# Optical Caching Network: A Seamless Bridge Between Electrical Packet Switching and Optical Circuit Switching

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**Abstract:** We propose a novel mechanism for instant access of latency-sensitive traffic using optical caching network. Lightpath setup delay can be avoided by caching-based optical circuit switching and the router workload can be reduced by 96%. 

## 1. Introduction

The emerging latency-sensitive applications such as autonomous driving (AD) and haptic virtual reality (VR) have put 100μs-level or even 10μs-level traffic access time and end-to-end latency requirements (Fig. 1(a)) on today's communication networks due to their moving features [1, 2]. As shown in Fig. 1(b), traditional electrical packet switching (EPS) networks are enabled by routers and fat "light pipes", which leads to long end-to-end latency at high load due to the long tail router's latency of as high as 100ms-level [3]. Researchers in [4, 5] have combined optical circuit switching (OCS) with EPS to reduce the end-to-end latency by reducing routers' workload (Fig. 1(c)). However, conventional OCS suffers from long lightpath (LP) setup delay (at 100ms level or higher), which cannot fulfill the traffic access time requirements of VR/AD applications.

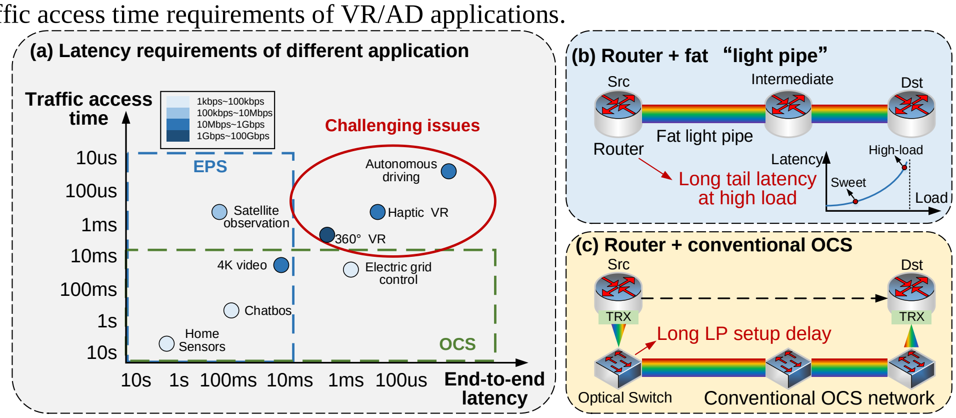


Fig. 1. Challenges of latency-sensitive applications

To solve the challenging issues, in this paper, we propose a caching-based OCS (C-OCS) mechanism for instant access of latency-sensitive applications. By establishing a fine-grained fully-connected optical caching network (OCN), the newly arrived connection request will be carried by a caching LP immediately without LP setup delay. The results of simulation and experiment show that the router workload can be reduced by 96% compared to EPS networks, and the LP setup delay is eliminated compared to conventional OCS networks.

## 2. Caching-based OCS Mechanism

To achieve instant access of latency-sensitive applications, an optical caching network is added between the EPS network and the OCS network in the proposed C-OCS mechanism, as shown in Fig. 2(a). Each router connects to several continuous optical transceivers (TRX) and burst-mode optical transceivers (BM_TRX) to reduce the workload of EPS network by transmitting traffic flows through OCS network and OCN, respectively. Fine-grained fully-connected caching LPs are maintained in the OCN as shown in Fig. 2(b). To provide sufficient all-to-all optical caching LPs, optical time slice switching technology [6] is used in the OCN. Upon the arrival of a traffic request, it will be carried by a preconfigured caching LP immediately without LP setup delay. At the mean time, a main LP (wavelength channel) will be established for the traffic. After the main LP is established, the traffic connection will be switched to it and the caching LP is available for the subsequent traffic requests. Considering about the scenario that multiple main LPs need to be established to vacant the caching LPs, fast parallel lightpath establishing [7] technology are deployed in the C-OCS network.

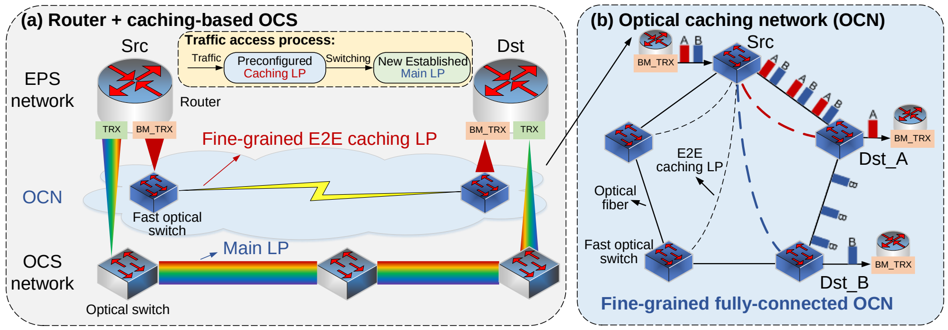

Fig. 2. C-OCS mechanism enabled by OCN

## 3. Network Experiment and Simulation

To evaluate the performance of the proposed C-OCS mechanism, we conduct a prototype experiment whose setup is shown in Fig. 3(a). The experiment topology consists two aggregate switching nodes (A1 and A2) and a core switching node (C1), as shown in Fig. 3(c). The SW1 switch in node A1 is deployed for switching the traffic connection from LP_cache to LP_main while other switches are used for maintaining time-sliced caching channels.

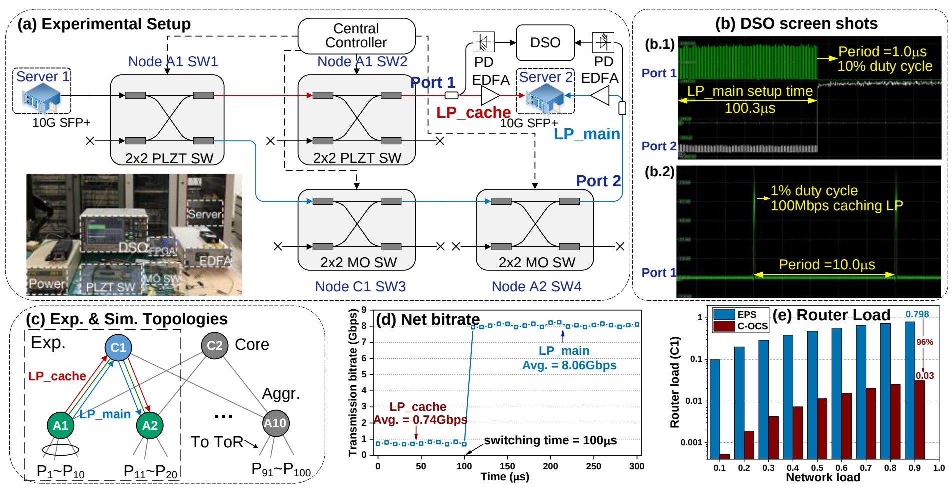

Fig. 3 Prototype experiment and simulation of C-OCS

The DSO screen shot in Fig. 3(b.1) shows that the setup delay of LP_main is 100.3μs (in commercial systems it may reach 100ms-level), the influence of which can be eliminated by C-OCS. Firstly, we set the time slice length and period to 100ns and 1μs, respectively. Fig. 3(d) shows the average net transmission bitrates of LP_cache and LP_main are 0.74Gbps and 8.06Gbps, respectively. To support larger network scales (e.g. 100 nodes), we enlarge the caching LP number by increasing time slice period to 10μs (100Mbps per channel), as shown in Fig. 3(b.2). This setup takes the price of increasing traffic accessing time from 1μs to 10μs, which is acceptable for most applications.

To evaluate the performance of C-OCS in larger-scale networks, we conduct a simulation under a 12-node fat-tree topology as shown in Fig. 3(c). As the network load (fraction of network capacity) increases, the average increasing rate of EPS network is about 22.7 times higher than C-OCS network (Fig. 3(e)). The router workload can be reduced by the C-OCS mechanism from 79.8% to 3.07%, which is over 96% at 90% network load. The result infers that the long end-to-end latency caused by the router's tail latency can be significantly reduced.

## 4. Conclusions

We propose a C-OCS mechanism for instant access of latency-sensitive applications. By establishing a fine-grained fully-connected optical caching network (OCN), the influence of LP setup delays and long tail router latencies can be avoided, which significantly reduces the traffic access time and the end-to-end latency at the same time.

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