Dynamic service Allocation with Protection Path

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Abstract

Path computation algorithms are necessary for providing optimal utilization of available resources. Static path assignment does not satisfy the real-time data traffic requirement, thus leading to inefficient network resource utilization and compromised services for customers. Dynamic assignment of bandwidth requires the use of online algorithms which automatically compute the path to be taken to satisfy the given service request. Many researchers have addressed online path computation algorithms, but they consider each link having a number of slots of bandwidth. They do not take into account the multiplexing mechanism which causes restrictions on the allocation of bandwidth and the fact that higher order trails have to be established to support any bandwidth requirement. The novel feature of this work is the development of new path computation algorithm for service provisioning in SDH/SONET. The feature of this algorithm is that it takes into account the multiplexing structure, which imposes restrictions on the allocation of bandwidth and support the Subnetwork Connection Protection (SNCP) as defined in SDH/SONET.

Keywords: *Synchronous Digital Hierarchy (SDH), Dynamic Path Computation, Synchronous Optical Network (SONET), Subnetwork Connection Protection (SNCP),Plesiochronous Digital Hierarchy (PDH), Quality of Service (QOS).*

1. Introduction

Today's telecommunications services are based on a diverse combination of technologies such as Ethernet, PDH, IP, SAN, DSL, ATM etc. Many of these technologies have always been clients of SDH. This has led to the need for providing differentiated services with different Quality of Service (QoS) requirements [1], [2]. SDH as a transport technology is used by many service providers to carry their main backbone traffic and also to provide bandwidth services to customers in the access side. SDH defines a multiplexing hierarchy [3] by which the low rate G.703 [4] signals such as E1,E3,E4 etc. are multiplexed into high rate signals for transmission.

The major limitations of today's SDH are:

- **Static provision**: Bandwidth allocated to a path cannot be reused for other purposes until the path is released. This static provisioning leads to Low bandwidth utilization.
- **Long time to provision**: It takes days or weeks to provision a path from one node to another. The process is manual and very costly.

Service providers require faster provisioning of services to satisfy more customer requests in less time. The solution to this problem is to have automatic provisioning systems. Engineers in Network Operator Centers (NOC) should be able to specify the end-to-end service and bandwidth required and the system should be able to provision the bandwidth automatically by calculating the appropriate path such that the network resources are optimally utilized. In this paper, we provide solutions to find the best path to be used to satisfy the requested service taking into account the used and the free capacity and the multiplexing mechanism.

2. Related work

Many researchers have worked on path computation problems in different networks. Researchers have been working on Routing and Wavelength Assignment problems to provide routes to the path requests and to assign wavelengths on each of the links along this route among the possible choices so as to optimize a certain performance metric [5], [6], [7]. This has been considered with both static and dynamic traffic demands.

The Virtual Concatenation for Data over SONET/SDH has been proposed for utilizing the inverse multiplexing capability [8]. Virtual concatenation is a technique which groups an arbitrary number of SONET/SDH containers, which may not be contiguous, to create a bigger container. A new scheme for dynamic bandwidth allocation and path restoration in SONET mesh networks, in response to demand bandwidth is presented in [9]. SDH management network architecture for different topologies is described in [10]. A sequential algorithm and a parallel algorithm for computing disjoint paths for QoS for SONET networks have been proposed in [11]. Bandwidth Allocation in WDM Networks is proposed in [12]. Service requirements have to be expressed as measurable QoS metrics such as bandwidth, delay, jitter, and loss rate. There are three types of metrics: additive, multiplicative, and concave [13].
Path computation involves identifying one or more paths through SDH network that satisfy the QoS parameters. Selecting a path that satisfies all the QoS parameters is an NP-complete problem [14]. Therefore, generally the

path computation simplifies the problem by searching for paths that can satisfy some of the QoS parameters.

3. Path computation problem

Path management in SDH is composed of three major components: link state information, path computation, and path protection. Link state information component collects information about SDH network topology, bandwidth availability, and other network resources availability. In this paper, we focus on path computation to minimizing the network resource consumption and balancing the network load.

The classic SDH standards defined procedures to transport all signals (E1, E2, E3, E4, T1, T2, and T3). This way, all former PDH services (ISDN or FRL) are today transported by hybrid PDH/SDH networks.

The common signals are mapped into their corresponding virtual containers VC-12, VC-4, VC-11, and VC-3. The lower order virtual containers like VC-11, VC-12, and VC-2 are pointed to by their tributary unit (TU) pointers. These are then multiplexed into tributary unit groups (TUG) which are then multiplexed into higher order virtual containers like VC-3 and VC-4. They are pointed to by their administrative unit (AU) pointers and then multiplexed into administrative unit groups (AUG) which are in turn multiplexed into one of the possible Synchronous Transport Modules (STM) which are the units of transmission in SDH see Fig 1.

Due to the multiplexing structure of SDH, each link has various integer units of capacity and the free capacity cannot be obtained simply by subtracting the allotted capacity from the maximum capacity.

According to the SDH multiplexing structure, higher order containers like VC-4 have to be used to create trails between the source and destination before provisioning any bandwidth between two nodes. Therefore to provision E1 bandwidth which maps to VC-12 between two nodes, a high order trail (VC-4) or a sequence of high order trails have to be used.

When a VC-12(LO trail) is mapped into a VC-4 (HO trail), then the HO trail cannot support a future VC-4 request since the full capacity is not available any more, but it can accommodate 2 VC-3 & 22 VC-12. If 3 VC-12s are provisioned in the 3 different VC-3s, then that VC-4 trail cannot accommodate any further VC-3 requests, because all VC-3s are broken. It can accommodate 60 VC-12 only or 18 VC-2 and 6 VC-12.

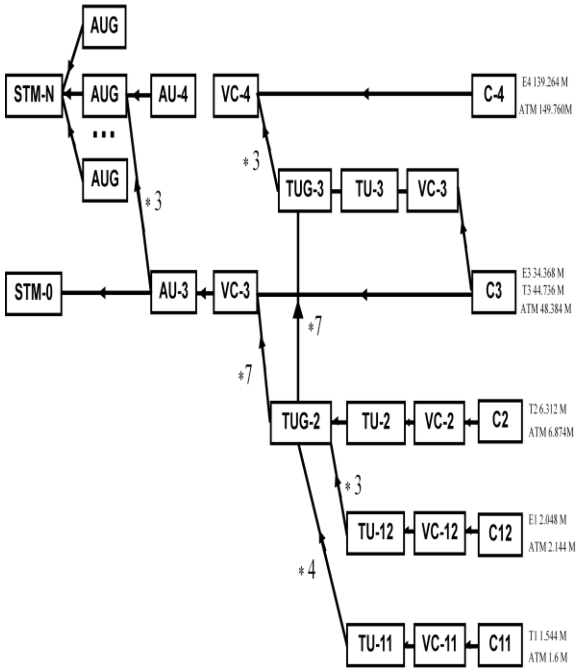

Fig. 1 SDH Multiplexing Structure

4. Computation algorithm

The path computation algorithms use two different objective functions to optimize network performance: the shortest path should be selected for minimizing the length of the path and the least loaded path, i.e. lowest allocated capacity, should be selected for load balancing. There is a third objective, which is the minimization of the number of request rejections.

Simple computation algorithm is shown in Fig. 2 find a working path for the requested service. The algorithm attempts to find the shortest path with either trails only or physical links. The search algorithm excludes the trails and links with insufficient capacity. The search process will be repeated until a path that can accommodate the requested capacity is found. The capacity will be provisioned on the founded/created trails.

Limitations of the Algorithm

- Does not take into account the available capacity in the links (for STM1 the capacity is 1VC-4, for STM4 the capacity 4VC-4 …)
- Search either path with trails only or path with links, if no path with trails can be found, all exists trails will be excluded from the search algorithm, this leads to low bandwidth utilization.

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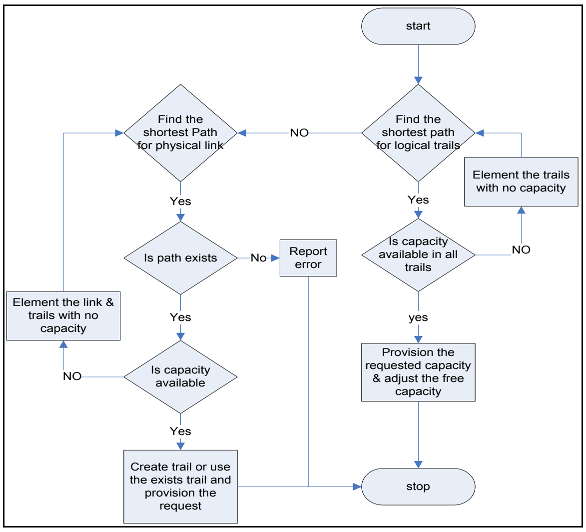

Fig. 2 Simple path computation algorithm

5. New algorithm

The shortest path computed by this algorithm will have a combination of both physical links and logical connection (trails & bearer) for the service path and protection path. There are two types of SNCP protection dedicated and shared protection. The dedicated SNCP (1+1) was used in this work.
Bearer will be created whenever links are created and the trails (LO, HO) will be created on demand as shown in Fig 3. Where:

Link connects two ports and is related to one bearer circuit. It is a connection between nodes via a port.
Bearer is the logical representation of a physical link. It introduces the physical link into the logical circuit hierarchy.

HO trail SDH High Order trail provides high bandwidth (155Mb/s) logical connectivity between active network elements.
LO trail SDH Low Order trail provides low bandwidth (2Mb/s and 45Mb/s) logical connectivity between active network elements.

Circuit represents a logical availability of bandwidth provided by the physical network of nodes and links.

The new algorithm consists of the following process:

1) Find the shortest path containing both links and bearers.
2) If no path exists (link & bearer) report error.
3) If the bearer has free capacity, then continue, otherwise ignore the bearer and return to step 1.
4) Provision the requested capacity using the multiplexing mechanism.
5) Find the protection path, exclude the links of the first shortest path and repeat steps 1 – 4.

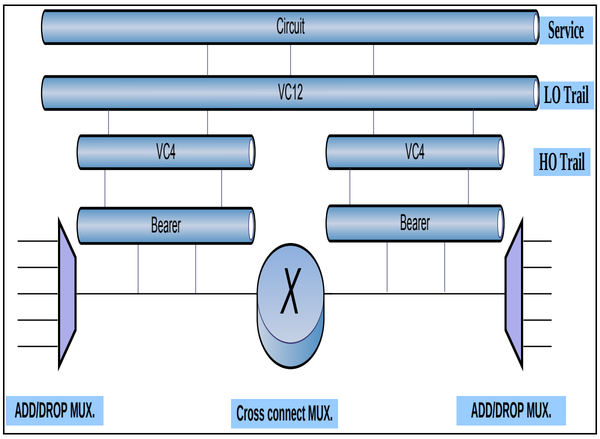

Fig. 3 End-to End service

The SDH is a TDM system with 125µs time slot, and the delay of a SDH path is depending on the path length. The new algorithms aim to find the shortest path with one protection path and with bandwidth guarantee. The following notations are adopted:

W(N,B)	SDH network with node set N and Bearer set B;
(s, d)	a node pair with source s and destination d;
P(s,…,d)	a path with source node s and destination node d;
b_i	available bandwidth of Bearer i, $\forall$ i$\in$ B;
b	bandwidth of a path, b=min{ bi | i$\in$ P};
b_r	bandwidth requirement for setting up a path.
Input:	W(N,B), source s, destination d, bandwidth requirement br, redo counters x and y
Output:	True, if two disjoint paths are found: working path P_w(s,…,d), protection path P_p(s,…,d) False, if fail to get P_w(s,…d) and P_p(s,…,d)

```
begin
for k = 0 to x
    for all Bearer i in B // filter the Bearer
        if ( b_i < b_r )
                remove Bearer i from W(N,B);
        end if
    end for
    // working path
    P_w(s,…d) = shortest path (W(N,B),s,d);

    if (Rsv(P_w(s,…,d))) // reserve shortest path
        for all intermediate nodes j in P_w(s,…,d)
            remove node j and its connection Bearer
            from W(N,B);
        end for
        for m = 0 to y
            //protection path
```

```
                    Pp(s,…,d) = shortest path (W(N,B),s,d);
                    if (Rsv(Pp(s,…,d))) // reserve br
                            return True;
                    else
                            update ( ); // update
                    information
                    end if
                end for
                return false;
        else
                update ( ); // update information
        end if
end for
        return false;
end

function: shortest path (W(N,L),s,d)
        returns: the shortest path P(s,…,d)
function: Rsv(P(s,…,d))
        returns: true, if successfully reserve br along path P
        false, if fail to reserve br along path P
function: update( )
        returns: update link state information
```

The search algorithm terminates when it finds the two paths service path and protection path and successfully reserves the requested bandwidth. According to the example shown in Fig. 4, the shortest disjoint path pair for the node pair (A, H) is: A-B-E-H with a total cost of 2+2+2 = 6. If the protection is requested steps 1-4 is repeated to find the second shortest path without using the links of the first shortest path. The protection path is A-C-G-H with total cost of 1+3=3 =7.

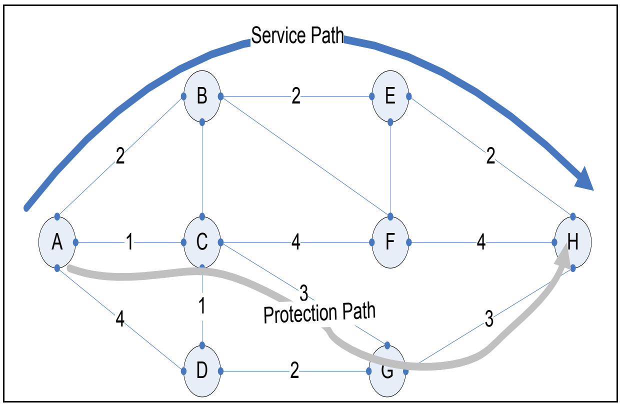

Fig. 4 Service path and protection path

Since the services can be provisioned only over VC-4 trails because of the SDH multiplexing structure, the LO trails will be mapped on HO trails and the HO trail will be mapped to the bearer. The bearers presents the capacity of the physical link, if the capacity of the link is STM-X, then X trails can be mapped on the bearer and use that link. A path is a sequence of links (physical connection) and logical connection (bearer & trails). Once the path is computed, the requested capacity has to be provisioned in the LO trails (In ETSI Low Order trails are VC-3s and VC-12s), or HO trails (VC-4) that belong to that path. To achieve this, the next free timeslot for each rate in the trail is maintained.

For Example, if the requested bandwidth is 2 MB (E1), The LO trail (VC-12) should be mapped in the HO trail (VC-4), if the HO trail exists then the next free timeslot will be used (VC-$12_{1..63}$, VC-$12_{1..21}$, VC-$12_{22..42}$, VC-$12_{43..63}$ depend on the multiplexing). If the HO doesn't exists a new one should be created and the LO trail will be mapped to the first timeslot (VC-12_1). The HO trail (VC-4_1) should be mapped to the bearer which representation of a physical link capacity. In SDH, the standard transport rates defined are STM-1, STM-4, STM-16, STM-64 and STM-256. The number after STM indicates the number of VC-4 trails that can be created on that bearer.

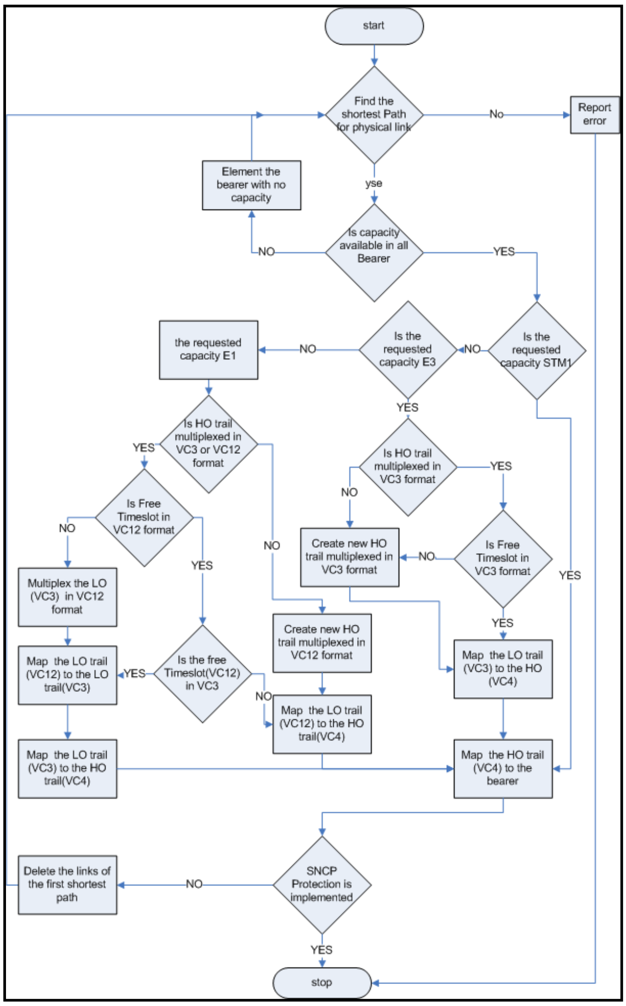

Fig. 5 Path computation using multiplexing mechanism with SNCP

The new algorithms compute a path for the given service request between two nodes for the requested capacity shown in Fig. 5. The search mechanism will exclude all links with available bandwidth less than the requested bandwidth. The shortest path service will be reserved when the bandwidth available. If protection is requested, all links and nodes on the service path will be excluded to ensure that the protection path is disjoint from the working path.

6. Conclusion

In this paper, new algorithm is proposed for service provisioning with dedicated protection in SDH/SONET networks. This algorithm take into account the multiplexing hierarchy defined by SDH/SONET which includes restrictions on the allocation of bandwidth.
The algorithm provides solutions for online path computation and guarantees QoS and balance network resource utilization. The mechanism of supporting shared protection paths will be studied as a future extension. It should be able to take into account the inherent protection capabilities provided in SDH/SONET like Multiplexed section shared protection.

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