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Analyse de performance des réseaux optiques à commutation en sous-longueur d'onde

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**Performance Analysis of
Subwavelength Switching Optical Networks**

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Orange Labs

Performance Analysis of Subwavelength Switching Optical Networks

- Ph.D. Thesis -

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*Părinților mei,
Pentru tot ce au făcut, fac și vor face pentru noi.*

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Abstract

A key challenge in today's networks is to bridge the gap between high-speed optical transmission and limited electronic processing. This can be achieved by enabling payload to be switched directly in the optical domain. A simple solution to provide optical switching is by allocating one wavelength channel to each source-destination pair, a technique called Optical Circuit Switching (OCS). Due to lack of sharing, OCS suffers from limited scalability. To overcome this issue, the capacity of each wavelength channel must be dynamically shared among different source-destination pairs. This requires data to be switched at subwavelength granularity by means of *subwavelength switching*.

In this thesis, we propose several solutions which enable subwavelength switching in optical networks. To show the relevance of the proposed solutions, we analyse their performance in terms of traffic capacity, flow throughput and packet delay. Performance is evaluated both through simulations and by means of appropriate queueing models.

We first consider the case of Metropolitan Area Networks (MAN) and we study the performance of synchronous time-slotted Wavelength Division Multiplexing (WDM) ring in which network nodes communicate by inserting and extracting data from time-slots. We present a fully distributed Media Access Control (MAC) protocol designed to ensure fairness. We also propose a burst assembly mechanism able to ensure low assembly delays and high fill rates of the optical time-slots.

We then propose subwavelength switching solutions which can be applied in the more general case of asynchronous wide area networks. We first propose to solve the contention problems of conventional Optical Burst Switching (OBS) and the low utilization issue of wavelength-routed OBS by implementing a two-way reservation OBS scheme in which the size of the optical burst increases proportionally with the network load so as to maximize resource utilization.

Next, we propose a solution for building an all-optical wide area network based on multipoint-to-multipoint lightpath sharing. We also design an associated MAC protocol and a dynamic bandwidth allocation algorithm and analyse the performance of the proposed solution. By means of a case study, we show that the proposed solution has the potential to considerably reduce power consumption with respect to current router-based architectures. Finally, we propose a novel optical device able to solve contention directly in the optical domain without requiring any optical buffering, electronic signalling or header processing. We show that this simple device can be used as a building block for dynamic and power-efficient short-range optical networks such as access networks or data centers.

Résumé

Un défi majeur dans les réseaux d'aujourd'hui est de combler l'écart entre la haute vitesse de la transmission optique et la vitesse plus limitée du traitement électronique des données. Une option est de commuter les données directement dans le domaine optique. Dans cette thèse, nous proposons plusieurs solutions permettant la commutation dans le domaine optique à une granularité plus fine que la longueur d'onde, technique que nous appelons commutation sous-longueur d'onde. Pour montrer la pertinence des solutions proposées, nous analysons leur performance en termes de capacité de trafic, de débit et de délai. La performance est évaluée à la fois par des simulations et en utilisant des modèles de files d'attente appropriés.

Nous considérons d'abord le cas des réseaux métropolitains (Metropolitan Area Networks, MAN) et nous étudions la performance d'un anneau optique avec multiplexage en longueur d'onde (Wavelength Division Multiplexing, WDM) dans lequel la communication entre les nœuds du réseau se fait par insertion/extraction de données dans des créneaux temporels. Nous présentons un protocole entièrement distribué conçu pour assurer l'équité dans ce réseau. Nous proposons également un mécanisme d'assemblage de paquets capable d'assurer des délais faibles ainsi que des taux de remplissage élevés.

Nous proposons ensuite des solutions de commutation sous-longueur d'onde qui peuvent être appliquées dans le cas plus général des réseaux asynchrones. D'abord, nous proposons de résoudre le problème des collisions de la commutation optique par rafale (Optical Burst Switching, OBS) par la mise en œuvre d'un mécanisme de réservation. Afin de maximiser l'utilisation des ressources, nous proposons d'adapter la taille de la rafale optique à la charge du réseau.

Ensuite, nous proposons une solution alternative pour construire un réseau coeur tout-optique. A cette architecture, nous associons un protocole d'accès ainsi qu'un algorithme d'allocation dynamique de bande passante et nous analysons les performances de la solution proposée. Par le biais d'une étude de cas, nous montrons que notre solution est capable de réduire considérablement la consommation énergétique par rapport aux architectures actuelles basées sur des routeurs IP. Enfin, nous proposons un nouveau dispositif optique capable de résoudre la contention directement dans le domaine optique. Nous montrons que ce dispositif simple peut être utilisé pour construire des réseaux optiques dynamiques à courte portée tels que les réseaux d'accès ou les centres de traitement de données.