

# Wavelength Routed Optical Neural Networks

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**Abstract** - In this paper wavelength routed optical neural networks are presented. Characteristics of flow-oriented models of routing were classified.

**Keywords** - Optical neural networks, wavelength routed, routing.

## I. INTRODUCTION

For the next networks generation wavelength routed optical neural networks are used as basic [1-3]. This is due to several features: scalability [4, 5], spatial reuse of wavelengths, the transparency of services, network durability. Therefore the design of wavelength routed optical neural networks is necessary to consider network technology and the influence of physical parameters of network elements. The information for optimal routing and data restrictions on routes that have special meaning is required.

Optical neural networks can provide important benefits during the computation. Size synaptic connections can be remembered in a hologram with a high density, some estimates give the theoretical limit of  $10^{12}$  bits per cubic centimeter. Although these values are not achieved in practice, the existing level of memory density is rather high. In addition, the weight may be modified in the process of network working, creating a fully adaptive system.

Despite widely escalated graph (graph-combinatory) models of routing [1, 2], that accepted as a basis for most of existent routing protocols - RIP (Routing Internet Protocol), IGRP (Interior Gateway Routing Protocol), EIGRP (Extended IGRP), IS-IS (Intermediate System - to - Intermediate System), OSPF (Open Shortest Path First), PNNI (Private Network - to - Network Interface), in the last analysis just flow-oriented models of routing are ever-broadening requested. On the one hand they considering the dataflow character of present-day traffic as mostly multimedia-based (voice, video, etc.), but on the other hand they more adopted for load-balancing solutions and quality of service provision at multi-service NGN telecommunications.

## II. THE CLASSIFICATION OF FLOW MODELS FOR ROUTING

An analysis of recently investigations and publications carry inference about the fact that a lot of approaches to float modeling for routing has been proposed until current study, into the bounds of existent and perspective telecommunications technologies [11,12]. Depending on features consideration deepness of structural, functional architecture and operation of telecommunication network, we obtain an optimization task using appropriate mathematical model. That's why commonly there are few methods to

calculate necessary path (set of paths)[13]. To solve that optimization tasks, a set of different methods should be used, combinatory Dijkstra algorithms (OSPF, IS-IS, PNNI), Bellman-Ford (RIP, IGRP, EGRP), Floyd-Warshall [11] for graph models, but for flow-models the methods of the mathematical programming and optimal control methods are more suitable[11,15].

There are specific features, conditions and implementation branch to each of flow models, their related algorithms and methods to solve routing tasks. Common conclusions could be found in most of the known studies, dedicated to analysis of the different routing models [11]. It is difficult, sometimes impossible effectively determine their benefits, shortcomings and most optimal conditions to use.

The target of this work is to obtain the numeric results of the comparative flow models analysis at different network topologies and users' network traffic characteristics. The comparative analysis completing for flow models of routing from the load-balancing solutions and quality of service provision positions allows defining with further their application.

There was comparative analysis carried out for five basic flow models of routing [11]:

M-1. The one-path routing model, based on finding the shortest path which consist of minimal number of hops, such is with RIP v1.

M-2. The multi-path routing model (MPRM) unlike previous M-1, supports load balancing through paths that equivalent by the cost (length). This case provides solving of the routing task by linear programming through minimize the objecting function

According to the physics of the solving tasks x-vector coordinates are merged by set of constraints, which simulates the conditions of the flow conservation into each network node.

M-3. The MPRM model with introduced metric of IGRP with load balancing through paths that non-equivalent by the cost (length). M-3 is represented by two previous methods with the difference that IGRP metrics corresponding c-vector coordinates are listed values of the transmission line throughput [9]. To formalize conditions of transmission lines overloading were introduced additional constraints.

M-4. The MPRM model, proposed by Gallager [11] which solves the routing task by non-linear programming with maximizing the objective function.

Definition provides the transmission lines utility coefficient mini-max optimization. Also conservation condition must be provided. For the outing variables some conditions are applied.

M-5. The Gallager's MPRM model which was developed in [14] by introducing the provision conditions for QoS by packets transmissions speed, their average delay, jitter and

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in-time delivery probability. In consequence of limited transmission lines throughput as the model M-5, as in models M-3 and M-4 the limitation connected with transmission line throughput was applied.

### III. VIRTUAL CHANNELS FEATURES IN OPTICAL NEURAL NETWORKS

In optical networks with static wavelength routing, the traffic is given as a fixed set of logical connections between pairs of access nodes. A set of connections determines the logical topology. Optical unit with cross-commutation (OXC) is a key element in optical networks with WDM [6]. Switching wavelengths of incoming fibers for the outcome, OXC makes transitional obstacles that have the same wavelength as the signal and impair the transmission characteristics seriously [7,8].

Interconnection of neurons using light beams can be positioned in three dimensions. The density of modes of transmission is limited only by the size of light sources, their divergence and size detector. Potentially, these dimensions can have a few microns value. All signaling pathways can operate simultaneously, thus providing a huge rate of data transfer. As a result, the system is able to provide a complete set of links that operate at the speed of light.

Many optical neural networks configurations that are studied can be divided into two categories: vector-matrix multipliers and holographic correlators. The process of most artificial neural networks can be described mathematically as a series of multiplying vector by a matrix, an operation of multiplication in each layer. To calculate the output layer input vector is multiplied by a weighting matrix, forming a vector. When the artificial neural network modeled on universal computers, calculations are lost, each operation must be executed gradually. Despite the great speed of some computations, the number of operations that are required for matrix multiplication is proportionally to the square of the dimension of input vector (if the input and output vectors have the same dimension).

If the outputs of photodetectors in the network are given back for controlling of appropriate light inputs, electro-optical Hopfield's networks are implemented. Threshold activation function must be provided for this. Today the activation function is better realized by electronic circuits that follow each photodetectors.

In the course light stream goes through the cylindrical lens, shining corresponding line of a light mask. This lens deploys light stream in a horizontal direction, keeping it unexpanded in the vertical direction.

Each photodetector responds to the light stream of the whole line, its electronic part implements threshold function and the resulting signal controls associated light source. Thus feedback loop is closed, including light sources, photodetectors and optical system. It should be noted that the stability of network is guaranteed even if the matrix is not symmetric. In addition, mandatory equality to zero of the main diagonal elements is not required.

### IV. CONCLUSION

For the next networks generation wavelength routed optical neural networks are used as basic. They can provide important benefits during the computation. Many optical neural networks configurations that are studied can be divided into two categories: vector-matrix multipliers and holographic correlators. Characteristics of flow-oriented models of routing were classified. The model analysis was carried out for routing, that accepted as a basis for existent telecommunication network protocols.

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