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Numerical Solution by Haar Wavelet Collocation Method for a Class of Higher Order Linear and Nonlinear Boundary Value Problems

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Abstract. In this paper, Haar wavelet collocation mechanism (HWCM) is developed for obtaining the solution of higher order linear and nonlinear boundary value problems. Mechanism is based on approximation of solution by Haar wavelet family. To tackle the nonlinearity in the problems, Quasilinearization technique is applied. Many examples are considered to prove the successful application of the mechanism developed for getting the highly accurate result. By using the HWCM, an approximate solution for higher order boundary value problems (HOBVPs) are obtained and compared with exact and numerical solutions available in the literature.

Keywords: Haar Wavelet, Quasilinearization, Collocation method and Boundary value problems (65L10)

INTRODUCTION

Higher order boundary value problems (HOBVPs) are getting huge attention from researchers because of the fact that many physical phenomena like hydro dynamic and hydromagnetic stability [1], induction motor with two rotor circuits [2], viscoelastic flows in fluid dynamics etc. are governed by the higher order boundary value problems. Therefore, to find accurate, efficient and simple solution of these problems has achieved the great significance during the last decades. Existence and uniqueness of solution of HOBVPs has been proved by Agarwal in his book [3]. General analytical solution for these kinds of problems has not yet been established. Therefore, researchers are using numerical techniques to find the solutions of HOBVPs. Many numerical mechanisms have been developed in the literature to solve these problems such as Adomian decomposition method (ADM), Variational Iteration Method (VIM), Variational Iteration Decomposition Method (VIDM), Optimal Homotopy asymptotic method (OHAM), Galerkin Method with Quintic B-splines (GMQBS), Legendre Galerkin method (LGM), Reproducing Kernel Space Method (RKSM), Modified Variational Iteration Method (MVID), Sextic B-splines Collocation Method (SBSCM), Petrov-Galerkin Method (PGM), Homotopy Perturbation Method (HPM), Quintic B-Spline Collocation Method (QBSCM). But many of these methods involve cumbersome calculation process which slows down the rate of convergence and some of these methods are also very sensitive to the initial guess and can fall in the process of infinite iteration for the wrong initial guess and hence can increase the computational cost.

In the past decade wavelet based numerical method has become predominant because of its simple applicability and high accuracy. Wavelet is a small wave which can be manipulated in two ways; one way is translation which means shifting of all points of wavelet in the same direction and for the same distance and other is scaling or dilatation which means stretching or shrinking of original wavelet. Mathematically wavelet can be represented as

$$\psi_{a,b} = \frac{1}{\sqrt{|a|}}\psi\left(\frac{t-b}{a}\right) \quad \ldots (1)$$

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Waiting Probability Based Traffic Grooming In Optical Networks

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ABSTRACT

In this paper, we have proposed an efficient traffic grooming model for optical networks. This model has low complexity and it can be easily implemented for traffic grooming problems. It is used to calculate the waiting probability of computer networks and then traffic grooming problems are addressed based on the calculated waiting probability. Waiting probability is always a major parameter during the analysis of network performance because it provides an estimate for the waiting of calls in the transmission route. This model can also be used to calculate some other key network parameters such as number of server required, ideal route length, number of free wavelengths required etc. based on a fixed value of waiting probability. This model can be applied on different network topologies for traffic grooming with equal efficiency.

1. Introduction

Traffic grooming is the term associated with the optimization of capacity utilization of a network. Major advantages of traffic grooming are better resource utilization, enhanced performance and reduced network cost. The major goal of traffic grooming is to maximize the network resource utilization. When resources utilization is optimal then the overall network performance will be increased. High speed and huge capacity are two major features of optical networks. High reliability is also expected along with high speed. Optical Networks are playing significant role in the modern networking. Different traffic grooming techniques are applied to these networks to optimize their performance. WDM technology offers a promising solution for fast and reliable networking. This technology is capable to cross connect between different transports systems at the same time different layers can be used within the same system (Barr, Kingsley and Patterson, 2005). Different multiplexing techniques, algorithms, methods etc. are used in different domains for effective traffic grooming of optical networks. Grooming of a network depends upon certain key parameters such as network planner, topology design, dynamic circuit provisioning etc. Traffic grooming is always a challenging job because the performance of network is a function of different parameters. Traffic grooming may be classified into two categories: traffic grooming for static traffic and traffic grooming for dynamic traffic. Static traffic grooming is relatively simple as the nature and volume of traffic is already known to the user. But in case of dynamic traffic grooming, these parameters are not known in advance. So dynamic traffic grooming is more challenging job. Now the networking trend is shifting towards mesh topology from the existing ring topology. It is again a challenge for traffic grooming (Zhu and Mukherjee 2003, Modiano and Lin, 2001). The basic idea of networking is to share the resources for optimal performance. The success of a network largely depends upon its ability to share and utilize the resources efficiently. Optical network has the ability to share resources efficiently within the network and with other networks as well. This efficient sharing of resources makes optical networks a very successful network. Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM) concepts were used for most of the networks in earlier days of communication. Recently, Wavelength Division Multiplexing (WDM) and Erbium-Doped Fiber Amplifier (EDFA) have changed the scenario of networking. Using WDM technology, multiple light beams of different wavelengths can be used in single optical fiber. Signals of different wavelengths can be amplified simultaneously using EDFA. These two technologies can transfer huge amount of data at very high speed (Mohan, Wason, and Sandhu, 2016, Wason and Kaler, 2010). Long distance telecommunication networks are deploying WDM systems on a point-to-point basis. The optical signals are being converted back to electronics signal at each node. This electronic switching and processing cost at each node may be very high and may lead to significant performance loss. Now the emerging wavelength routed WDM systems utilize photonic cross connects (PXCs). These are capable of switching and processing data entirely in the optical domain. These optical devices are configured across the network between source and destination nodes (Chlamtac, Ganz and Karmi, 1992). All optical networks have gained a lot of popularity the networking era during past few years. The major reasons for this popularity are exceptionally high bandwidth, very low loss rate and very low bit error rate. A typical single fiber is able to provide speed upto 25 THz and very low loss rate in the range of 0.2dB/Km. The bit error rate is typically in the range of 10^{9} to 10^{15}. In all optical networks the

Traffic Grooming of Different Architectures in Optical Networks

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Abstract- Optical networks have increased the transmission capacity of networks tremendously due to different reasons. Wavelength division multiplexing (WDM) is one of the major reasons for the increased capacity. Optical networks are capable of providing a very high speed for huge amount of data transmission. Their transmission capacity is limited due to certain network elements. These elements are electronics in nature and have limited processing capabilities. These electronic devices may be efficiently groomed to enhance the performance of a network. Traffic grooming has become an important issue for research purpose. Due to various advantages offered by traffic grooming, it has gained commercial attention as well. Traffic grooming of a network depends on various parameters. One important parameter is network topology. Ring and mesh network topologies are commonly used in networks as these are suitable for long haul and wide area networks (WAN). So the traffic grooming of ring and mesh network topologies are significant. Various network architectures based traffic grooming is discussed and analyzed in this paper.

Keywords— Traffic Grooming, Node Architecture, WDM Networks.

I. INTRODUCTION

Wavelength Division Multiplexing (WDM) along with optical fiber offers a very reliable solution to accommodate the exponential growth of volume of data transmission in wide area networks. It is also good choice for Local Area Networks (LAN). A single optical fiber strand can offer a bandwidth of 50 Terabits per seconds. This bandwidth may further be sub-divided into multiple non-overlapping wavelength channels or frequencies. It is possible due to the use of WDM technology. These channels are able to operate at any speed. These channels may provide speed in Gigabits per second [1, 2]. Even after such a high speed is available with optical fiber networks, the overall speed of network is still limited to some Megabits per second. We can improve network performance and reduce cost of transmission using traffic grooming. Traffic grooming is to optimize the network resources to maximize the network performance. There are multiple low-speed traffic connections in the network. These may be converted into high capacity circuit pipes. Traffic grooming problem can be considered in different scenarios. One way is to satisfy all traffic demands within available resources of the network and keep the network cost minimum. Another way is to optimize the network throughput for a set of resources and traffic requests. Some common multiplexing techniques used for network traffic grooming are:

- Space Division Multiplexing (SDM) - In space division multiplexing, the available physical space is sub-divided to increase the bandwidth. Multiple fibers may be bundled together into a single cable.
- Frequency Division Multiplexing (FDM) – in frequency division multiplexing, the available spectrum of frequency is partitioned into independent channels. It is also called Wavelength division Multiplexing (WDM). It partitions the available optical spectrum into different wavebands. These wavebands are then divided into separate wavelength channels.
- Time Division Multiplexing (TDM) – Time division multiplexing partitions the time domain of bandwidth into repeated time slots. These time slots are of fixed length. Multiple signals are able to share a given wavelength due to the property that they are non-overlapping in time.
- Packet Division Multiplexing (PDM) – This multiplexing provides virtual circuit service in an Internet Protocol/Multiprotocol Level Switching (IP/MPLS) over WDM network architecture. So, multiple IP traffic streams or virtual circuits may share the bandwidth of a WDM channel [3].

II. SONET RING NETWORKS

SONET ring is very commonly used optical network infrastructure. SONET ring network, generally use point-to-point transmission technology. The traffic is added/ dropped to/from the high-speed channels using Electronic Add Drop Multiplexers (ADM) at intermediate nodes [4].

One ADM is required per wavelength at each node to add/drop traffic on each particular wavelength. Now WDM can support over a hundred wavelengths simultaneously on a single fiber line. Each ADM has a significant cost, so it is not economically feasible to put the same amount of ADM's at each network node as maximum traffic may be just bypassing a particular intermediate node. Optical add-drop multiplexers (O-ADM) can address this problem. It is able to optically bypass maximum wavelength channels. It has the capacity to drop only the wavelengths carrying the traffic destined to the desired node. A complete optical wavelength circuit between a node pair of electronic components is called a lightpath. ADMs constitute a significant cost in a particular SONET/WDM ring network. So network cost may be significantly reduced by designing specific and efficient optical bypasses. Different node architectures without O-ADM in a SONET/WDM ring network are shown in Fig.1 [4, 12, 13].

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