed base stations, transmit special bursts of information which can be detected by other VDL/4 users within range. These bursts support, among other functions, a means to determine when a mobile user is within range of a compatible ground station.

The ACARS, VDL/2 and VDL/4 protocols and networks are not compatible with one another. As a consequence, the transmission and reception of digital information via these protocols may be expected to occur with different sets of user equipment operating in non-overlapping portions of the frequency spectrum (i.e., different frequency channels).

Certain existing users may wish to transition from ACARS or VDL/2 networks to emerging VDL/4 networks. Unfortunately, due to the current limited deployment of VDL/4 ground assets (e.g., fixed base stations and networks), these users may be forced to carry equipment for both systems (e.g., ACARS and VDL/4), and participate in both systems, in order to assure the availability of services over a specified route structure or operating region. This can lead to increased crew workload, increased complexity of operational procedures, and increased recurring and nonrecurring costs as a consequence of the need to operate in two networks over the course of a single flight or series of flights.

Summary of the Invention

It is a primary object of the present invention to overcome the above-noted deficiencies of the prior art.

It is another object of the invention to provide an improved network architecture.

It is a further object of the invention to provide an easy transition to that improved network architecture.

To achieve the above and other objects, one aspect of the present invention is a network architecture for air/ground data communications which reuses currently-deployed and operational equipment while eliminating the need for application gateway(s) maintained by service provider(s) on the ground. Specifically, this invention comprises a new application gateway on the aircraft which allows a) the deletion of the application gateway maintained by the service provider on the ground, and also allows b) the reuse of existing onboard application gateways and customer premises application gateways. This invention treats the data path between a customer aircraft and a customer ground-based end-system as contained within a single network, similar to the concept of the ATN, but does not require the replacement of existing application gateway equipment onboard customer aircraft or at customer premises facilities on the ground. The invention offers the following benefits:

a) The centralized architecture used today, with high workload and high reliability requirements on the service provider's protocol conversion system, is replaced with a distributed architecture where necessary protocol conversions are performed on customer aircraft and at customer premises on the ground. By distributing the protocol conversion task to numerous customer nodes, the individual workload at each node is reduced to a degree which allows the customer-specific functions to be supported in a mobile device, and overall network reliability can be enhanced (i.e., since a critical point of failure represented by the service provider's application gateway is eliminated, although the service provider should still maintain high reliability);

b) The service provider's data processing systems need not read the payload of each message (i.e., since the service provider role is only network communications and routing as opposed to an application gateway). This enhances reliability since a) most outages in the present system are due to software crashes and upgrades, which can be minimized since service provider functionality is reduced and b) the network can route around failed nodes. Customer data security is also enhanced since the payload is not read by the service provider (and can therefore be encrypted with keys maintained by the customer alone);

c) Increased customer flexibility since the configuration tables are maintained by the customer, can be updated at will without dependence on human workload scheduling by the service provider, and do not affect other users.

d) Ease of transition, and reduced user cost relative to implementation of ATN, since existing avionics and ground equipment can be reused.

The present invention is distinguished from the prior art in the following respects: a) it relates to an aeronautical mobile networking environment as opposed to fixed wireline, terrestrial cellular or satellite-based mobile communications; b) the two incompatible networks are already bridged -- the improvement of the present invention is achieved by effectively moving the network access point for the ground/ground network into each participating mobile station (i.e., by replicating, at numerous mobile stations, certain functions of a pre-existing fixed ground-based application gateway currently maintained by a service provider, each set of replicated functions tailored to a particular customer, thereby allowing communications to fully bypass said pre-existing fixed ground-based application gateway and associated networking facilities. Prior systems tailored to mobile communications include features in the ground infrastructure as well as the mobile stations); c) the present invention is also distinguished from the prior art, and current operational practice in the field of aeronautical data communications and networking, in that the responsibility for protocol enhancements can be shifted to the customers and away from the network service provider.

Another aspect of the invention is directed to a time-phased deployment and implementation method for a new end-to-end network architecture intended to support data communications between customer aircraft and customer ground facilities. The time-phased deployment and implementation method allows graceful upgrade of services by customers, reduces technical and operational risk associated with new services, and enables cost-saving features such as network emulation and store-and-forward capability which would not otherwise be available. In one embodiment, the present invention enhances overall quality of service by allowing operation in either of two service provider networks depending on network availability.

Still another aspect of the invention is directed to a hybrid radio apparatus for transmitting and receiving digital information via multiple incompatible systems A, B, C,... It comprises a hybridization module which, in conjunction with other equipment, allows the reuse of certain equipment and the partial or complete emulation of the protocols associated with at least one of the multiple incompatible systems A, B, C,... This partial or complete emulation is not normally achieved within the confines of a single station of any of the incompatible systems A, B, C,... The hybrid radio apparatus offers the following benefits:

a) reuse of the human interface equipment for a single system (simplifies user workload and operational procedures; reduces procurement and ongoing logistics costs);

b) simultaneous reception on two or more incompatible networks (enhances quality of service);

c) automatic mode switching based on preset or user-specified cost or procedural considerations;

d) capability to exchange digital information with other users whenever connectivity with appropriate stations, supporting any of the incompatible protocols supported by the apparatus, is available (enhances quality of service).

Brief Description of the Drawings

Preferred embodiments of the present invention will be set forth with reference to the drawings, in which:

FIG. **1** illustrates a conceptual view of the existing air/ground network architecture.

FIG. **2** illustrates a conceptual view of the improved architecture according to the present invention.

FIG. **3** illustrates a conceptual view of an intermediate stage in the transition from the existing air/ground network architecture to a future air/ground network architecture according to the present invention.

FIG. **4** illustrates a detail for one embodiment of the present invention during the second intermediate phase of transition.

FIG. **5** illustrates a conceptual view of the subject operational environment. Two of possibly N incompatible networks are illustrated.

FIG. **6** illustrates a conceptual view of the mobile user's equipment to operate in Network A alone, Network B alone, or both Network A and Network B using traditional means.

FIG. **7** illustrates a conceptual view of the hybrid radio apparatus and associated equipment, which allows the mobile user to operate in either Network A or Network B. This figure also tabulates five installation options for the hybrid radio apparatus.

FIG. **8** illustrates a detailed view of the hybrid radio apparatus and associated equipment for a preferred embodiment, wherein Network A is ACARS or VDL/2 and Network B is VDL/4.

Detailed Description of the Preferred Embodiments

Various preferred embodiments of the present invention will be set forth in detail with reference to the drawings.

FIG. **2** illustrates an alternative network architecture according to the present invention, wherein the service provider's application gateway **17** is eliminated and the ground/ground network **18** is expanded to become an end-to-end network **30** comprising selected aircraft avionics as well as ground stations **26**, internetworking facilities (not shown) and customer premises application gateway(s) **27**. The aircraft equipment includes a legacy application gateway **23** which may be the same as the present system application gateway **13** illustrated in FIG. **1**, and a new additional application gateway **24** which comprises the functions of customer-specific protocol conversion and routing functionality for the end-to-end network **30**. The onboard radio **25** and ground station **26** may be legacy systems or new systems, or may comprise a mixture of new and old systems. Since the new application gateway **24** must interoperate with the old application gateway **23**, a necessary feature of this architecture is that the air/ground network of the present system may be considered to exist in a virtual sense as the network **29** comprising selected protocol elements in the legacy application gateway **23**, the new application gateway **24**, and the signal path(s) between them.

Since the new application gateway **24** is intended to support data communications for a single aircraft, processing load is low and software complexity is low. Therefore, in a preferred embodiment the functionality of the new application gateway **24** may be incorporated in the same chassis that houses the (new) radio equipment **25**.

A downlink message is originated in an aircraft **21** either by onboard equipment **22** or the legacy application gateway **23** (messages may also be originated by the new application gateway **24**, but the procedure for handling these messages is obvious and will not be described). In FIG. **2** the legacy application gateway **23** supports only the protocol defined by ARINC Specification 618, so in this case the new application gateway **24** converts the message from an ARINC 618 format to a different format tailored to the end-to-end network **30**. An example of such a format is ARINC Specification 620 (possibly compressed using a standard stream compression algorithm) over TCP/IP, allowing direct communication with the customer premises application gateway **27** using industry-standard network protocols.

Downlink information is passed from the new application gateway **24** (if present) to the radio equipment **25**, thence to a ground station **26** over an RF communications link, and thence to customer premises application gateway **27** over a ground network that can comprise numerous nodes (not shown). The customer premises application gateway **27** interprets the message and passes it as required to other customer equipment **28**.

As in the present system, each link between pairs of hardware elements may operate with different physical, link layer and subnetwork layer protocols. For example, in the preferred embodiment of the present invention, the RF link between airborne radio equipment **25** and ground station **26** relies on physical, link layer and subnetwork layer protocols defined by draft ICAO-standard VHF Data Link Mode 4.

Since the new application gateway **24** emulates the behavior of the service provider's application gateway **17** as perceived by the old application gateway **23**, messages may be delivered from the old application gateway **23** to the new application gateway **24** and held for later delivery, for example if a suitable end-to-end network path is not immediately available. So another feature of the present invention is an enhanced store-and-forward capability (the application gateway may already support store-and-forward capability catering to times when the e.g. ACARS air/ground network is not available. The enhanced store-and-forward capability disclosed here additionally allows storage when an e.g. ACARS air/ground network is available but a new end-to-end network is not available).

Uplink information passes from ground-based customer equipment **28** to an aircraft **21** by following a path substantially in reverse order to that described for a downlink message.

A variation of the present invention is to alter the legacy application gateway **23** so that it supports the end-to-end network protocol directly. In this case the new application gateway **24** may be deleted, the legacy application gateway **23** (modified or replaced) communicates directly with the radio equipment **24**, and the end-to-end network **30** encompasses portions of the modified or replaced legacy application gateway **23** functionality. In this case the air/ground network **29** of the existing system does not exist on the aircraft even as a virtual element.

One advantage of the present invention is that the application gateway **17** of FIG. **1**, between air/ground and ground/ground networks, is eliminated from the ground-based networking architecture. The application gateway may be considered to exist in virtual sense onboard each aircraft, e.g. in the protocol bridge **24** of FIG **2** or a redesigned/replaced airborne application gateway **23**. However, by eliminating the application gateway from the ground networking architecture, data processing workload on the service provider's network is reduced and a critical point of failure is removed. The cost of maintaining a highly reliable application gateway is avoided, and overall system availability is expected to improve. Hardware elements can fail on individual aircraft and at individual customer premises, but these failures do not compromise overall network availability for other users.

A second advantage of the present invention is that information can be routed between ground stations and customer sites over any available path (e.g., the internet).

A third advantage of the present invention is that individual users may tailor their messages independently of one another and independently of the network service provider, and the tailoring can change as the configuration of the aircraft changes. This avoids errors due to unintentional user-to-user ambiguity, eliminates delays associated with service provider workload scheduling, and provides increased user flexibility. A customer can also update the configuration remotely without requiring that the aircraft be taken out of service for equipment removal and replacement.

A fourth advantage of the present invention is that users may upgrade their services incrementally, switching to a new network service provider (with a new application gateway **24**, and possibly a new radio **25** which may be housed in the same chassis), while reusing existing avionics such as an ACARS MU. At a later stage, the existing ACARS MU can be modified or replaced and the functionality of the new application gateway **24** adjusted appropriately.

A fifth advantage of the present invention is an enhanced store-and-forward capability.

A sixth advantage of the present invention is an improvement in delivery guarantees since a delivery acknowledgement via the single end-to-end network has greater significance than a delivery acknowledgement via the present system air/ground network alone, and since various end-to-end requirements can be satisfied in a manner that can only be emulated with the legacy application gateways.

A seventh advantage of the present invention is the potential for customer encryption independent of the service provider.

As noted above, the present invention encompasses not only the new network architecture in its final form, but also the transition thereto. That transition will now be described.

FIG. **3** illustrates a conceptual view of a network architecture associated with an intermediate stage of transition according to the present invention. The aircraft equipment includes a legacy application gateway **23** which may be the same as the present system application gateway **13** illustrated in FIG. **1**, and a new additional application gateway **24** which comprises the functions of customer-specific protocol conversion and routing functionality for the end-to-end network **30**. The onboard radio **25** and ground station **26** may be legacy systems or new systems, or may comprise a mixture of new and old systems. If the onboard radio equipment **25** is new equipment which does not interoperate with the present system, then in this intermediate stage of transition the customer aircraft maintains legacy radio equipment **32** which interoperates with the present system ground station **33**. However, in a preferred embodiment the new application gateway **24**, new radio equipment **25** and legacy radio equipment functionality (equivalent to the capability represented by the legacy radio equipment **32**) are provided in a single chassis which connects to the legacy application gateway **23** and also an antenna for RF communication with suitable ground stations **26** (for the new end-to-end network **30**) and **33** (for the old air/ground network **29**). One of the functions of the application gateway **24** is to monitor the availability of RF communications to suitable ground stations **33** in the present air/ground network **29,** and suitable ground stations **26** the new end-to-end network **30.** This monitoring function may rely on various messages transmitted by the ground stations **33** and **26** and received by the radio equipment **32** (or its equivalent functionality) and the radio equipment **25**, respectively, and may also rely on link and subnetwork setup and maintenance status associated with the respective protocol state machines.

When the aircraft **21** is operating in a region supported only by the present system (represented by the air/ground network **29** and the ground/ground network **31**), downlink information is passed from the legacy application gateway **23** to the new application gateway **24**, then to the legacy radio equipment **32** (or the equivalent radio equipment functionality), then to the ground station **33**, the service-provider application gateway **34**, and the customer-premises application gateway **35** (where it may be routed as needed according to customer requirements). Information is encoded using the protocols of the present system air/ground network **29** and the present system ground/ground network **31** with the service provider application gateway **34** providing protocol conversion and routing functionality. Uplink information from the customer ground facility is routed along a path essentially in reverse order. For both uplink and downlink information exchange, multiple data packets may be exchanged in each direction on each link of the network path and each link between pairs of hardware elements may operate with different physical, link layer and subnetwork layer protocols.

When the aircraft **21** is operating in a region supported by the new end-to-end network **30** (including appropriate ground station facilities **26**), downlink information is passed from the legacy application gateway **23** to the new application gateway **24**, then to the new radio equipment **25**, then to the ground station **26**, and the customer-premises application gateway **27** (where it may be routed as needed according to customer requirements). Information is encoded using the protocols of the new end-to-end network **30** with the new airborne application gateway **24** providing protocol conversion and routing functionality. Uplink information from the customer ground facility is routed along a path essentially in reverse order. For both uplink and downlink information exchange, multiple data packets may be exchanged in each direction on each link of the network path and each link between pairs of hardware elements may operate with different physical, link layer and subnetwork layer protocols. In this mode of operation, the air/ground network of the present system may be considered to exist in a virtual sense comprising selected protocol elements in the legacy application gateway **23**, the new application gateway **24**, and the signal path(s) between them.

When the aircraft **21** is operating in a region where neither the present system nor the new system is available, real-time communications between the aircraft and the customer ground facility are unavailable. However, since the new application gateway **24** is capable of emulating the air/ground network functionality of the application gateway **34** (equivalent to the present system application gateway **17** of FIG. **1**), an enhanced store-and-forward capability exists at this stage of the transition (although the storage node is still on the customer's aircraft). Downlink messages can be "delivered" from the legacy application gateway **23** to the new application gateway **24** and held pursuant to predefined customer-specific policy guidelines until a suitable downlink opportunity exists via the new end-to-end network **30**. This store-and-forward capability may also be used when an aircraft **21** is operating in a region that supports the present system (represented by the air/ground network **29** and the ground/ground network **31**), and said region does not support the new end-to-end network **30.** This store-and-forward may enable a reduction in cockpit workload and may be beneficial, for example, when communicating data which is not time critical if there is a significant cost disparity between the present system and the new end-to-end system.

In a variant of the present invention, the new application gateway **24** supports data protocols to allow direct interworking with selected onboard equipment **22** (e.g., in accordance with ARINC Specification 619) allowing the legacy application gateway **23** to be bypassed or removed (i.e., if all onboard equipment currently connected to the legacy application gateway **23** is re-routed to connect with the new application gateway **24**).

In another variant of the present invention, the customer-premises application gateways **27** and **35** are realized in a single computer with multiple ports allowing connection to the present system ground/ground network **31** and also the new end-to-end network **30**.

In a preferred embodiment of the present invention, the RF link between airborne radio equipment **25** and ground station **26** relies on physical, link layer and subnetwork layer protocols defined by draft ICAO-standard VHF Data Link Mode 4. Subnetwork control information, transmitted by radio stations compliant with this protocol, allows the geographic tracking of aircraft. This information can be delivered as auxiliary data to the customer ground facility in order to support flight following, and also to allow the more efficient scheduling and routing of uplink communications. Furthermore, if this information is made available to the new application gateway **24**, in conjunction with data base information describing known coverage of available networks, the new application gateway can make routing decisions based on imminent network availability (i.e., due to the projected flight plan of the aircraft), as well as current network availability.

Uplink information passes from ground-based customer equipment **28** to an aircraft

21 by following a path substantially in reverse order to that described for a downlink message.

As will be understood from the above description, FIG. **2** illustrates a conceptual view of a network architecture associated with a final stage of transition according to the present invention. In this stage of transition, data communications are fully and solely supported by the new end-to-end network **30** and the associated airborne and ground-based elements. All elements of FIG. **2** are also contained in FIG. **3** and behave in a similar fashion, as described in relation to FIG. **3**, in support of data communications by the new end-to-end network **30**. However, certain elements of FIG. **3** have been deleted in the shift to a final stage of transition illustrated in FIG. **2** The deleted elements of FIG. **3** are those elements that were solely associated with the present system (i.e., legacy radio equipment **32**, ground station **33**, service provider application gateway **34**, ground/ground network **31** and customer premises ground/ground network application gateway **35**).

In a variant of the present invention, the transition is frozen for an indefinite period of time at the intermediate stage illustrated in FIG. **3** in order to preserve a residual or backup capability via the present system.

FIG. **4** illustrates a detail for one embodiment of the present invention during the second intermediate phase of transition wherein the new application gateway **48** and new radio equipment functionality **47** are housed in a single chassis **43**. In this embodiment the legacy application gateway **42** (e.g. an ACARS MU) connects to the new application gateway **48** contained in chassis **43** via transmit (TX) and receive (RX) audio lines and a push-to-talk key signaling line. The legacy application gateway **42** also connects directly to the legacy radio equipment **44** for the purpose of frequency control tuning (this signal could be passed through the chassis **43**, but this is not required). The chassis **43** is also connected to the legacy radio equipment **44** by TX/RX audio lines, PTT signal line and antenna. The chassis **43** is direct-connected to an existing VHF antenna **45** and may optionally communicate with other onboard equipment such as an FMC or GPS receiver **41**. The antenna relay **46** provides a fan-out from the existing VHF antenna to the legacy radio equipment **44** and the new radio equipment functionality **47** for the purpose of radio reception, and a hard switch from either the legacy radio equipment **44** or the new radio equipment functionality **47** to the existing VHF antenna **45** for the purpose of radio transmission. When the host aircraft is operating in a region with network support via the present air/ground network only, and real-time communications via this present air/ground network are desired, TX/RX audio and PTT signal indications are transparently passed between the legacy application gateway **42** and the legacy radio equipment **44**, and the antenna relay **46** switches the legacy radio equipment **44** to the existing VHF antenna **45** for the purpose of radio transmission by the legacy radio equipment **44**. However, if radio transmissions by the new radio equipment functionality **47** are required, transmissions by the legacy application gateway **42** and the legacy radio equipment **44** can be temporarily delayed by asserting the RX audio line in a manner to trigger the carrier detect function of the legacy application gateway **42**. When the host aircraft is operating in a region with network support via the new end-to-end network, and real-time communications via this new end-to-end network are desired, the new application gateway **48** interoperates with legacy application gateway **42** via the TX/RX audio lines, performs the necessary protocol conversions, and interoperates with the new end-to-end network via the new radio equipment functionality **47**. The new application gateway functionality **48** monitors RF reception from the legacy radio equipment **44** and the new radio equipment functionality **47**. When operating in a region where both a legacy air/ground network and a new end-to-end network are available, communications can proceed by either path so described in accordance with policy guidelines defined by the customer. In a preferred embodiment, RX audio is asserted during periods of RF transmission by the new radio functionality **47**, and immediately prior to such periods, in order to prevent simultaneous transmission attempts by the legacy application gateway **42**.

When the PTT key line is asserted, the legacy radio equipment **44** has priority access to the VHF antenna **45** in order to support emergency voice operations.

One advantage of the present invention is the ability to support a more rapid transition to a full end-to-end network, compared to the transition plan for the present system. Information can be delivered at lower cost via the new end-to-end system since that system avoids the need for a service provider application gateway and hence has reduced costs.

A second advantage of the present invention is higher quality of service due to network availability via multiple networks.

A third advantage is that the present system capability is retained as a backup in the event of service failures associated with deployment of the new end-to-end system.

A fourth advantage of the present invention is that individual users may tailor their messages independently of one another and independently of the network service provider. This avoids errors due to unintentional user-to-user ambiguity, eliminates delays associated with service provider workload scheduling, and provides increased user flexibility.

A fifth advantage of the present invention is that users may upgrade their services incrementally, switching to a new network service provider (with a new application gateway **24**, and possibly a new radio **25** which may be housed in the same chassis), while reusing existing avionics such as an ACARS MU.

A sixth advantage is a store-and-forward capability which may ease cockpit workload.

A hybrid radio usable in the transition will now be described with reference to FIGS. **7** and **8**.

FIG. **7** illustrates the generic embodiment of the hybrid radio apparatus **73**, which comprises a hybridization module **74** for System A, a radio B **75** for System B, and a radio A **76** for System A (optional). The hybridization module **74** provides a partial or complete emulation of the airborne radio equipment for System A as well as a partial or complete emulation of the ground-based hardware and software elements for System A. This differs from the traditional means of integrating the capability to use multiple networks or systems into a mobile platform. If radio A is present in the user's equipment, both radio A and radio B may be active simultaneously in their respective networks. The emulation allows HIMU A **71** to operate as if it were participating in Network A, whether information is conveyed via Radio A **76** operating in Network A or Radio B **75** operating in Network B. When the mobile user is in the operating region of Network A, and not in the operating region of Network B, for example, the hybridization module is relatively passive and merely routes signals between the HIMU A **71** and the radio A **76** of System A. When the mobile user is in the operating region of Network B, the hybridization module emulates, as required, the mobile radio equipment and ground-based protocols for System A. This allows HIMU A **71** to operate as if it were still active in Network A, allowing the re-use of HIMU A. However, the uplink and downlink data is actually handled via radio B **75** operating in Network B, with appropriate internetworking by the service provider to reach an intended intermediate network or end-system on the ground. When the mobile user is in a region of overlapping coverage between

Network A and Network B, the hybrid radio apparatus and its hybridization module may operate in either of the modes described herein, with the choice dependent on pre-set programming or mobile user commands. Typically but not always, this choice may be based on cost of service or quality of service available via the two networks. The choice may be automatic or manual (i.e., by the human user). If automatic, the human user is not necessarily aware of which network has been selected, although an indicator may be provided.

If both radio A **76** and radio B **75** are present, the hybrid radio apparatus may simultaneously monitor the radio activity detected by both (note: in some implementations the receive capability may be disabled during transmissions by the mobile station. However, mobile station transmissions are typically of short duration and low duty cycle, and not all implementations are so limited). This monitoring activity allows the hybrid radio apparatus (or the human user) to make a decision on which network is most appropriate for any given communication event. The decision may be based on which networks and services are available at a given instant of time, and may also be based on geographic location, cost, quality of service and other parameters.

If System A and System B support identical applications, only a single HIMU is required. In FIG. **7**, this is illustrated as the HIMU A **71** for System A. The mobile user can operate in either network via this unit. If System A and System B support dissimilar applications, a dedicated HIMU may be required for each system (as illustrated by HIMU A **71** and HIMU B **72**). The decision to install and operate a dedicated HIMU for each system depends on the applications and needs of the user.

The radio A **76** for System A is shown as optional in FIG. **7.** If deleted, the mobile user can still operate in Network B using the HIMU A **71** of System A (or the HIMU B **72** of

System B if this HIMU is installed). The radio A **76** for System A may be deleted to conserve weight, power and maintenance and logistics expenses if, for example, Network B expands to cover the area of operations of the mobile user.

The hybrid radio apparatus comprises the ability to support the five distinct installation options identified in FIG. 7. In installation option 1, the user relies exclusively on the HIMU A **71** for System A but is served by either Network A or Network B depending on pre-set or user-commanded selection criteria. In this fashion, a transparent user interface is provided to both networks. In installation option 2, a HIMU B **72** for System B is available to support applications not available via System A. Installation options 3 and 4 are similar to installation options 1 and 2, but the radio A **76** for System A has been deleted and all communications flow via Network B. In installation option 5, only functionality associated with System B is installed. The hybridization module is not required in this case, but may be retained to avoid equipment replacement expenses if, for example, the user is transitioning operations from Network A to Network B. By offering these distinct installation options, the hybrid radio apparatus can satisfy the needs of a broad range of users, allow the re-use of some existing equipment, and support cost-effective transition from System A to System B as regions of coverage for Network A and Network B vary over time.

FIG. 8 illustrates elements of a preferred embodiment for the case where Network A is ACARS and Network B is VDL/4. The hybridization module **81** comprises the ACARS MU interface **82**, the ACARS MSK modem **83**, the service selection module **84** and elements of the communications processor **85**. The control/display device(s) providing the human interface are not shown, but these could be interconnected to the ACARS MU **86**, the FMC **87**, or the Communications Processor **85** via, for example, the ARINC 429 interface **88**. The radio equipment comprises the ARINC 716 R/T **89** and the GFSK R/T **90** for this embodiment, which provides for services via ACARS and VDL/4 networks. This embodiment shares the human interface for the ACARS system and reuses the ACARS radio equipment in geographic areas where VDL/4 services are not available. The elements of FIG. 8 are described below.

Accommodation for a front panel data loader/built-in test equipment (BITE) interface **91** provides a method of updating the avionics software without requiring removal of the avionics from the aircraft. The communications processor **85** software, ACARS MSK modem **83** software, and GFSK MODEM **92** software can be updated via this interface. This interface is described in ARINC Specification 615-3 "Airborne Computer High Speed Data Loader." This interface also accommodates portable diagnostic equipment that can command the BITE, and record and display the results of the BITE.

Accommodation for a Flight Management Computer (FMC) **87** allows for installations where the aircraft FMC provides position and velocity data (a Global Positioning System (GPS) receiver could also be used). This interface is an ARINC 429 listen only interface. Interfaces to at least two FMCs or GPS receivers would typically be provided. The communications processor software would monitor all the FMCs (for example) and select the active one.

The ACARS MU interface **82** provides a fan-out of the TX audio signal from the ACARS MU **86** and provides this signal to the ARINC 716 VHF AM radio **89** and to the ACARS MSK MODEM **83**. The signal "RX Select" from the Communication Processor **85** controls the source of RX audio provided to the ACARS MU **86**. RX audio is provided from the ACARS MSK modem **83** when the ACARS MU **86** is communicating via the VDL/4 network and from the ARINC 716 VHF AM radio **89** when the ACARS MU **86** is communicating via an ACARS network.

When no transmissions are being made, the communications processor **85** receives incoming data via ACARS (on the ARINC 716 radio **89**) and also the VDL/4 network (on the GFSK R/T **90** and GFSK modem **92**). This allows the communications processor to determine which networks are available to the mobile station and which services are available on each network. The communications processor **95** can then determine which network should be used for any given user transmission. Incoming data from both networks may be routed to appropriate end systems onboard the aircraft.

The data key line from the ACARS MU **86** controls the ARINC 716 transmitter **89** in traditional ACARS-only installations, but is intercepted by the service selection module **84** of the hybrid radio apparatus **81**. When the 716 radio is not being used for data communications with an ACARS network, this signal is prevented from being asserted to the ARINC 716 transmitter **89**, thus preventing the keying of the transmitter. As part of the network control protocol for the ACARS network, the ACARS MU **86** may attempt to initiate network entry, keep-alive and handoff transactions as a result of uplink messages it receives from ACARS ground stations via the ARINC 716 radio **89**. These can be intercepted by the communications processor **85** and the appropriate ground station responses emulated via the ACARS MU interface **82**, without ever allowing transmission by the ARINC 716 radio **89**. In this way, the ACARS MU **86** acts as if it is active in an ACARS network even when it is not.

The ACARS MSK modem **83** is active when the ACARS MU **86** is communicating via the VDL/4 network; it provides the interface between the communications processor **85** and the ACARS MU **86**. The demodulation of receive audio from and modulation of transmit audio to the ARINC 716 VHF AM radio **89** is not required since communications in this case is via the VDL/4 network. The ACARS MSK modem **83** is used solely for interface between the communications processor **85** and the ACARS MU **86**. This MSK modem function is simple to implement since a low distortion high signal-to-noise ratio signal is assured. If the ACARS MU **86** is replaced with a Communications Management Unit (CMU), and the ARINC 716 radio **89** is replaced with an upgraded version such that the interface between these two devices is digital information as opposed to a modulated MSK signal, the ACARS MSK modem **83** can be deleted and the nomenclature for the TX AUDIO and RX AUDIO lines would be modified accordingly.

The service selection module **84** allows for the selection of inter-operation with either the VDL/4 or ACARS network. The communications processor controls the ACARS MU interface **82** and determines the source of RX audio provided to the ACARS MU **86**. TX audio, from the ACARS MU **86**, is fanned out to the ACARS MSK modem **83** and to the ARINC 716 VHF AM R/T **89**. An antenna switch is also provided so that a single VHF antenna can be shared between the ARINC 716 AM VHF radio **89** and the VDL/4 GFSK VHF radio **90**. Control of the push-to-talk (PTT) signal to the VHF AM radio **89** is also provided to ensure that the transmitter is not active when it is not connected to the VHF antenna. Selection of either the VDL/4 network or an ACARS network can be controlled by the communications processor **85** based on navigation information, VDL/4 network management policy, and receipt of VDL/4 ground uplinks. This provides an automatic selection capability that is transparent to the pilot, based on pre-set decision rules.

The signal "Voice/Data Select" is also monitored by the communications processor

85 to determine if the ARINC 716 R/T is being used for voice communications. When this signal indicates that the ARINC 716 R/T **89** is being used for voice communications, the VHF antenna is switched to the ARINC 716 R/T. Voice use of the ARINC 716 R/T could indicate an emergency condition, and therefore takes precedence over all other uses of the VHF antenna and preempts both ACARS network use and VDL/4 network use of the VHF antenna.

The communications processor **85** provides the host for the software that implements VDL Mode 4 TCP/IP protocol functions, mimics the operation of the ACARS network, and provides the interface between these two network protocols. The data loader interface **91** allows for software updates and configuration file changes without removal of the unit from the aircraft. The communications processor **85** also provides the capability of updating the GFSK modem **92** software via the data loader interface. The ability to update modem and communications processor software and configuration files via the RF using FTP protocol may also be provided.

While various preferred embodiments of the present invention have been set forth above, those skilled in the art who have reviewed the present disclosure will readily appreciate that other embodiments can be realized within the scope of the invention. For example, communication protocols other than those disclosed can be used. Therefore, the present invention should be construed as limited only by the appended claims.

We claim:

1. An end-to-end network for air/ground data communications between a customer aircraft and a customer ground facility, the network comprising:

on the aircraft, a first radio for communicating with the end-to-end network and an application gateway for connecting the first radio with other equipment on the aircraft by network protocol conversion; and

on the ground, a second radio for communicating with the first radio and a ground network for transmitting the data communications between the second radio and the customer ground facility,

wherein the data communications among the first radio, the second radio and the ground network use a common network protocol so that network-layer protocol conversions between the aircraft and the ground network are not required.

2. The end-to-end network of claim 1, wherein some or all of the ground network is a part of the worldwide Internet.

3. The end-to-end network of claim 1, wherein the ground network uses network control and routing protocols which are interoperable with the worldwide Internet.

4. The end-to-end network of claim 1, wherein the ground network uses network control and routing protocols which are interoperable with the Aeronautical Telecommunications Network (ATN).

5. An end-to-end network for air/ground data communications between customer aircraft and customer ground facilities, the end-to-end network comprising:

on the aircraft, first and second application gateways representing first and second network interface points of a network supporting a legacy air/ground networking protocol, and one network interface point for a network supporting a legacy ground/ground networking protocol; and

on the ground, a radio for communicating with the aircraft and a ground network supporting the legacy ground/ground networking protocol;

wherein the second application gateway and the network interface point jointly support all customer-relevant protocol conversions and processing required to provide internetworking between a) the legacy air/ground networking protocol and the legacy ground/ground networking protocol, thereby allowing bypass of a service-provider application gateway on the ground.

6. The end-to-end network of claim 5, wherein some or all of the ground network is a part of the worldwide Internet.

7. The end-to-end network of claim 5, wherein the legacy ground/ground networking protocol is interoperable with the worldwide Internet.

8. The end-to-end network of claim 5, wherein the legacy ground/ground networking protocol is interoperable with the Aeronautical Telecommunications Network (ATN).

9. The end-to-end network of claim 5, wherein at least one of the second application gateway and the network interface point implements a store-and-forward capability.

10. The end-to-end network of claim 5, wherein at least one of the first and second application gateways supports protocol configuration tailoring remotely.

11. The end-to-end network of claim 5, wherein user data is encrypted and passed transparently through the ground network without decryption in the ground network.

12. A method for transitioning from a first data networking protocol using an air/ground network and a ground/ground network to a second data networking protocol using

an end-to-end network, the method comprising:

(a) installing a new application gateway on an aircraft, the new application gateway emulating said air/ground network as perceived by onboard equipment on the aircraft and providing an application gateway for said ground/ground network while also providing a link between the onboard equipment and the end-to-end network, allowing said air/ground network and ground/ground network to be bypassed in favor of said end-to-end network; and

b) implementing a transition in first, second, and third stages, wherein the first stage uses the first air/ground network and ground/ground network, the second stage is a hybrid networking architecture wherein aeronautical air/ground data may be routed through the air/ground network and the ground/ground network or through the end-to-end network, and the third stage is a networking architecture characterized solely by use of the end-to-end network providing service from the aircraft to customer premises on the ground.

13. The method of claim 12, wherein connectivity to the air/ground network and ground/ground network is retained in the first, second and third stages in order to enhance service availability.

14. The method of claim 13, wherein messages are routed preferentially over the first air/ground network and ground/ground network, or the second end-to-end network, based on policy guidelines specified by a customer.

15. The method of claim 13, further comprising performing a store-and-forward technique, allowing delayed transmission of messages intended for the air/ground network via the end-to-end network, in order to reduce measured usage of the first air/ground network and ground/ground network.

16. The method of claim 12, further comprising converting the new application

gateway to interoperate with selected existing onboard equipment.

17. In a user's fleet of aircraft, a method for transitioning fleet operation from a first data networking architecture using an air/ground network and ground/ground network to a second data networking architecture using an end-to-end network, said method occurring over an extended period of time as individual aircraft are suitably equipped, said method comprising the steps of:

(a) installing application gateway and radio equipment on fleet aircraft allowing interoperation with either said first data networking architecture or said second data networking architecture;

(b) demonstrating operationally that the said second data networking architecture achieves desired performance;

(c) adjusting policy guidelines for routing of traffic via said first data networking architecture or said second data networking architecture; and

(d) removing unneeded equipment associated with said first data networking architecture.

18. A hybrid radio apparatus for a mobile radio station capable of operating in at least two different radio networks simultaneously, employing at least two different protocols, the hybrid radio apparatus comprising:

a hybridization module for at least a first one of the networks; and

radio equipment for at least a second one of the networks;

said hybridization module comprising electronics and software necessary to emulate some or all protocols of the first network, and communicating at a peer level with protocols of the second network resident in the hybrid radio apparatus, said emulation and peer level communication allowing an appearance of communication via network A.

19. The hybrid radio apparatus of claim 18, wherein the hybridization module is tailored to a set of network protocols which contains at least one member selected from the group consisting of ACARS, VDL/2, and VDL/4.

20. The hybrid radio apparatus of claim 18, wherein the radio equipment is designed to operate with a set of systems which contains at least one member selected from the group consisting of ACARS, VDL/2, and VDL/4.

21. The hybrid radio apparatus of claim 18, wherein the hybridization module operates for ACARS and the radio equipment operates for a VDL/4 network.

22. The hybrid radio apparatus of claim 18, wherein the hybrid radio apparatus automatically decides to operate via the first network or the second network, when both the first network and the second network are available, based on pre-set or user-specified decision criteria.

23. A hybrid radio apparatus for a mobile station, the hybrid radio apparatus comprising:

a hybridization module which emulates protocols normally in one or several ground facilities providing services for a first network or system;

mobile radio equipment operating on a second network or system which is different from the first network or system; and

mobile equipment usable with the second network or system over the mobile radio equipment and over the first network or system over the hybridization module.

24. The hybrid radio apparatus of claim 23, wherein the mobile equipment comprises a human interface and management unit.

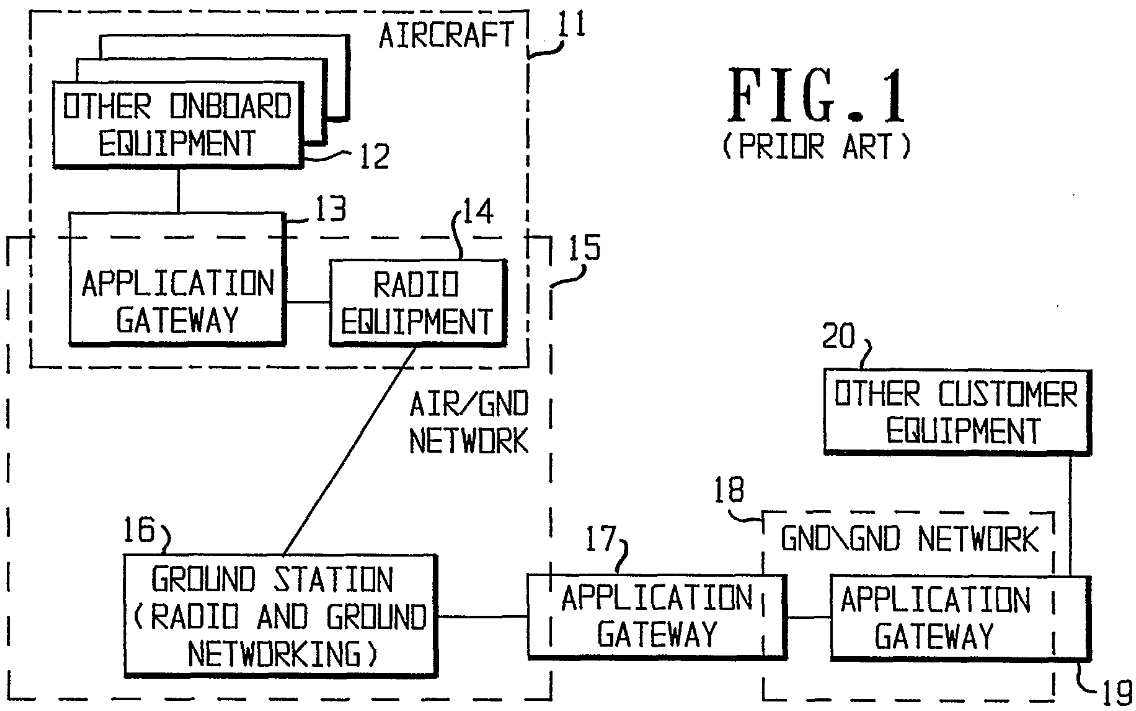


FIG.1
(PRIOR ART)

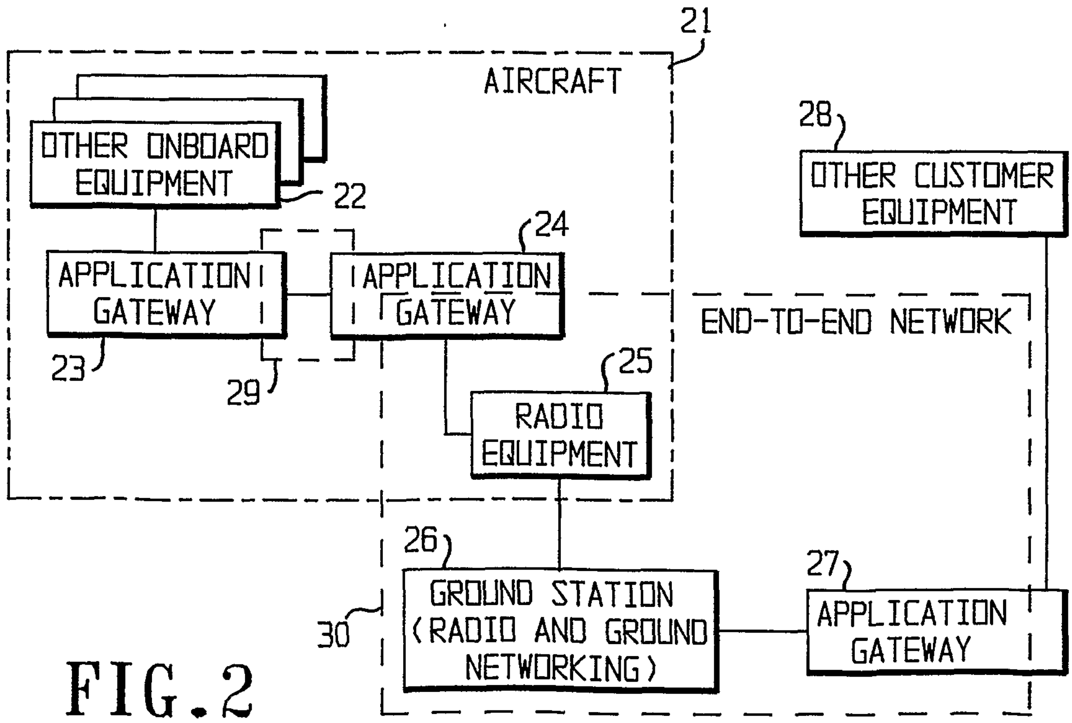
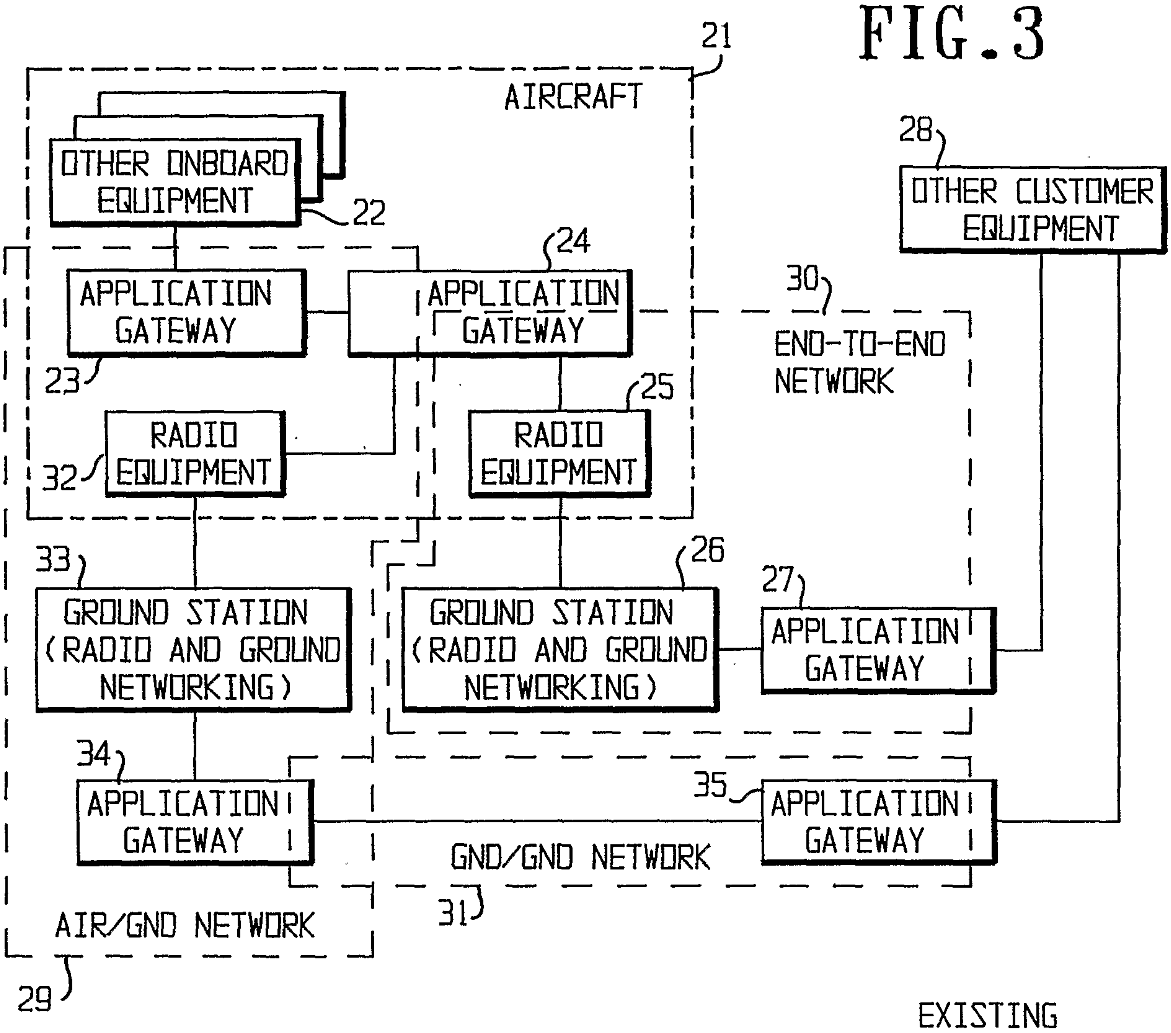


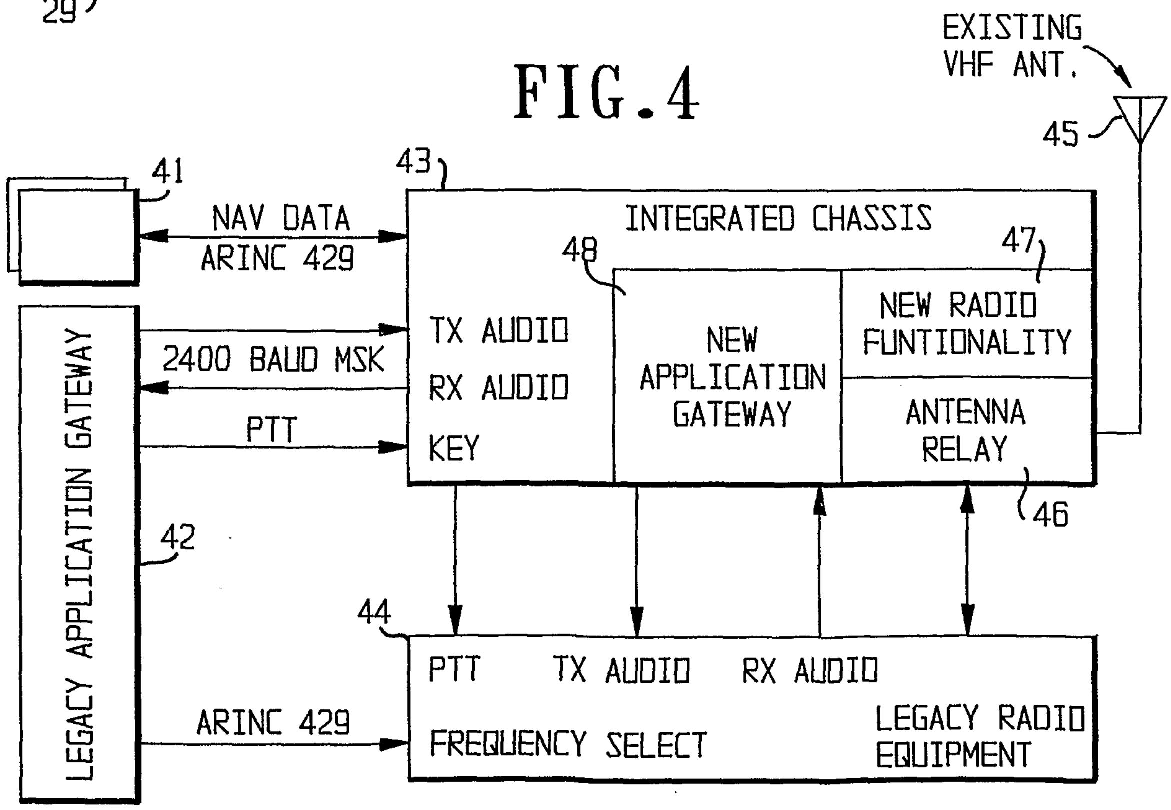
FIG.2

FIG.3



21
AIRCRAFT
OTHER ONBOARD EQUIPMENT
22
24
APPLICATION GATEWAY
APPLICATION GATEWAY
23
28
OTHER CUSTOMER EQUIPMENT
30
END-TO-END NETWORK
RADIO EQUIPMENT
32
25
RADIO EQUIPMENT
33
GROUND STATION (RADIO AND GROUND NETWORKING)
26
GROUND STATION (RADIO AND GROUND NETWORKING)
27
APPLICATION GATEWAY
34
APPLICATION GATEWAY
35
APPLICATION GATEWAY
GND/GND NETWORK
31
AIR/GND NETWORK
29

FIG.4



EXISTING VHF ANT.
45
41
43
NAV DATA
ARINC 429
INTEGRATED CHASSIS
48
47
NEW RADIO FUNTIONALITY
TX AUDIO
2400 BAUD MSK
RX AUDIO
NEW APPLICATION GATEWAY
ANTENNA RELAY
PTT
KEY
46
LEGACY APPLICATION GATEWAY
42
44
PTT
TX AUDIO
RX AUDIO
ARINC 429
FREQUENCY SELECT
LEGACY RADIO EQUIPMENT

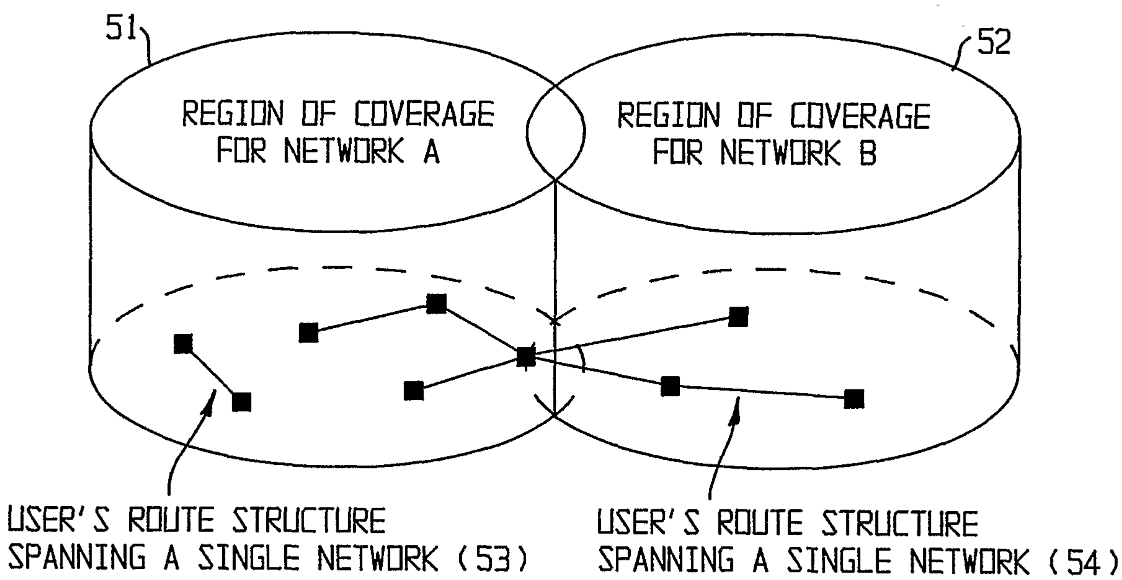


FIG. 5 (PRIOR ART)

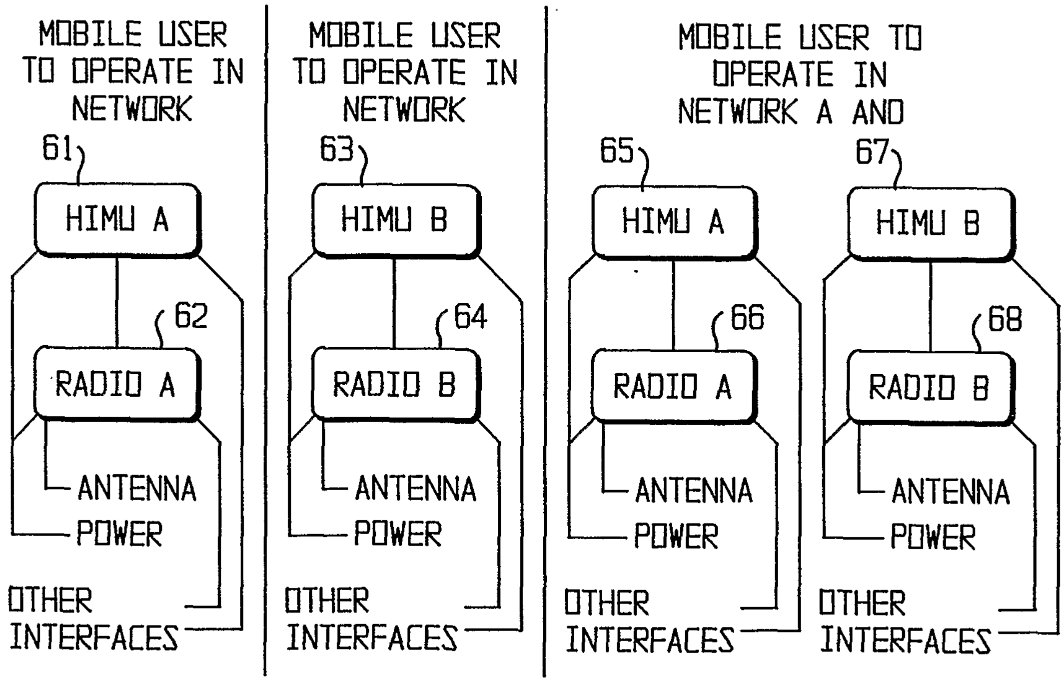
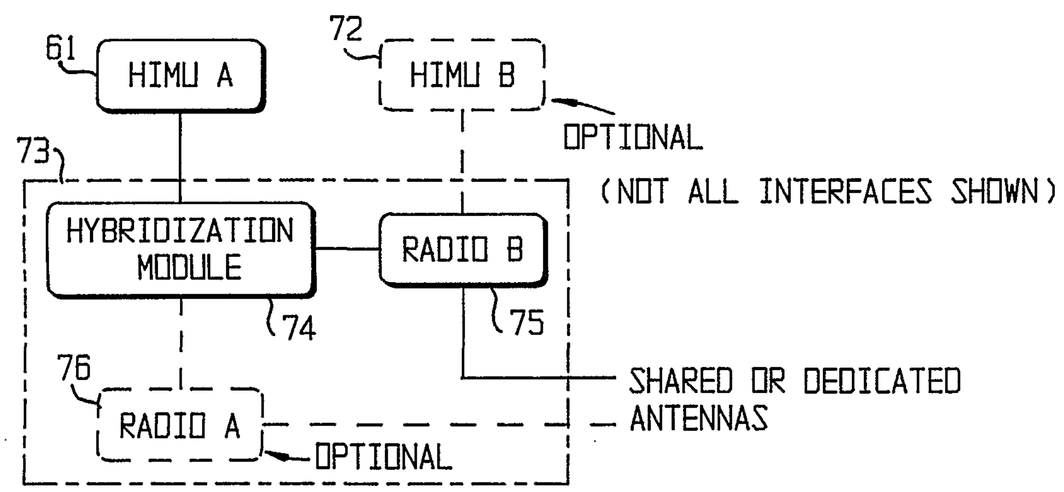


FIG. 6 (PRIOR ART)



INSTALLATION OPEN	HIMU A 71	HIMU A 71	RADIO A 76	RADIO A 76	HYBRIDIZATION MODULE 74	ANTENNAS (NOT SHOWN)
1	YES	NO	YES	YES	YES	ONE OR TWO
2	YES	YES	YES	YES	YES	ONE OR TWO
3	YES	NO	NO	YES	YES	ONE
4	YES	YES	NO	YES	YES	ONE
5	NO	YES	NO	YES	NO (OPTIONAL)	ONE

FIG.7

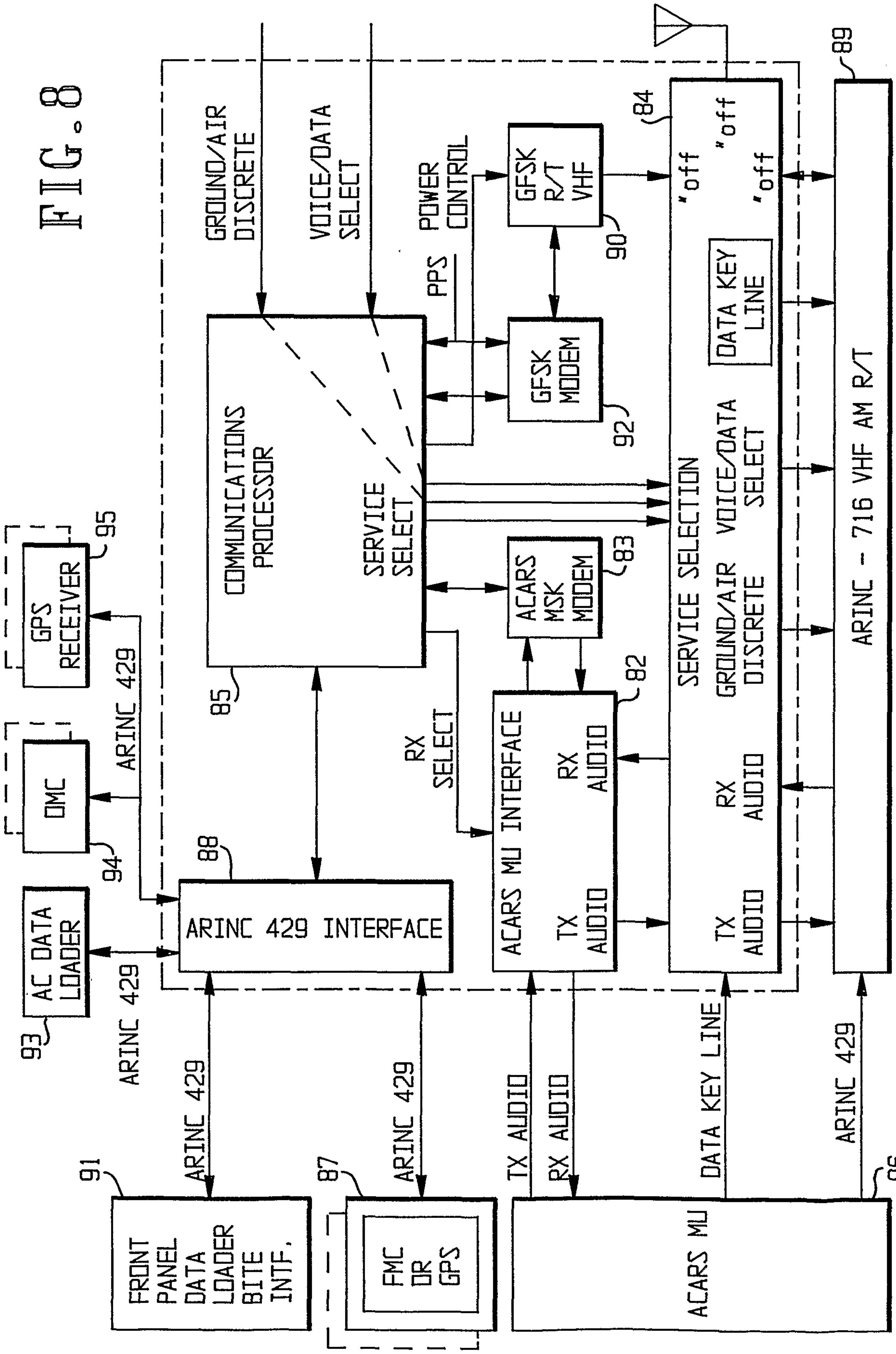

GROUND/AIR DISCRETE
VOICE/DATA SELECT
POWER CONTROL
PPS
GFSK R/T VHF
90
GFSK MODEM
92
84
"off
"off
"off
DATA KEY LINE
89
COMMUNICATIONS PROCESSOR
SERVICE SELECT
85
ACARS MSK MODEM
83
82
SERVICE SELECTION
GROUND/AIR DISCRETE
VOICE/DATA SELECT
RX AUDIO
TX AUDIO
ARINC - 716 VHF AM R/T
GPS RECEIVER
95
ARINC 429
OMC
94
RX SELECT
ACARS MU INTERFACE
RX AUDIO
TX AUDIO
88
ARINC 429 INTERFACE
AC DATA LOADER
93
ARINC 429
ARINC 429
ARINC 429
TX AUDIO
RX AUDIO
DATA KEY LINE
ARINC 429
91
FRONT PANEL DATA LOADER BITE INTF.
87
FMC OR GPS
ACARS MU
86

FIG. 8