Polynomial Interpolation Methods for Wavelength Division Multiplex Mesh Networks with Dedicated Optical Path Protection

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Abstract- **The arithmetical methods solve successfully the survivability problems of the telecommunication networks. These methods are either accurate ones or approximation ones. In this paper, new approaches are done for the survivability problems of the telecommunication networks, based on polynomial interpolation methods. The results are about same and to correct the differences, Turbo Pascal data types are changed. Our purpose is to assist to select the best model.**

Keywords: error, polynomial interpolation methods, dedicated protection, WDM.

I. INTRODUCTION

More and more infrastructures of the world are exhausted their capacity when the traffic increases. In the face of growth in traffic, network operators must continuously forecast bandwidth demand to properly dimension their networks and make the correct investments for the future. The consequences of under-investing are poor network performance and dissatisfied subscribers while over investing ties up capital that could have been better spent elsewhere. As a consequence, researchers all around the world have proposed a plethora of models that forecasts bandwidth demands. The evaluation criterion of the performance of these models is the accuracy of the results. Optical WDM (Wavelength Division Multiplex) mesh network designs have been based on suitable mathematics. That is assumed that all of the values and results of mathematical computations are presented with high precision and reduced precision. In this paper, new approaches are studied, compared and presented, for the survivability problems of the telecommunication networks, based on polynomial interpolation methods. The first polynomial interpolation method originates from Lagrange interpolation method (starting from polynomials of Lagrange and produces a general polynomial) and the second from Vandermode matrix

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The first polynomial interpolation method has less precision than the second one, so they called approximate and accurate ones, respectively. To obtain the best results several floating-point formats are used and they are adequate to delete the errors. When these methods are not used the degradations can be severe. The WDM optical mesh networks are high capacity telecommunication networks based on optical technologies that provide routing, grooming and restoration at the wavelength level as well as wavelength based services. For a WDM system with many channels on a single fibre, a fibre cut would result in multiple failures, causing many independent systems to fail. The optical path with dedicated 1+1 protection on optical layer of optical WDM mesh networks can perform protection switching faster and more economically. The optical path with dedicated 1+1 protection problem is solved and calculating the final available capacity for each link as well as the total value by two polynomial interpolation methods, the accurate one originates from Vandermode matrix and the other one that is approximate one originates from the polynomials of Lagrange. The results of two methods are compared. The general polynomial interpolation problem has the form: given some points and find a polynomial which goes exactly through these points. In telecommunications, the set of data points are integer numbers because they correspond to optical channels and obtained by the reduction of the fiber available capacity when its wavelengths are occupied by several optical paths. It is also valid for the optical network. This research has been done in relation to the methods and the problems associated with planning, protection and restoration of optical networks. In [1] the authors present OTN (Optical Transport Network) evolution from an operator’s point of view, including the history of the transport network, the role of the OTN, and the motivations and requirements for OTN evolution. For a WDM system with many channels on a single fibre, a fibre cut would results multiple failures, causing many independent systems to fail [2][3][4][5][6][7][8][11] [12]. There are also several approaches to ensure fibre network survivability [2][3][4][6][7][11]. Network survivability is defined as the capability of a communication network to resist any link or node interruption or disturbance of service, particularly by warfare, fire, earthquake, harmful radiation or other physical or natural catastrophes. The existing methods in solving these problems use special algorithms. We suggest a proposal that it is two new approaches based on the polynomial methods and represent the detail algorithm description and its program. The advantage of these approaches is that the polynomial methods solve the same telecommunication problem (of this kind) by several methods simultaneously and they can verify each other in accepted tolerances.

The following analysis presents the solution of the problems associated with the survival optical networks on the basis of the polynomial interpolation methods and the corresponded problem is solved. The role of the Difference Calculus is in the study of the Numerical Methods. Computer solves these Numerical Methods. The subject of the Difference Equations is in the treatment of discontinuous processes. The reduction of the available capacity of each working optical fiber is a discontinuous process when connection groups of several sizes pass through it. The network final available capacity is revealed as a polynomial because the final available capacity of the individual working optical fibers is also a polynomial. The reduction of the available capacity of each working optical fiber is a discontinuous process when connection groups of several sizes pass through it. The subject of the Difference Equations [9] is in the treatment of discontinuous processes. The network final available capacity is revealed as a difference equation because the final available capacity of the individual working optical fibers is also a difference equation. The reduction of the available capacity of each working optical fiber is a discontinuous process when connection groups of several sizes pass through it. In [12], the authors begin with an overview of the existing strategies for providing transport network survivability and continue with an analysis of how the architectures for network survivability may evolve to satisfy the requirements of emerging networks. In [13], the author presents the finite differences, their methods and their problems when they are used to solve problems of this kind. In [14], the authors lay the foundation of switching node designs for future WDM-SDM optical networks. In [15], the authors present a simulation study of the Model Evaluation Criterion MMRE (Mean Magnitude of Relative Error). In [16], the authors provide an overview of the latest developments and possible approaches with respect to flexible optical networking and the emerging benefits that spatially flexible networking approaches can offer. In [17], the authors propose a control and management architecture to allow the network to be dynamically operated. In [18], the authors present a generic step-by-step methodology for evaluating the total cost of migrating from a capacity – exhausted WDM network to different upgraded alternatives. In [19], the authors describe a model that forecasts bandwidth demands of aggregate subscribers on residential fixed access networks.

This paper is broken down in the following sections: Section II shows how the interpolation methods and the finite differences that are used for each optical fiber and illustrates the optical fiber final available capacity; Section III describes the problem, its formulation, its algorithm, an example and the proposals with discussion; Section IV draws conclusion and finally ends with the references.

II. THE OPTICAL FIBER AND THE POLYNOMIALS

In the mathematical field of numerical analysis, interpolation is a method of constructing new data points within the range of a discrete set of known data points. It means, it is a method of estimating values between known data points. The polynomial interpolation is the interpolation of a given data set by a polynomial. In telecommunications, the set of data points are integer numbers because they correspond to optical channels and obtained by the reduction of the fiber available capacity when its wavelengths are busy by several optical paths. It is valid for the optical network. These data points represent the values of a function for limited number of values of the independent variable. Before studying the interpolation polynomials and construct the interpolation pairs (y_i,x_i) and their use in optical WDM mesh networks survivability, it is necessary to provide a short comprehensive presentation of the differences computation. Let's assume that $y_1,y_2,\ldots,y_n$ is a sequence of numbers in which the order is determined by the index n. The number (n) is an integer and the y_n can be regarded as a function of n, an independent variable with function domain the natural numbers and it is discontinuous. Such a sequence shows the available capacity reduction of a telecommunication fibre network link between two nodes when the telecommunication traffic of 1,2, …, n source-destination node pairs pass through. It is assumed that the telecommunication traffic unit is the optical channel that is one wavelength (1λ). The telecommunications traffic includes optical connections with their protections. The total connections of a node pair form its connection group. The first order finite differences represent symbolically the connection group of each node pair that passes through a fiber. This connection group occupies the corresponding number of optical channels and it is the bandwidth that is consumed by connections of a node pair through this fiber. The first order finite differences are used to represent the connection groups in optical channels of the node pairs that pass through an optical fibre. An equation of the first order finite differences gives the available capacity of an optical fibre network link when a connection group passes through it. This available capacity is provided for the connection groups of the other node pairs that their connections will pass through this optical fiber. When the first connection group of Δy_1 connections passes through an optical fiber network link with installed capacity of y_1 optical channels the first order finite difference equation gives the available capacity $y_{2\,(y_1+1)}$ which is written as following

$$y_{1+1} = y_1 - \Delta y_1$$

The sequence $\Delta y_1, \Delta y_2, \Delta y_3, \ldots, \Delta y_n$ represents the connection groups that pass through this optical fiber network link. When Δy_1 subtracted from y_1, creates y_2, when Δy_2 subtracted from y_2, creates $y_{3,\ldots,}$ when Δy_n subtracted from y_n creates y_{n+1} which is the total unused available capacity of this optical fiber. Thus the total unused available capacity of each network optical fiber is calculated after n connections groups pass through it. The total unused available capacity of each network optical fiber is also written as a polynomial function. The assessment of the polynomial function coefficients is done with the values that the polynomial function represents for 1, 2,…,n, n +1. The values of the function y_{n+1} for each n must be integral because each value represents optical channels.

The general form of a polynomial function that gives the available capacity of the optical fiber network link after the serving n connection groups, is as follows

$$y_{n+1} = \sum_{r=0}^{n} \alpha_r * (n+1)^r \qquad (1)$$

The assessment of the polynomial function coefficients is done with the values that the polynomial function represents for 1,2,…, *n*, *n* +1. It means that there are linear systems of (n+1) equations with (n+1) unknown coefficients. The values of the coefficients depend of the number of the connection groups and the connections of each connection group. The values of the function y_{n+1} for each *n* must be integral because each value represents optical channels.

In this paper the independent variable is the available capacity of an optical fiber and it is given by suitable interpolation polynomial. The construction of data points (x_i, y_i) of each optical fibre interpolation polynomial is the following.

- If none connection group passes through fiber, the polynomial is constant with value equal y_0 to the WDM system and there is one only data point $x_0=0$.

- If one connection group with size Δy_1 passes through a fiber, the polynomial is first degree with values y_0, y_1 ($=y_0-\Delta y_1$) and the corresponded two data points $x_0=0$ and $x_1= \Delta y_1$.

- If two connection groups with sizes Δy_1, Δy_2 pass through a fiber, the polynomial is second degree with values y_0, y_1 ($=y_0-\Delta y_1$), y_2 ($=y_1-\Delta y_2$) and the corresponded three data points $x_0=0$, $x_1= \Delta y_1$, and $x_2= \Delta y_1 +\Delta y_2$.

- If three connection groups with sizes Δy_1, Δy_2, Δy_3 pass through a fiber, the polynomial is third degree with values y_0, y_1 ($=y_0-\Delta y_1$), y_2 ($=y_1-\Delta y_2$) , y_3 ($=y_2-\Delta y_3$), and the corresponded four data points $x_0=0$, $x_1= \Delta y_1$, $x_2= \Delta y_1 +\Delta y_2$ and $x_3= \Delta y_1+ \Delta y_2 +\Delta y_3$.

- If four connection groups with sizes Δy_1, Δy_2, Δy_3, Δy_4 pass through a fiber, the polynomial is forth degree with values y_0, y_1 ($=y_0-\Delta y_1$), y_2 ($=y_1-\Delta y_2$), y_3 ($=y_2-\Delta y_3$), y_4 ($=y_3-\Delta y_4$) and the corresponded five data points $x_0=0$, $x_1= \Delta y_1$, $x_2= \Delta y_1 +\Delta y_2$,$x_3= \Delta y_1+ \Delta y_2 +\Delta y_3$ and $x_4= \Delta y_1+ \Delta y_2 +\Delta y_3 + \Delta y_4$ and so on. The general term of the available capacity of the fiber is written

$$y_n=y_0-x_n \quad \text{with} \quad x_n= \sum_{j=0}^{n} \Delta y_j$$

I shall write the available capacity of each optical fiber as a general interpolation polynomial for the below two cases. The interpolation polynomial construction is originated from either Lagrange polynomials one (first) or Vandermode matrix method (second). Generally, if we have (n+1) data points where no two data points are the same, there is exactly one polynomial of degree at most (n) going through all the data points. The general interpolation polynomial form is below

$$p(x) = \sum_{r=0}^{n} \alpha_r * x^r \qquad (2)$$

Then we need to find the coefficients α_r based on the given values. The coefficients are estimated for each suitable method. These are generating linear systems of (n+1) equations with (n+1) unknown coefficients. The values of the coefficients depend of the number of the connection groups and the connections of each connection group. The method of Vandermode matrix is more accurate than the other one because is simpler one. In terms of Lagrange polynomials

$$p(x) = \sum_{i=0}^{n} \left(\prod_{0<j<n} \frac{x-x_j}{x_i-x_j} \right) y_i \qquad (3)$$

with i different to j, (x_i, y_i) the data points. It is showed that the coefficients of the monomials after 1st degree are too small and could be neglected and all polynomials are about linear ones.

In this paper, the interpolation polynomials are constructed using two methods and compared each other for several data types of TURBO PASCAL. Interpolation polynomials are a sum of monomial ones.

III. THE PROBLEM AND ITS SOLUTION

A. The problem

The network has the important optical network architecture which is the WDM one that supports *lightpaths*. Lightpaths are end-to-end connections made up of connected WDM channels. The network topology and other parameters are known as WDM and optical fiber capacity, one optical fiber per link with an extension to a 1+1 fiber protection system. So this network is characterized by one working fiber per link, edges of two links, links of two optical fibers, one for working and one for protection. The connections are lightpaths originating in the source nodes and terminating at the destination nodes proceeding from preplanned optical working paths. Additionally, the same number of optical paths is preselected for the preplanned fully disjoint backup paths, (1+1 dedicated protection connection). So the connections are protected. The connections of the same node pair form a group along the network. The preplanned protection paths do the dedicated protection of the connection groups. So a suitable number of wavelengths per link along the network is used. The solution is the calculation of the final available capacity of the network for a given table. This table contains the number of the node pairs, the node pairs and the number of the connections of each node pair when their working and protection paths are preplanned. For each method one model is done and two models are done totally. So the model of the polynomial interpolation method based on Vandermode matrix structure is called second (2nd) one and the other first (1st) one. The presentation of the polynomial interpolation models is more difficult so it is not showed. The results are calculated and compared for each data representation type of Turbo Pascal, each other. I prove that the polynomial interpolation method based on Vandermode matrix (second) is not introducing errors in the solution of the problem. The other polynomial interpolation method (first) does it but these errors could be minimized with several ways and the results are improved. All requests for connection are satisfied and form connections.

B. The formulation

The network is assumed to be an optical WDM mesh network with the circuit switched (or packet switched but the packets are adjusted to follow preplanned paths) as a graph. Each vertex represents the central telecommunications office (CO) with the OXC while each edge represents two links. Each edge link has a couple of optical fibers. All optical fibers have the same capacity as the WDM system. All nodes are identical. The numbers of working and protection connections that pass through each optical fiber are different. Polynomial equations are calculated for each optical fiber, for polynomial methods. For all network links, the general equation of the polynomial function has two column matrices, the left one that is equals with the right one. When all connections have been set up then each element of the column matrix must be greater or equal to zero. In other cases some connections are not possible. The total final available capacity of the network for the polynomial methods is given by the equation (4).

$$\sum_{i=1}^{2p} p_i,(x) = \sum_{i=1}^{2p} \sum_{r=0}^{n(i)} \alpha_{i,r} * (x)^r \qquad (4)$$

$$p_{i,(x)} >= 0 \quad ,n(i)>0$$

This is the formulation of the *polynomial function* method problem for the interpolation method with the x to be integer number because corresponds to wavelengths and for x which is generated by suitable values of connection group sizes p_i,(x),gives the available capacity of each (i) optical fiber and the sum of p_i,(x) the network available capacity. The values of the coefficients ($\alpha_{i,r}$) or simpler (α_r) depend of the number of the connection groups and the connections of each connection group. The coefficients ($\alpha_{i,r}$) for each link are calculated by a linear system of (n+1) equations with (n+1) unknown values. The calculated values of the coefficients give available capacity for the link which is a little different than the real one. This little different is ought to the errors of the coefficients. In this paper, these little differences could be calculated subtracting the available capacity of the first method from the accurate one which is the polynomial interpolation method based on Vandermode matrix (second method). The coefficients of the interpolation method for the first method introduce more errors because are more complex. The rounding errors are rise by approximating a fraction with periodic decimal expansion by a finite decimal value or truncate it to the smaller value.

C. The algorithm

Our algorithm describes the operation of the WDM optical fiber mesh network. TURBO PASCAL is used to program the models [6]. The algorithm has the following steps and phases.

First step Network parameters

TABLE I
THE SYMBOL OF THIS PAPER

S/N	SYMBOL	COMMENTS
1	q	Node number
2	p	Edge number
3	G(V, E)	Network graph
4	V(G)	Network node set
5	E(G)	Network edge set
6	2p	The number of working and backup fiber for 1+1 line protection
7	n	The number of source – destination nodes pairs of the network
8	n(i)	The total number of the connection groups that passes through the fibre (*i*) and means that each fibre has different number of connection groups pass through it
9	$n(i)_w$	The number of the working connection groups that passes through the fibre (*i*) and means that each fibre has different number of connection groups pass through it
10	$n(i)_p$	The number of the protection connection groups that passes through the fibre (*i*) and means that each fibre has different number of connection groups pass through it
11	K	The number of the wavelengths channels on each fiber that is the WDM system capacity
12	Cinst	The total installed capacity
13	Cav	The total available capacity
14	Cw	The total working capacity
15	Cpr	The total protection capacity
16	C_b	The total busy capacity
17	$\Delta y_{i,j}$	The first order of finite difference that corresponds to a group of optical connections that passes through the optical fiber ***i*** with serial number (***j***) respectively.

Initially the following data are known: network topology, node number, edge number, link number per edge, working optical fiber number per link, protection optical fiber number per link, wavelength number per optical fiber, optical fiber numbering. This information allows the computer to draw a graph and an OXC is on the vertex of the graph [10]. Each edge corresponds to two links with opposite direction to each other. All fibers have the same wavelength number and all links the same fiber number. The computer reads the adjacency matrix and is informed about the network topology.

Second step Connection selections

In this step, the number of the connection node pair, the connection node pair selection for connections and the desired connection group size are done. The preplanned working and the protection optical paths for connections of every node pair are also provided.

Failure-free Network Phase

Third step Wavelength allocation

In this step, wavelength allocation is initiated. A working connection starts from the source node and progresses through the network occupying a wavelength on each optical fiber and switch to another fiber on the same or other wavelength by OXC, according to its preplanned working optical path up to arrive at the destination node. Simultaneously, the protection connection starts from the source node and progresses through the network occupying a wavelength on each optical fiber and switch to another fiber on the same or other wavelength by OXC, according to its preplanned protection optical path up to arrive at the destination node. So there is full and dedicated protection for this connection. The number of connections of each node pair is equal to its connection group size. After a connection (working as well as protection) has been established, the available capacity is also calculated. These results are for one connection.

Forth step. Presentation of the polynomials

The total available capacity of each optical fiber is calculated and represented as well as the polynomial which generates it for all cases. These results are for all connections.

Fifth step. Results and comparisons thereof

Having the desired connection group size the total results are computed that are the total sum of the individual connection group size, the total installed capacity, the total protection capacity, the total busy capacity and the available capacity. These results are compared and showed in tables side by side for each model so that the differences to be looked.

Network with failure Phase

When a failure occurs and a link is cut, the optical fibers of this link are also cut and the optical fiber protection 1+1 and the network topology change. The connection groups that passed through the cut link are also cut and the restoration is carried out passing through the preplanned protection paths of

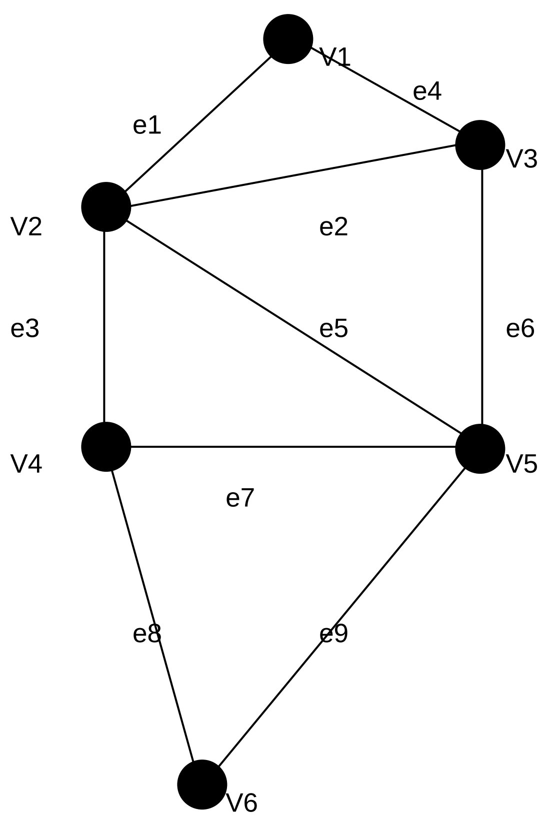

Fig. 1. The mesh topology of the network.

TABLE 2
ORDER, SIZE, WORKING PATH, PROTECTION PATH OF EACH NODE PAIR

Node Pair	Node Pair	Working Path	Protection Path	Size a
$[S_1,D_1]$	$[V_1,V_2]$	V_1,V_2	V_1,V_3,V_2	1
$[S_2,D_2]$	$[V_1,V_3]$	V_1,V_3	V_1,V_2,V_3	2
$[S_3,D_3]$	$[V_2,V_3]$	V_2,V_3	V_2,V_1,V_3	5
$[S_4,D_4]$	$[V_2,V_4]$	V_2,V_4	V_2,V_5,V_4	2
$[S_5,D_5]$	$[V_2,V_5]$	V_2,V_5	V_2,V_4,V_5	2
$[S_6,D_6]$	$[V_3,V_2]$	V_3,V_2	V_3,V_1,V_2	3
$[S_7,D_7]$	$[V_3,V_1]$	V_3,V_1	V_3,V_2,V_1	1
$[S_8,D_8]$	$[V_3,V_5]$	V_3,V_5	V_3,V_2,V_5	4
$[S_9,D_9]$	$[V_4,V_2]$	V_4,V_2	V_4,V_5,V_2	1
$[S_{10},D_{10}]$	$[V_4,V_5]$	V_4,V_5	V_4,V_2,V_5	2
$[S_{11},D_{11}]$	$[V_5,V_4]$	V_5,V_4	V_5,V_2,V_4	5
$[S_{12},D_{12}]$	$[V_6,V_4]$	V_6,V_4	V_6,V_5,V_4	2

TABLE 3
THE NUMBER OF CONNECTION GROUPS THAT PASS THROUGH EACH OPTICAL FIBER

Fiber,i	n(i)	Fiber,i	n(i)	Fiber,i	n(i)
1	3	7	3	13	3
2	2	8	2	14	3
3	2	9	4	15	0
4	4	10	2	16	1
5	3	11	1	17	0
6	2	12	0	18	1

other links. The computer is informed of the cut link and modifies suitably the network parameters. The cut optical fiber sets its wavelengths to zero. The connection groups that passing through the cut link set their using wavelengths to zero and through the others to free.

D. Example

The network and the results are presented shortly because the paper must be short. The topology of the network is presented by the graph G (V, E). The vertex set has q=6 elements and the edge set has p=9 elements. Each edge is an optical link of two directions with one working fiber for each direction. Thus there are 2*p=2*9=18 optical fibers. Connection groups transverse the mesh network and correspond to *n* source-destination node pairs. WDM system capacity has 30 wavelengths.

The problem is solved for *n=12 of 30 possible* connection groups. These have their order and sizes for each source-destination node pair, their working paths and their protection paths as shown in *table 2*. The results are showed. It is obvious that the dedicated path protection mechanisms use more than 100% redundant capacity because their lengths are longer than their working paths. The total length of working paths is twelve (12) optical channels and the total length of protection paths is twenty-four (24) ones. Similarly for the same connections requested group size the capacity that is used by the protection paths is larger than the corresponding working paths. The numbers of connection groups that pass through each optical fiber are showed in the table 3. (Fiber, i) shows the optical fibers. The n(i) shows the number of the connection groups that pass through each optical fiber. The polynomials that calculate the available capacity of each optical link for each method for the following cases are not represented. In the

TABLE 4
INTERPOLATION POLYNOMIALS OF THE FIRST POLYNOMIAL METHOD FOR SOME OPTICAL FIBERS

Interpolation Polynomial	Points, x
$P_{12}(x)=30$	0
$P_{11}(x)=-x+30$	0,4
$P_6(x)=0*x^2-x+30$	0,1,3
$P_1(x)=1,49*10^{-7}x^3-1,07*10^{-6}x^2-0,99999x+30$	0,1,3,6
$P_9(x)=9,3*10^{-9}x^4-1,7*10^{-7}x^3+1,3*10^{-6}x^2-x+30$	0,2,4,8,10

table four (4), five interpolation polynomials of the first polynomial interpolation method of corresponded fibers are showed for data type single. The column INTERPOLATION POLYNOMIAL, the interpolation polynomials are written and in the column POINTS, x the data points from which the polynomial must pass. The symbol $P_{12}(x)$ means that the polynomial of 12th fiber and the independent variable x. The corresponded polynomials of the second polynomial interpolation method have the coefficients after first degree equals to zero. None connection group passes through fiber 12 so the polynomial is constant with value 30 which is the WDM system capacity and there is one only data point 0. One connection group with size 4 passes through fiber 11 so the polynomial is first degree with values 30, 26 and the corresponded two data points 0 and 4. Two connection groups with sizes 1, 2 pass through fiber 6 so the polynomial is second degree with values 30, 29, 27 and the corresponded three data points 0, 1 and 3.Three connection groups with sizes 1, 2, 3 pass through fiber 1 so the polynomial is third degree with values 30, 29, 27, 24 and the corresponded four data points 0, 1, 3, 6. Four connection groups with sizes 2, 2, 4, 2 pass through fiber 9 so the polynomial is forth degree with values 30, 28, 26, 22, 20 and the corresponded five data points 0, 2, 4, 8, 10. It is showed that the coefficients of the monomials after 1st degree are too small and could be neglected. All polynomials are about linear ones.

The matrixes with dimension (18x1) of the available capacity of all network optical fibers are neglected for all types of TURBO PASCAL. A total table 5 is showed for the total network available capacity of all data types as single, real, double and extended. In this table, Column (1) gives the data

TABLE 5
THE TOTAL NETWORK AVAILABLE CAPACITY PER TYPE DATA REPRESENTATION

(1)	(2)	(3)
Single(4)	450	450,00010332460
Real(6)	450	449,99999999831
Double(8)	450	450,00000000000
Extended(10)	450	450,00000000000

type, column (2) gives the available capacity of the second polynomial interpolation method, second model and the column (3) gives the available capacity of the first polynomial interpolation method, first model.

Time complexity of the second model is ‘order q^3, $O(q^3)$ and the other model has exponential order or 2^q,order, $O(2^q)$.

In the figure 2, the logarithm of error of the total available capacity versus the WDM system capacity is showed for the case of the first polynomial interpolation method

In the table 6 the average and the standard deviation for the

TABLE 6
THE AVERAGE AND STANDARD DEVIATION FOR THE ERROR OF THE FIGURE 2 PER DATA TYPE REPRESENTATION

Data Type	Function Type	aver	stdev
Single	Log	-4,038	0,4611
	Arithmetic	9,2E-05	2,9E+00
Real	Log	-9,667	0,5750
	Arithmetic	2,2E-10	3,7581

error of the figure 2 for data types single and real, is represented. In the column data type, the two data types are showed, in the column Function type, the type of function is showed which is log (logarithmic) function of the error or arithmetic value of the error (no logarithmic function of the error), in the columns *aver* the average of each of two data types for the figure 2 and in the column s*tdev*, the standard deviation for the two data types of the figure 2 are showed.

The results for the several data types of Turbo Pascal for the first polynomial interpolation method show that data types changing can improve partially or fully the performance of the methods and make it more accurate when suitable care have be taken and there are not other error sources.

E. Discussion and Proposals

There are many forecasts in the telecommunications industry about the future of bandwidth demand. None of these forecasts adequately address the realistic demands on future networks, a critical consideration for operators making investment decisions on their network infrastructure. Filling that need is the purpose of this model developed and described in this article. There are several advantages of the forecast, compared with using real data [13]. In this study, I use simulation to investigate a WDM mesh network with dedicated optical path protection comparing the simulation results of two models, which are the second polynomial interpolation method and the first polynomial interpolation method.

In this protection scheme, when a single failure of a cut link occurs or other failure on main optical path so that the main connection cuts then the connection is routed by backup path.

The use of the polynomial methods is possible for the study of the problems related to the protection and restoration of connections and has the advantage that is not using the large matrix with the active links of the network. The active links are the links that pass through the optical paths. For better presentation of this research a short example is used that depicts the results in these methods. The algorithm provides for each source-destination node pair and a desired connection group size, a value of the total available capacity of the network. The connection length depends on the number of hops. The network has a complete protection for optical path connection. It is a switch circuit network (or a packet switch network but the packets are adjusted to pass through preplanned paths) so that one lightpath corresponds to one optical connection. Different wavelengths may be used for each connection in each hop, so that wavelength conversion is used. These methods solve problems with small networks because when the connections groups that pass through a link increases, then the number of the (n+1) equations with n+1 unknown of the linear system also increases and it is difficult to be solved to calculate the coefficients. The accurate method is easier and more accurate than the corresponded approximate one. The first polynomial interpolation method is more difficult because the polynomial coefficients are more complex. For the approximate method, the error becomes worse when the degree of the polynomial also increases. The polynomial interpolation methods are approximated very well by the corresponded linear interpolation method because after the linear term the other coefficients are about zero and it is a very serious advantage.

In Turbo Pascal for the PC, the best precision is 15 decimal digits and some differences that appeared are ought to the errors of the polynomial methods. For the precision, the *different* types are used that are floating point formats and provide good dynamic range in addition to high precision. The model of the first polynomial interpolation method produces more errors and losses in accuracy (loss significant digits), but these errors could be deleted changing the variable declarations without no other modifications to the program. The second model overcome these problems using more exact numbers and changing the algorithm, revising the equations of the coefficients. The type single gives a lot of problems, after the type real reduces the problems in the higher degree polynomials, the type double deletes the problems as well as the type extended. The last type is used when the type double can not delete the problems such as in the polynomial interpolation method. For small networks, Turbo Pacal data types can convert the approximate method to an accurate one when there are any types of errors.

For the table 4, when none group goes through the optical fiber, then the degree of the polynomial function is 0, when one group goes through, then the degree of the polynomial function is 1, when two groups go through, then the degree of the polynomial function is 2, etc.

IV. CONCLUSION

The impressive growth in the use of communication networks introduces severe requirements concerning higher bit rates, longer distances with less delay, higher reliability and better cost efficiency. To accommodate to the list of stern demands, communication networks are more often based on optical techniques. In existing communication networks, optical techniques are however only used to enable long-distance transmission between electrically implemented modules. Things like switching, time multiplexing and frequency multiplexing are still established in the electrical domain. In future communication networks, however, transfer of data is established using a number of different optical techniques. The most important optical technique is Wavelength Division Multiplexing (WDM), which considerable enlarges the information transfer capacity of an optical fibre. To this end, WDM divides the available bandwidth of a fibre into a number of independent wavelength channels, which enables a concurrent transport of distinct data signals. Nowadays, research concentrates on implementing several types of modules based on WDM. These modules include for instance optical cross-connects, which adopt functionality of electrical switches.

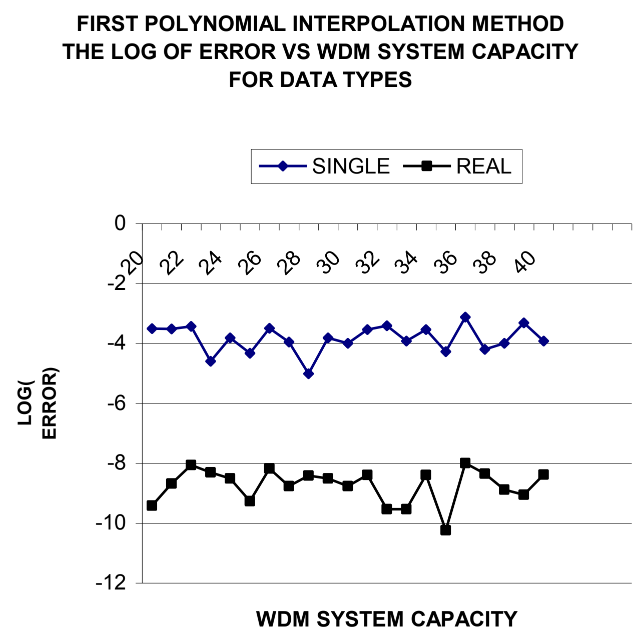

Fig. 2. The logarithm of the error of the total available capacity versus the WDM system capacity for the first polynomial interpolation method.

In this paper, the performance of two models are compared each other for the dedicated protection optical path method of the WDM mesh networks. The polynomial methods make it possible to research and study the dedicated protection problems of the optical paths but more attention must pay. So a more suitable method is produced to solve telecommunication problems such as planning of a completely protected network, complete protection for any failure occurs on optical path, node or link e. t. c. The polynomial approximate method could be converted to an accurate one using the several data types of Turbo Pascal and there are not any types of errors. The first polynomial interpolation method produces more errors but it has the advantage of the conversion to linear interpolation method. It has capability to convert to an accurate one. This is ought that error is done to small and neglected. This conversion is full for small networks but may be partial for larger networks. The second polynomial interpolation method does not produce errors and it can convert to linear interpolation method. It is an accurate and simple method.

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