Ka 밴드 위성 ATM망에서 QoS 보장을 위한 동적 자원 관리 알고리즘

(An Algorithm of Dynamic Resource Management for QoS Guarantee Across Ka-band Satellite ATM Systems)

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요 약 광대역 종합 정보 통신망이나 인터넷과 같은 대규모의 망에서 고 품질의 서비스 보장은 점점 더 중요해지고 있다. 비동기식 전송 모드(ATM)는 고 품질의 서비스 보장을 위해 채택된 가장 강력한 기술이다. 위성은 한정된 자원(대역폭)을 가지고 있다. 따라서, 하부의 ATM 망과 Ka 밴드 위성을 연결하여 광범위한 대역폭을 요구하는 다양한 멀티미디어 서비스들을 효과적으로 제공하기 위해서고 품질의 서비스를 보장해 주는 효율적인 동적 자원 관리 방법이 절실히 요구된다. 본 논문에서는 Ka 밴드 위성 ATM 망에서 고 품질의 서비스를 보장해 주는 효율적인 동적 자원 관리 알고리즘을 새롭게 제안하였다. 제안된 동적 대역폭 제어 알고리즘은 다양한 성능분석을 통해 호 손실률 측면에서 기존의 방법에 비해 훨씬 향상된 성능을 보여준다.

Abstract The support of Quality of Service (QoS) becomes increasingly important in the modern networks such as B-ISDN and Internet as the scale of network infrastructure is expanded. Asynchronous Transfer Mode (ATM) provides the strongest possible definition for the QoS. Satellite has the limited resources (bandwidths). To guarantee the QoS requirements in linking ATM networks via Ka-band satellite, an efficient dynamic resource management is required to support various multimedia services with a broad range of bandwidth requirements. We present a new dynamic resource management algorithm in the Ka-band satellite ATM (SATM). The proposed dynamic resource management algorithm is shown to successfully improve network performance such as call loss probability through the computer simulation.

1. Introduction

Internet and ATM are two major developments in fixed telecommunication networks. Satellite communication systems can play important roles in these evolving telecommunication networks and strengthen the capabilities of global information infrastructure (GII). ATM is the switching technology of Broadband Integrated Services for Digital Networks (B-ISDN) and designed to effectively support multimedia information services. ATM has many advantages such as dynamic resource allocation, statistical multiplexing, priority queuing, and multicast.

SATM can reduce traffic congestion problems and provide better quality of service to remote users where fiber-optic networking costs could be prohibitive. The Telecommunications Industry Association (TIA) has recently formed a SATM group to study the various issues such as reference model, media access technology, mobility management. Also, ATM Forum Wireless ATM Group has established liaison with TIA to initiate standardization efforts in the satellite ATM [1-3].

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Most of Internet users have experienced delay due to traffic congestion. If satellite communication networks are properly designed, it could enlarge the communication reachability globally with very flexible resource on demand capabilities. In case of next generation satellite such as Ka-band SATM, it is necessary provide the various multimedia and Internet services with QoS guarantee. Therefore, the concern about resource management with QoS guarantee has been increased steadily because of explosive usage of the Internet services. Satellite has the limited resources. A limited satellite resource may restrict the use of applications that require high bandwidth capacity. In order to provide these applications with required QoS [4], an efficient resource management is should be developed in Ka-band SATM. In this paper, we propose a new dynamic resource management algorithm by using the concept of worst call loss probability. The proposed algorithm is shown to successfully improve network performance such as call loss probability.

In Section 2, we describe previous works and current research issues with respect to resource management in the SATM with QoS guarantee. In Section 3, we present new dynamic resource management algorithm and new dynamic resource management algorithm with QoS guarantee for multiple transmission links which several sources and destinations. The call loss probability over VP passing through multiple transmission links from ATM networks to satellite links is derived. The call loss probability is the key factor, which measures the QoS in the SATM. In Section 4, the comparative performance evaluation is made to illustrate the effectiveness of the proposed algorithms. Finally, in Section 5 the conclusion follows.

2. Previous Works and Current Research Issues

Current satellite network consists of three segments such as ground, user, and space segment. The ground segment consists of gateway earth stations (GESs), network control center (NCC), and operation control centers (OCCs) [5]. Among these ground segments, the NCC manages network resource management, which is crucial to the efficient usage of the space segment ensuring a high level of end-user data throughput. The NCC runs a central resource management algorithm that ensures fair and efficient resource management. Under the condition of limited resource of a satellite, the resource should be shared between earth stations fairly and a flexible and efficient resource management algorithm is required to guarantee QoS. It is important to assign the resource dynamically and efficiently based on the various user requirements.

The resource management in the satellite is performed when the connection is set up. In the SATM, both fixed and dynamic resource management depending on the type of connection is possible. SATM should satisfy at least four ATM service classes; constant bit rate (CBR), variable bit rate (VBR), available bit rate (ABR), and unspecified bit rate (UBR). For example, fixed resource management mechanism can be used the CBR and real time VBR services during the connections set up time. Also, dynamic resource management mechanism uses three levels of fairness in assigning resource to each terminal; outgoing, incoming, and system fairness [6].

There are three steps of resource management in the satellite network [7]. In the first step, NCC allocates satellite link resource to each earth station based on the burst time plan (BTP). The BTP can be either continuous burst or a combination of a number of sub-burst times from the TDMA frame. Within BTP, each earth station defines burst time and restricts the number of burst cells. In the second step is the virtual path (VP) management based on the each burst time plan within satellite link resource. Finally, in the third step is the virtual channel (VC) management within the capacity of virtual path. To implement resource management effectively, the management of the satellite link resource should be mapped into the

VP architecture in the ATM networks and the each connection mapped into the VC architecture.

3. Dynamic Resource Management Algorithm with QoS Guarantee

3.1 Dynamic Resource Management Algorithm (DRMA)

In this section, we present a new dynamic resource management algorithm, which can be applicable to the Ka-band SATM with multiple transmission links. Since delay is proportional to the hop count of the links along VP route, it is assumed that the shortest VP path between source and destination is selected first when there are several VPs between a source and a destination.

The dynamic resource management algorithm in the SATM over multiple transmission links is described below. It is similar to the one presented in [8] except that the network management operation to test the resource availability is performed at each node along the VP route. These test operations of resource availability may negatively affect the delay characteristics experienced by a request call. The average delay due to this test operation, and the call loss probability over multiple transmission links are derived.

The resource management in the SATM consists of multiple links; several terrestrial links and two space links. Two space links are more sensitive to environments such as weather conditions than terrestrial links. In this paper, we exclude environmental factor such as bad weather condition. Of course, it is required to handle the interface between terrestrial and space links. The new dynamic resource management algorithm is described below.

<u>**Dynamic Resource Management Algorithm (DRMA)**</u>

◆ Step 1: Request resource (bandwidth) increase if it is insufficient for new call arriving at the end node.

◆ Step 2: Test whether each node along the selected VP route can support the required resource increase. If any one of the node can not find predefined free resource for the resource increase, then reject the request and refuse the incoming call, keeping the current resource. Try to find another VP route to the destination if available, and go to Step 1.

◆ Step 3: If every resource increase request along the VP path is allowed, then let the resource manager to increase the resource and set up a virtual channel for the call.

◆ Step 4:Taking into account of the virtual path utilization condition and other constraints, decrease the resource after the connection is released, if possible.

Here, the resource increase is accomplished with predefined discrete resource change step size as in [8]. In order to evaluate the effectiveness of the proposed DRMA, and to simplify the analysis of call loss probability for multiple transmission links, it is assumed that every call has the same resource, and resource is allocated deterministically. It is also assumed that incoming call has Poisson arrival pattern, as in [8]. The analysis under these assumptions may not be strictly valid because the resources of calls generally vary and they have burstiness in the realistic SATM. But, the analysis is still valid for evaluating the essential nature of the resource management mechanism.

When there is no remaining VP resource either at the initial moment or after the resource decrease during the service operation, the delay experienced by the incoming call at Step 2 of the algorithm DRMA might be significant. The delay may not be so negligible as to meet the quality of service requirement of the incoming call. For a given VP, let path(VP) denotes the set of nodes and links along the VP, and delay(VP) the average delay experienced by the call setup message at Step 2 for the resource management. Then, the delay(VP) is formulated as follows:

$$delay\ (VP) = \sum_{l \in D(l)} \{ f_1(l) + f_2(l) + f_3(l) \}$$

D(l) is defined as follows.

$$D(l) = \{ link | link \in path(VP) \} \cap \\ n \in \{ node \mid node \in path\ (VP) \}$$

Table 1 The Defined Parameters

parameter	illustration
n	the number of virtual paths multiplexed per link for $n = 1, 2, ..., N$
L_i	the *ith* transmission link associated with the virtual path for $i = 1, 2, ..., L$
VP_{k,L_i}	the *kth* virtual path for the ith transmission link for $k = 1, 2, ..., n$
i_{k,L_i}	concurrent connections of virtual channels in VP_{k,L_i} contained to the *ith* transmission link for $k = 1, 2, ..., n$
a_{k,L_i}	traffic offered to VP_{k,L_i} which is measured by in Erlangs for $k= 1, 2, ..., n$
C_{L_i}	the link capacity normalized to the call resource for the link L_i

Here, f_1 is a function determining the cell propagation delay over the link, and f_2 is a function determining the processing delay for the resource management. This may include the delay associated with database access, decision making process, queueing delay for the network management message transfer, and so on. f_3 is a function determining the delay due to return message from the management node to the source node.

In order to analyze the dynamic resource management over multiple transmission links in the SATM, we define the parameters as Table 1.

The effectiveness of the DRMA varies with the bandwidth change step size. Let $W_{k,L_i}(i_{k,L_i})$ denotes normalized bandwidth of the *kth* virtual path which has i_k concurrently connected virtual channels at the link L_i. The $W_{k,L_i}(i_{k,L_i})$ is defined below in Equation (1).

$$W_{k,L_i} = \mu_{p+1,k,L_i} \qquad (1)$$

$$\textit{where,} \quad \begin{matrix} \mu_{p,k,L_i} < i_{k,L_i} \leq \mu_{p+1,k,L_i} \\ \mu_{p,k,L_i} < \mu_{p+1,k,L_i} \end{matrix}$$

If the resource change step size is denoted as S, then

$$\mu_{p,k,L_i} = pS \qquad (2)$$

where, $k = 1, 2, ..., n$ *and* $p = 0, 1, ...$ *and* $i = 1, 2, ..., L$

The definition of $W_{k,L_i}(i_{k,L_i})$ implies that the unused bandwidth of VP_{k,L_i} zero when there are μ_{p,k,L_i} if a new call arrives [8]. The algorithm DRMA takes the resource requirement expressed in Equation (1) as equivalent capacity taking into account the burstiness, burst length and statistical multiplexing effect can also be employed.

In order to evaluate the effectiveness of the proposed dynamic resource management over multiple transmission links, we derive the call loss probability of multiple transmission links. First, we present the call loss probability of arbitrary link contained to multiple transmission links. Each transmission link is assumed to be independent of the other one. It is known that the call loss probability of arbitrary link depends on the number of virtual path contained to each transmission link. The call loss probability of the transmission link is describe below in Equation (3) ~ (6).

$$B_{k,L_i} = \sum_{(i_{1,L_i}, i_{2,L_i}, i_{n,L_i}) \in I_{k,L_i}} \cdots \sum \left(\frac{a_{1,L_i}^{i_{1,L_i}}}{i_{1,L_i}!} \frac{a_{2,L_i}^{i_{2,L_i}}}{i_{2,L_i}!} \cdots \frac{a_{n,L_i}^{i_{n,L_i}}}{i_{n,L_i}!} \right) P_o \qquad (3)$$

$$P_o = \left(\sum_{(i_{1,L_i}, i_{2,L_i}, i_{n,L_i}) \in I_{k,L_i}} \cdots \sum \frac{a_{1,L_i}^{i_{1,L_i}}}{i_{1,L_i}!} \frac{a_{2,L_i}^{i_{2,L_i}}}{i_{2,L_i}!} \cdots \frac{a_{n,L_i}^{i_{n,L_i}}}{i_{n,L_i}!} \right)^{-1} \qquad (4)$$

$$I_{L_i} = \left\{ (i_{1,L_i}, i_{2,L_i}, i_{n,L_i}) \mid 0 \leq C_{L_i} - \sum_{i=1}^{n} W_{i,L_i}(i_{i,L_i}) \right\} \qquad (5)$$

$$I_{L_i} = \{ (i_{1,L_i}, i_{2,L_i}, i_{n,L_i}) \mid W_{i,L_i}(i_{i,L_i}) = \mu_{p,k,L_i} \} \cap \left\{ (i_{1,L_i}, i_{2,L_i}, i_{n,L_i}) \mid 0 \leq C_{L_i} - \sum_{i=1}^{n} W_{i,L_i}(i_{i,L_i}) = \mu_{p+1,k,L_i} - \mu_{p,k,L_i} \right\} \qquad (6)$$

Based on the Equation (3), the call loss probability equation for the VP network with different source and destination nodes is derived as shown in Equation (7). In Equation (7), m is the number of transmission links pass through the kth virtual path.

$$P_k = \sum_{i=1}^{m} \binom{m}{i} B_{k,L_i}^{i} (1 - B_{k,L_i}^{i})^{m-i} \qquad (7)$$

The call loss probability is an important parameter for the evaluation of the effectiveness of the DRMA. The measurement of call loss probability for a SATM network employing the algorithm DRMA using Equation (6) illustrates the fact that there exist several virtual paths with worst call loss probability (WCLP). Therefore, we present new dynamic resource management algorithm, Resource Management with Minimal Worst Call Loss Probability (RM_MWCLP) which could effectively satisfy the minimal WCLP requirements of SATM services.

3.2 Resource Management with Minimum Worst Call Loss Probability (RM_MWCLP)

In the algorithm RM_MWCLP, the loss probability of the virtual paths over multiple transmission links are periodically monitored by NCC, and they are categorized into two classes: one with WCLP, and the other with non worst call loss probability (NWCLP). In order to guarantee the QoS requirement, the one with WCLP is paid more attention in resource management. In other words, the algorithm tries to equalize the QoS of virtual paths while preserving the overall network performance within reasonable bounds. The algorithm RM_MWCLP is described below.

e minimal WCLP is calculated periodically by monitoring the loss probability of the virtual paths over the multiple transmission links.

Resource Management with Minimal Worst Call Loss Probability (RM MWCLP)

◆ Step 1: For the new call request to the VP with WCLP, follow the Steps 1, 2 and 3 of the DRMA.

◆ Step 2: For the new call request to the VP with NWCLP, if the available resource of the virtual path over the multiple transmission links is greater than resource change size, i. e., for q = 2, 3, , then, employ the Steps 1, 2 and 3 of the algorithm DRMA. Otherwise, the call request is rejected.

◆ Step 3: Taking into account the virtual path utilization condition and other constraints, decrease the resource after the connection is released, if possible.

For the simple case with $q = 2$, the resource change step is defined as shown in Equation (8).

$$\mu_{p,k,L_i} = pN \tag{8}$$

In the Equation (8), N is equal to the resource change step size S for the virtual path with WCLP, ad for the virtual path with NWCLP, it is chose to be $2S$. For the algorithm RM_MWCLP, the call loss probability is derived using the Equations (3) ~ (5) and Equation (9) shown below. In the Equation (9), N is also equal to the resource change step size S for the virtual path with WCLP, and for the virtual path with NWCLP, it is also chose to be $2S$. The call loss probability defined in the Equation (7) can also be applied here without any modifications.

$$I_{k,L_i} = \{(i_{1,L_i}, i_{2,L_i}, i_{n,L_i}) \mid W_{k,L_i(i_{L})} = \mu_{p,k,L_i}\} \cap \left\{(i_{1,L_i}, i_{2,L_i}, i_{n,L_i}) \mid 0 \le C_{L_i} - \sum_{i=1}^{n} W_{i,L_i(i_{L})} = (\mu_{p+1,k,L} - \mu_{p,k,L})N\right\} \tag{9}$$

4. Performance Evaluation

In this section, we evaluate the performance of the proposed DRMA and RM_MWCLP by the computer simulation. For the simple case where the satellite ATM network consists of several transmission links, the simulation result is found to be well conforming to the analytic result derived from the Equation (1) through (9). The performance was evaluated in terms of call loss probability. For the more realistic case where VPs traverse over a multiple of transmission links in complex ways, the calculation of Equation (1) through (9) is not easy. Therefore, the simulation may be the only alternative for the evaluation. We first assume that all the calls require the same resource, and secondly assume that a call arrives with Poisson arrival distribution and a holding time has a negative exponential distribution. And, thirdly assume that error probability of link in the space part - both from GES to satellite (uplink) and from satellite to GES (downlink) is negligible.

In the model used for the analytic method the capacity of each transmission link is assumed to be 20 and there must be more than one VP between

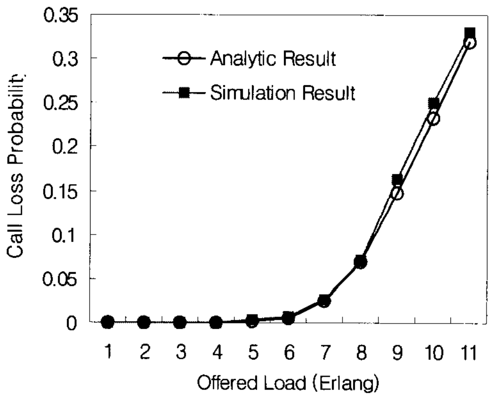

Fig. 1 Call loss probability for Simple Case

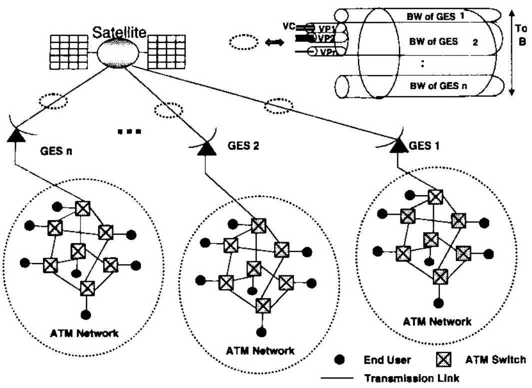

Fig. 2 Network model

any two end nodes. Figure 1 shows the call loss probability of DRMA for the given input traffic offered to the SATM. As shown in Figure 1, the results of the simulation method and analytic method are very similar, which demonstrates the validity of the simulation method for the simple case. In Figure 2 below, we show the network model considered in this paper.

We use the LNBL Network Simulator (NS) over the Sun SPARC Server1000 workstation with Solaris 2.8 operating system. The NS is a simulation tool developed by the Network Research Group at the Lawrence Berkeley National Laboratory and an extensible, easily configured and programmed event-driven simulation engine. It can obtain for free at public domain. Based on the figure 2, our simulation model consist of six ATM switches which are source node as well as destination node, two ATM cross connects, and seven transmission links. It is assumed that at least one VP with capacity defined in Equation (1) and (2) is established between any hops. Furthermore, all the transmission links are assumed to be independent of each other.

We first make an experiment to obtain the call loss probability of many targets VPs, which have different source and destination nodes, passing through the multiple transmission links. In Figure 3, we compare the result of the algorithm DRMA with that of fixed resource algorithm. The amount

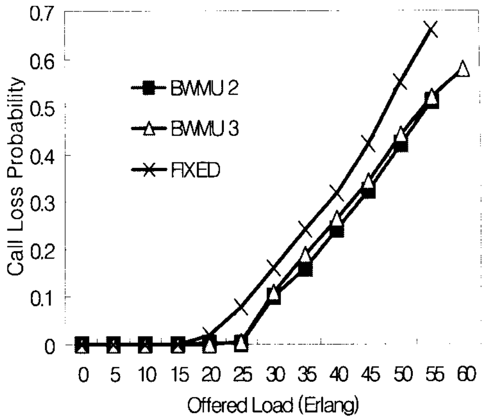

Fig. 3 Call loss probability using DRMA

of traffic to the source nodes is increased with stepwise resource modification unit (BWMU) S of 2 (BWMU 2) and 3 (BWMU 3) for the simulation of the algorithm DRMA.

As shown in Figure 3, if the amount of traffic is less than 10 Erlang, the call loss probability for the cases with BWMU 2 or BWMU 3, and fixed BWMU are equal zero. This implies that all requests of call connections are accepted. However, as the amount of the traffic flowed into the source nodes is increased, we know that the case with BWMU 2 or BWMU 3, applying the DRMA, has far less call loss probability in comparison with the case with fixed resource management algorithm. BWMU 2 gives 3% improvements when the traffic amount is 20 Erlang, 8% at 30 Erlang, and 12% at 40 Erlang. BWMU 3 gives 1% improvements when the traffic amount is 20 Erlangs, 5% at 30 Erlang, and 7% at 40 Erlang.

Assuming that there are more than one VP established between any hops, we know that there exist at least 30 VPs established in the network model shown in Figure 2. We measure the call loss probability of each VP, applying the algorithm DRMA to the network model shown in Figure 2, where the average amount of traffic supplied to any end nodes is taken to be 40 Erlang. From this experiment, it is found that there exist many VPs, which have WCLP, which is shown in Algorithm of Figure 4. In order to guarantee the QoS requirement of SATM in terms of the call loss probability, the resources of these VPs with WCLP should be controlled. The algorithm RM_MWCLP tries to avoid the generation of these VPs with WCLP by monitoring and controlling the current usage of the entire VP resource over multiple transmission links. If not controlled, the QoS requirements of the SATM will not be satisfied due to the VPs with WCLP. The results of applying the algorithm RM_MWCLP is shown in Algorithm B of Figure 4.

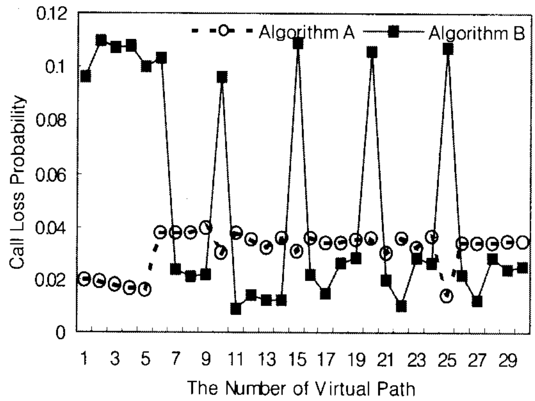

Fig. 4 Call loss probabilities of VPs using DRMA and RM_MWCLP

As shown in Figure 4, the algorithm RM_MWCLP performs better in guaranteeing the QoS requirements of the network. In other words, the call loss probabilities are being made smooth for the entire VPs. It is also found that the smoothness is increased as the monitoring period is decreased. It is noted that the decreased monitoring period implies that the overhead of network management is increased. This may adversely exploit the benefit of VP concept such as the reduction of node processing cost.

5. Conclusion

There are many research activities of resource management mechanisms in the SATM network. In order to satisfy the QoS for each connection in the SATM, the dynamic resource management is required. There are many issues related to resource management with QoS guarantee in the SATM. For instance, fixed resource management, demand resource management, support for multicast/broadcast, support for specified quality of service, use of on-board processing (OBP), use of on-board switching, need for preemption, need for service availability, and dynamic resource management [4].

In this paper, we present new dynamic resource management algorithm with QoS guarantee in the Ka-band SATM. To evaluate the performance of the proposed algorithm, the simulation is done with respect to the call loss probability. Simulation results show that the proposed algorithm demonstrates good performance in fine weather. However, we only consider ATM network as backbone network. In the future, we expand this result to wireless backbone network over satellite in order to absorb various mobility functions - handover, location management, personal and terminal mobility.

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