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Research of a New Non-Layer Protocol Architecture for Satellite Network

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Abstract

The traditional hierarchical network architecture has the defect of redundancy and no interaction between the layers. These defects have bad impact on QoS and network security. Hierarchical network protocols are difficult to be used to satellite network. This paper analysis the different network protocol architecture and propose a new network protocol architecture for satellite-Component-based network architecture, this architecture is proposed for eliminating of hierarchical network design flaws. Network protocols will be divided according to the function for forming of low coupling functional components. It provides high quality services to the application using combined components.

Keywords*: protocol, non-layer network, component*

1. Introduction

Since Jet Propulsion Laboratory (JPL) start interplanetary Internet research in 1998 which was funded by the U.S. Defense Advanced Research Projects Agency (DARPA), the concept of the ground Internet has been extended to the space. The international community has made up some standards or recommendations on the space network and the interconnection of the ground and space technology. However, because the satellite network is different from the wired network, even different from the general wireless network, which makes the typical network protocols including the hierarchical protocol and implementation can not apply to the satellite network.

Satellite network need to face with large latency, high-bandwidth network environment, besides the network topology space often occur dynamical change, to adapt the space environment, saving on-board processing and transmission resources, we need more simple and reliable networking protocol. Because of the long delay and code error on inter-satellite and satellite–ground link, space network can not use the network protocol of the ground.

The architecture of the hierarchical network still exist some problems. Layered network architecture have many control redundancy between the layers, for example the transport layer, link layer will use error control. Another problem of the layered network architecture encountered was the original design does not support QoS and network security. In order to support QoS, there develops many protocols, such as RSVP, RTP, RTCP, etc., but they can only ensure the QoS of end to end, and useless for the intermediate nodes on the network, resulting waste of resources.

2. Background

Current classical network protocol is TCP/IP, the entire network will be divided into five layers: the application layer, transport layer, network layer, data link layer and physical layer. With the continuous development of space technology, CCSDS (Consultative Committee for Space Data System) developed a series of criteria applied to spatial data systems and recommendations, the same network is divided into five layers: the application layer, transport layer, network layer, data link layer and physical layer. In order to connect with the ground network, people began to study and design integrated hierarchical network architecture protocol, such as IP OVER CCSDS, it protocol architecture shown in Figure 1.

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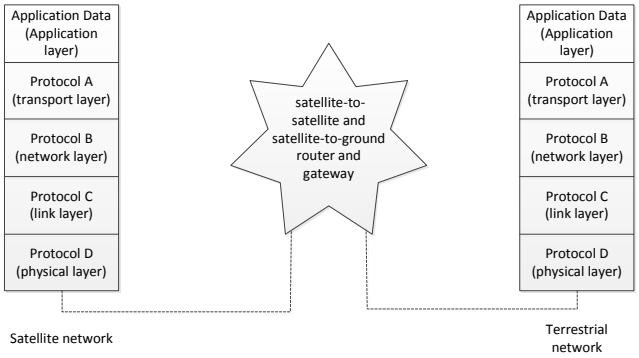

Figure 1. Space Hierarchical Network Protocol Architecture

In this architecture, in order to achieve the required services, some of the layers contain irrelevant implementation mechanisms, or lack the necessary implementation mechanisms. Also, the same function may occur in a number of layers, such as flow and error control occur in the date link layer and in the transport layer also. In order to overcome the existing layered protocol stack irrelevant features, functionality deletions and duplications and other defects, people began to study high-performance network architecture.

In 1990, Clark and Tennenhouse proposed application-level network architecture framing theory [1]. The theory attempts to optimize network protocol performance, reduce the protocol defects caused by excessive levels of the OSI model protocol. The study is based on the traditional hierarchical network, the network performance caused by excessive levels of protocol defects. The study is based on the traditional hierarchical network, optimize network performance, but did not resolve it's own problems of hierarchical network.

Boecking proposed MCS (Modular Communication System) architecture [2-4] is a typical object-oriented network architecture, which attempts to meet emerging applications on network performance and quality of service to different requirements .

The object,the basic elements of Object-Oriented Network Architecture module, is decomposed into a set of network service of layers and surfaces. On the same layer,the network architecture is similar. The services of the object is fulfilled using its adjacent lower object services; Further, a horizontal surface is defined outside of the longitudinal direction. The object at different levels but the same side can complete collaboratly some network functions, so it can guide the layer services to the specific aspects such as communication management, assembly, access, control and transmission. Its architecture model shown in Figure 2.

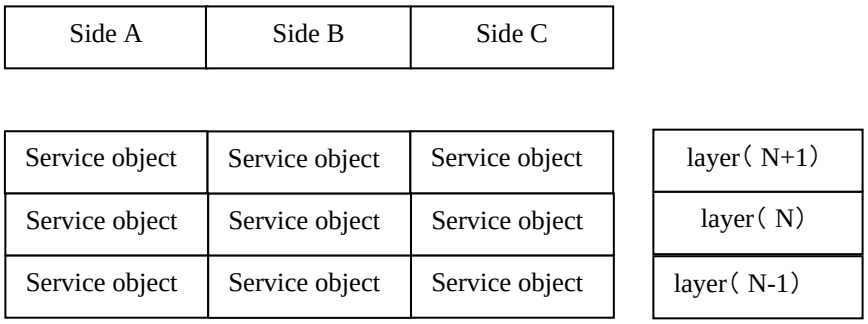

Figure 2. Object-Oriented Network Architecture module

As an attempt to improve the performance of hierarchical network architecture, MCS does not seem to be respected by professional, from its birth to the present, in addition to small-scale modeling research, no other publication of MCS usage. it's reform of the hierarchical network architecture is not thorough. Between the object does not have any mechanism to ensure there is no functional redundancy; hierarchy reserved is limited the function cooperationfo the part of the network, the paid to establish an independent surfaceis lager than

destroying directly the independence of the hierarchy for each one to complete cross-layer network functions.

Active Network (AN: Active Network) technology is a new network architecture, it is proposed by the U.S. Defense Advanced Research Projects Administration Defense (DARPA) in 1995, allowing users to define their needs for their specific application or the specific type of business of current network conditions. The active network can achieve real-time customization services and service deployment, greatly reducing the variety of active network development and deployment of new services without having to go through lengthy standardization process.

Active Network uses store-and-forward structure, consisting of a group of nodes called the active node network nodes. Active network is a new network computing model different from the traditional passive data transferm model and the group of active nodes that perform the appropriate operation of the program. Active Network has two meanings. One is called intermediate nodes (such as routers, switches), not only to complete store-and-forward functions of network-level storage, and can proactive compute using the so-called active packets containing data and code; the other is to perform these computings according to network applications and services request. Thus, by programming the network, new services can quickly access to the network. For users, Active Network can dynamically change the service and in accordance with special applications for service optimization. Its architecture model shown in Figure 3.

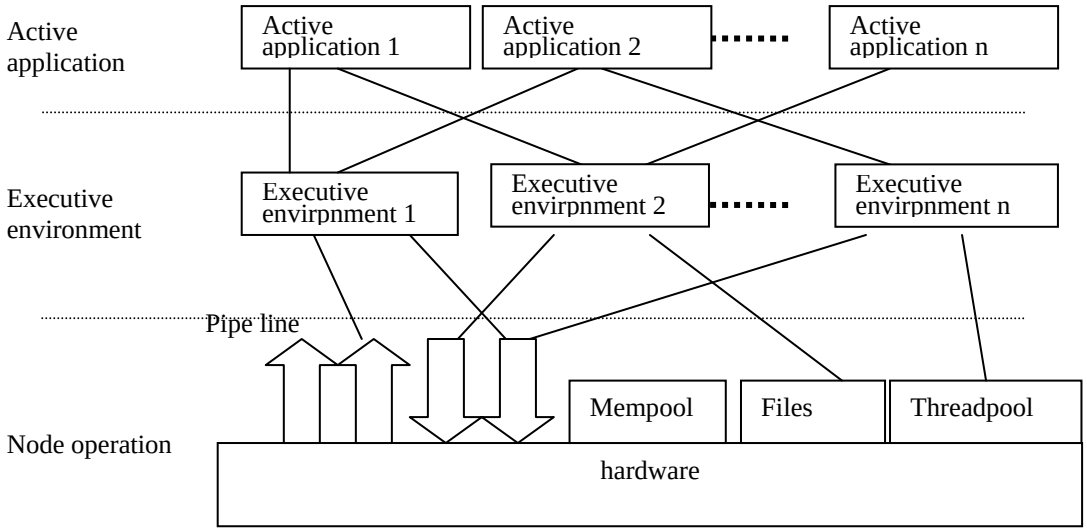

Figure 3. Active Network (AN) Architecture Module

Dissatisfaction with the hierarchical network architecture, the U.S. Defense Advanced Research Projects Administration Defense DARPA established a special fund of the new network architecture. Under the aiding of the fund, three units of Massachusetts Institute of Technology (MIT), the International Computer Science Institute (ICSI), USC Information Sciences Institute computer branch began to study non- hierarchical role-based computer network architecture together. In Oct 2002, in order to solve the problems of hierarchical network architecture interlayer interactions and difficult to expand into new service, Braden and other people propose a non-hierarchical role-based network architecture. This structure requires a larger protocol (such as IP or TCP) modular reorganization, making it into smaller units with a variety of specific tasks to correspond.

As a non-hierarchical network architecture, role-based network architecture called a role to form the elements of the communication system. Because the role is not organized hierarchically, so the interactions between the roles are much richer than the traditional hierarchical protocol Role-based network architecture is a group of the role and use of the protocol stack, role mapping a specific network transactions. Network data processing by the various roles may use multiple network protocols, and the use of protocol sequence is also not

strictly limited as hierarchical network architecture, but can be combined flexibly depending on the circumstances, which can meet a variety of different applications demand and is the different of the hierarchy protocol stack.

In role-based network architecture, the network function is completed together by the roles distribution on different nodes. The data transmitted over the network packet contains the role and function of head (RSH: Role-specific header) of the packet indicates the type of role for processing and location of the process and also includes the original data is required. Role and relationship between the packet is shown in Figure 4.

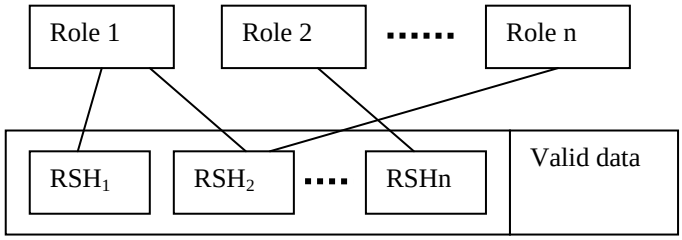

Figure 4. Role and Relationship between the Packet

Role-based network architecture can effectively remove the redundancy functions of each layer, the interaction between the different roles cooperation is not limited between layers, easy to design and implementation of new roles to meet the needs of new applications, and good scalability, is currently a strong contender of the hierarchical network architecture

With the continuous development of network technology and human increasing demand on the network, the network need to quickly adapt to change is becoming increasingly important, future network will inevitably require network equipment and network architecture with the overall scalability. Active Network's idea is to accommodate future network flexibility and dynamic scalability requirments, while the system performance, security and interoperability, etc. to meet or exceed the level of the existing network. How to fell the research achiievements together and to use on the Internet, especially in the military field applications, are still a problem to break.

3. A New Component-based Protocol Framework

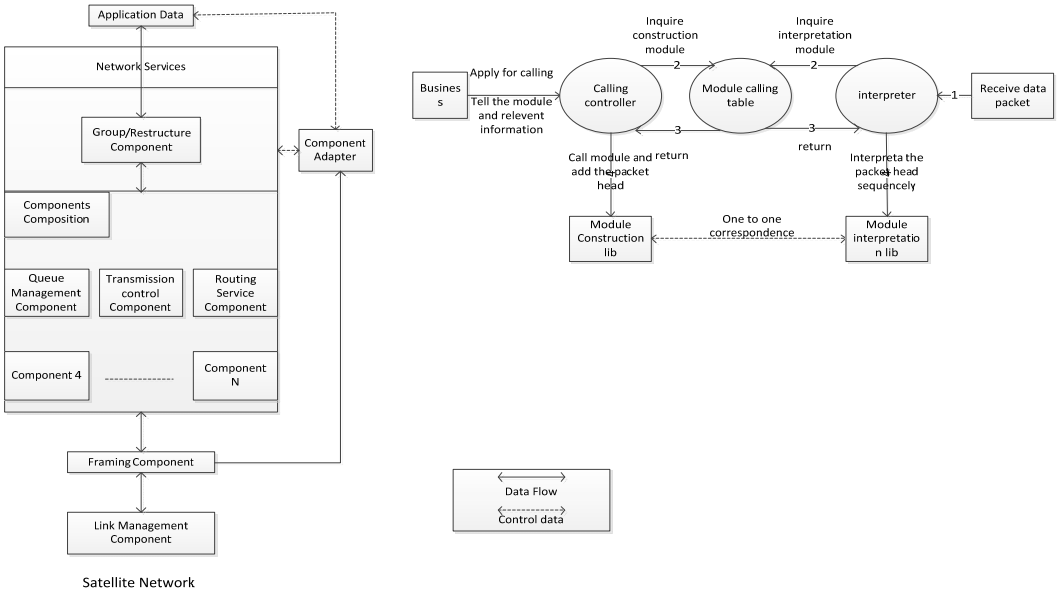

Figure 5. Component-based Integrated Space Network Protocol Architecture

In accordance with the requirements for network information transmission function of integration of space-ground, component-based network protocol divided the whole protocol into different component modules. Component-based protocol is shown in Figure 5. According to network appliance feathers, the invoking relationship between some parts of the components are relatively fixed(such as the data deliver and receiver part),however, each component is loose coupling, so we can make up different components flexibly by adapter on the basis of appliance requirement to provide network services to specific appliance.

Component based design, aiming at the changes of application requirement, can conduct component extension for routers, QoS, network safety, etc. Facing to new application that might occur in the future, component-design is no longer keep Patching when come across new requirements and new functions like layered networks. Instead, it would be more flexible we add in new functional components and new design ideas under the requirement of new appliance (order between components, etc).

4. Component-based Protocol Model

On the basis of component-based network architecture, the following will be described components in detail.

Component-based protocol divided into three main parts: the component library, component repository and component adapters. All component information is stored in the component repository; component library and component repository are managed under the component adapter's. When the network function module is used, data generated by the application directly interact with component adapters. Applications do not need to care about how to select a component, but only specify configuration properties in the list according to component adapters, fill out a configuration properties list called Component Call Table, and submit it to the component adapter; after receiving the configuration list, the component adapter analyze every specific configuration property values submitted by the applications, and select different components from the component library automatically to form a service to meet the application requirements for the application to provide network services.

4.1. Component Library

Component library is the specific implementation of various components divided according to the network capabilities, each of which contains different implementation model, and each implementation model is divided into constructor functions and interpreted functions. The constructor function severs for the sender while the interpreted function for the recipient. Different implementations of each component comply with a uniform interface. For example, a standard interface is established for routing service components according to its function, then the routing service component 1, component 2 and component 3 are different from algorithm, the interface is identical. These unified interface indicate the input, output and the measurement indexes of various components, as well as the interdependent relationships between various components. Unified interface makes the internal structure of the component library more flexible and standardized. All components are stored in the component library for future use. It's very convenience to add, uninstall, update and maintenance the component library according to the criterion provided by a uniform interface, which ensures overall consistency of components.

4.2. Component Information Database

Component repository is mainly to improve the component adapter's ability of component retrieval. The specific implementation of each component includes a component head, which consists of the component's version number, classification, effect and indicators. Collection of all component heads forms component information database. When one component complementation is added, a corresponding component head will be simultaneously added to the component information database. As for uninstalling a component, you just need to remove the component implementation first, and then the component adapter delete the corresponding component head from the component information database. Component's update requires the component adapter operates in the component library and component information database simultaneously.

4.3. Component Adapter

Component adapter is the dispatch center of the whole network protocol, which connects component library and component information database, and assume the functions of component scheduling, updating and maintenance.

Component adapters retrieve component information database based on the property configuration submitted by applications, determine network capabilities on-and-offs, and then choose the specific components of the selected function to provide services for the application data.

According to the functions, component adapter can be divided into constructor section and interpreter section. The constructor is the specific implementation of the component adapter on the sending end. It provides a fine sending service interface for application data, analyses and processes the attribute information submitted by application data, and then retrieve component information database to get functional component information according to the results of the analysis, and call the specific component from component library to implement functional services in the end. The interpreter is the specific implementation of the component adapter on the receiving end. It reads data from the network interface by calling the framing component and link management component, and then interprets the received packet header, creates a list of invoking interpreter components according to the header information, and based on the list, queries the component library, calls the interpreter function to complete the service.

4.4. System Operating Model

Based on service quality requirements, the operating mode of component-based protocol system is that different types of services can configure and invoke the function module components. Shown in Figure 6, the specific service functions are all implemented by constructor calling required components. In the process of business data adding headers, each operation that requires sending data packet must query the invoking component list and related components' information via the constructor, and then invoke corresponding component constructors from component library in sequence to fill the required components information in packet header.

The interpretation process of the packet header is the other way around. The nodes receive a packet, submit it to the interpreter for uniformly processing. The interpreter don't need to sort component invoking list here, because at this time the packet headers are already placed in sequence. All it needs to do is to sequentially reads the component identification of each packet header, and then calls the corresponding protocol component from the component library.

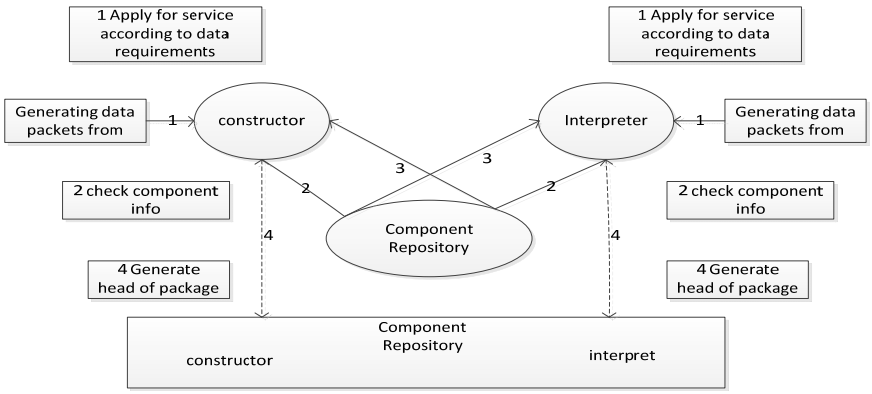

Figure 6. System Working Model

4.5. The Data Package Format of Component-based Protocol

Because of the reconfigurable and choosability of the module. the data package isn't similar to the static head pack form of traditional TCP/IP protocol stack. The new format must

accommodate newly-add head pack in any time, but also support free definition to head pack to offer nice extensibility. The definition of head pack format as shown in Figure 7.

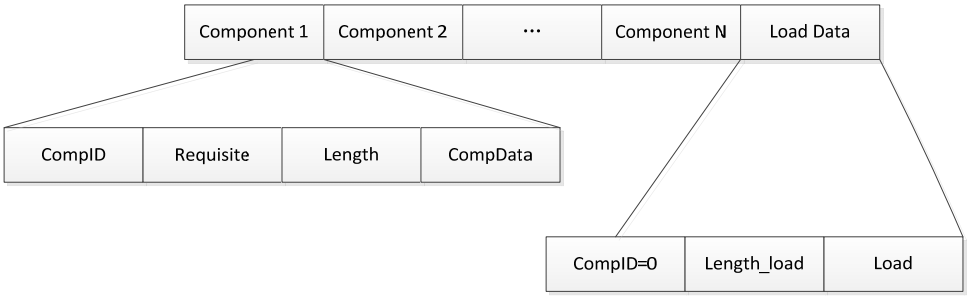

Figure 7. Packet Format

The description of each part of the head pack as shown in Chart 1.

Chart 1. Introduction of the Head of Packet

name	Function
CompID	Component id
Requisite	Indicate whether the component need to be Handled
Length	Indicate the length of the component data
CompData	Contain the data required by the component
Length_Load	Indicate the length of Paydata
Load	The load data of the data packet

5. Module Division and Scheduling Sequence

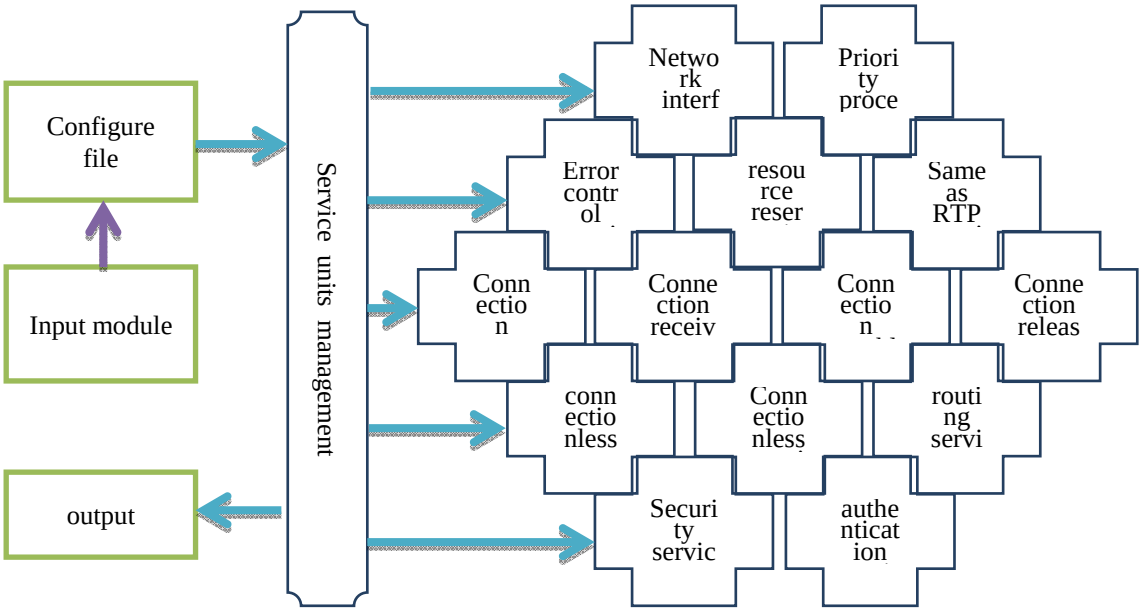

Figure 8. Modules Calling Relationships

After the analysis of the traditional TCP/IP reference model and ISLs environmental, the functiosns will be divided into the following several network modules: error control module, routing module, the service queue management module, fragmentation and reassembly function modules, framing module, channel allocation function modules, network management and security module, transmission control module and link management module.

In the traditional hierarchical protocol architecture, each of the sequence of function calls is already implicit in the relationship between the layers, that is to say, the upper layer function is called first, but in the non-hierarchical structure, it is obvious for new mechanisms to determines the order module calls. Some modules calls need sequence, and the order of some modules are interchangeable. Each system must maintain a module called sequence table to determine the module calling sequence, different implementations of the same functions with the same priority, in order to ensure the realization of the same function module is called only once, as long as the newly added modules have a reasonable order of arrangement, there have not the disorder problems, the application layer tell the system that it needs to call the module, the caller call the mdule according to the calling form. Modules calling relationships see Figure 8.

5.1. Require Sequential Description of the Calling Module

1) Channel allocation module must be the last one called, and its function is to decide on the channel competition modes of each node;
2) Framing module, changing the packet into frame, coupled with the frame boundary , the module should call before the channel allocation module;
3) The framing error control module should be called after the module because we try to checkout all bits of the packet;
4) Routing module should try to put to the rear, because each intermediate routing node for each packet error detection process are first, then find the route, so the routing module on error detection module can speed up the process;
5) Service queue management module, depending on the needs and provide different services;
6) Fragmentation modules, fragmentation should be one-time, because businesses need to call the module is predictable, fragmentation module can be put to the top, and because each fragmentation for the route, the service provider should be independent carried out, it should be put to the top of these modules.

5.2. Some other Non-essential Order of Modules can be Random

1) Security module, location uncertain, depending on the data to be protected, if only to protect the actual data load can be put to the top, For protection routing address, you can add before the routing module;
2) Authentication module, a package may after certification is considered to be safe or to meet certain requirements, there will be a security authentication header, such modules in the order is not important, and not have to be processed;
3) Chain together with the chain is different implementations of the same function they have the same priority number, the middle leave some blank serial number in order to facilitate the future addition of new modules, the caller can use RoleID and SubID to find the corresponding entriesdepending on the module quickly

6. Key Service Components Functional Design

Through the existing hierarchical network functions analysis and satellite wireless network applications demand analysis, the basic functions of the network division are defined as functional components.

6.1. Grouping/reassembly Component

The function of grouping/reassemblying component is to divide a long packet fragmentation into shot unit so that the frame length can meet the maximum allowable on the link data.

6.2. Queue Management Component

Using active queue management strategy based on traffic. To ensure different types of applications and QoS in the satellite network, each traffic stream is in the transmit, receive, and the intermediate node maintains a separate queue.

6.3. Routing Service Component

Routing component maintain necessary routing and link state information and send the source-side data packet via the correct path to the destination. The forwarded packet check the routing table to determine the next hop node, and according to the link and load status select the best path.

Routing component header information CompData Format Design:

| Source Address | Destination Address | jump address | next hop address | Hop Limit |

6.4. Transmission Control Component

Considering the characteristics of the satellite network environment, aiming at improving the information transmission efficiency and reliability, the point to-point transmission control mechanism is proposed, its characteristic is the feedback between two points, and the intermediate node can alse be involved in the transmission control process. This can ensure fairness between applications, adjust the congestion immediately and avoid the influence of the different streams.

6.5. Error Control Component

Error control components ensure the correctness and reliability using error control and recovery retransmission. The component selects the appropriate error detection/correction strategy and retransmission recovery strategy according to satellite network environment. As a result of receiving feedback information point to point transmission interval time is greatly reduced, so retransmission recovery strategy can be selected depending on the application and link quality ACK confirmation, confirmation or negative confirmation.

6.6. Network Management and Security Components

Because of the satellite network link openness, spatial information transfer faces more security threats. Almost all authentication technology or privacy data transmission are dependent on the application layer encryption technology. if we implement the internal cryptographic security in protocol suite, the application can implement security policies and save costs more flexible. System administrators can apply the security mechanisms uniformly for the external communications.

6.7. Framing Component

Dynamical frame format is needed for compating with different transmission systems and link protocol. In the side of transfer, the frame component will pack data packet containing sufficient data services into the desired frame format and framing with a specific string to identify the beginning and ending of frame; At the receiving side of the component, the received bit stream can be interpreted as data frames and the data header information will be sent to the component adapter.

6.8. Link Management Component

Link management component completes bitstream transmit and receive functions and collect the link information that will be transmitted to the framing components. It also manages the physical link and determines the allocation way of the common channel resource and access way of each node, so that the data frames will be transmissed effictively via the transmission channel.

7. The Integration of other Network Systems

Component-based network architecture aimed at current TCP/IP network transport layer and network layer. By defining a new protocol suite, we can enable component-based software and network protocol TCP/IP protocol, SCPS (Space Communications some standard)

system compatible, which can be used in existing network programming environment. Existing network applications can be used in component-based network environment with a small amount of rewriting. At the link layer of the protocol, you can add new content, or use an existing link protocol, and it is necessary to obtain the link layer information only when component-based resource management protocol.

8. Conclusion

Aimed at the satellite characters, a new network protocol architecture, component-based protocol, is proposed, this architecture broke the network protocol level concept, which make the network protocol design and develop more flexible. Aimed at new services and new demands, users only need to add functional components and organize the component based applications required. there is no level concept, the problems of redundancy, poorless of interaction are not exist. Users can focus its energy on allocating all of the network resources to obtain high quality of services.

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