Light & NOS

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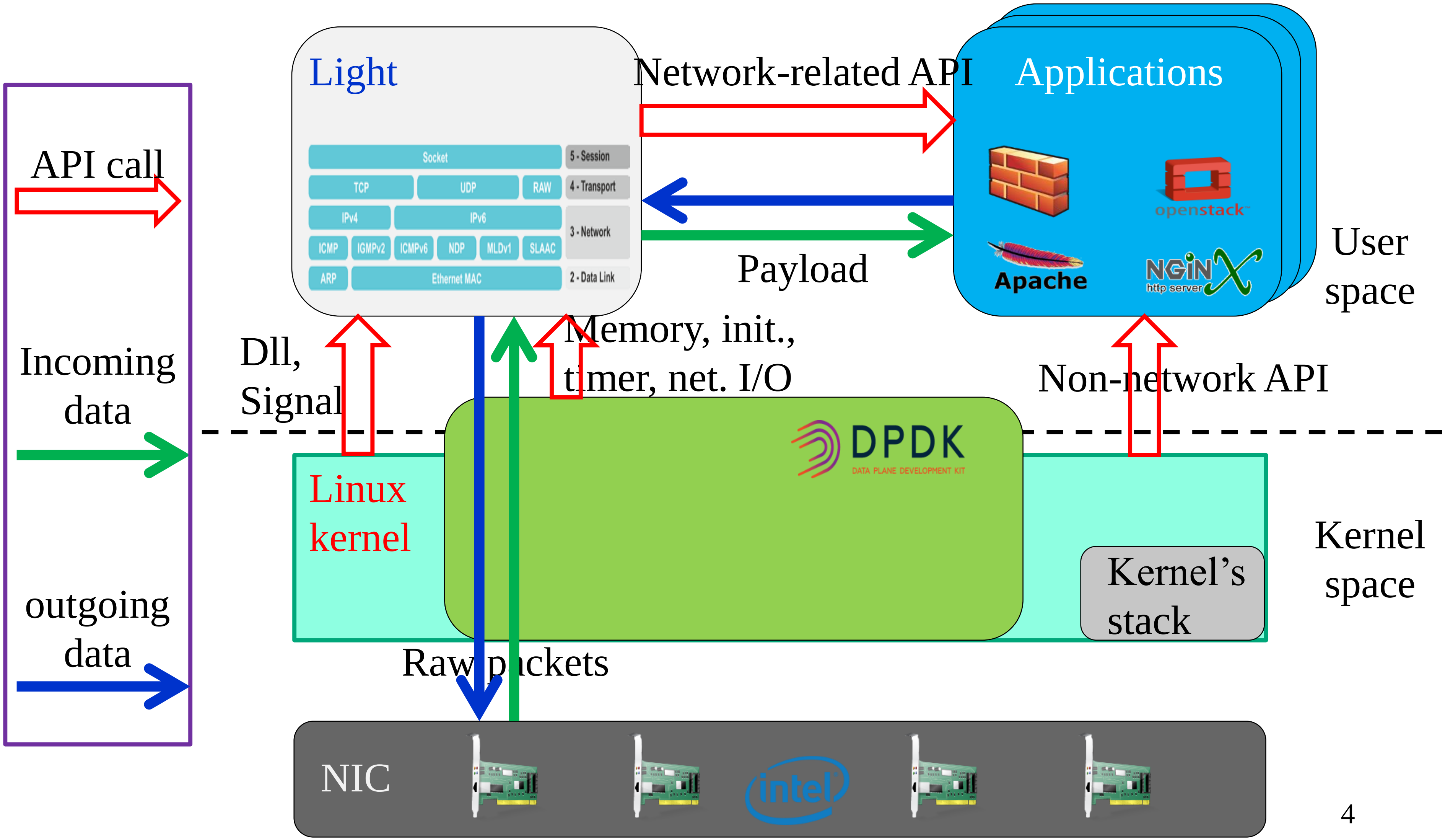
The Power of DPDK

- **Performance gain**
  - As claimed: 80 CPU cycles per packet
  - Significant gain compared with Kernel!
- **What we care more…**
  - How to leverage the performance gain to serve more applications
  - A great opportunity
    - Decoupling network operation from the kernel / operation system
    - Network can thus develop independently

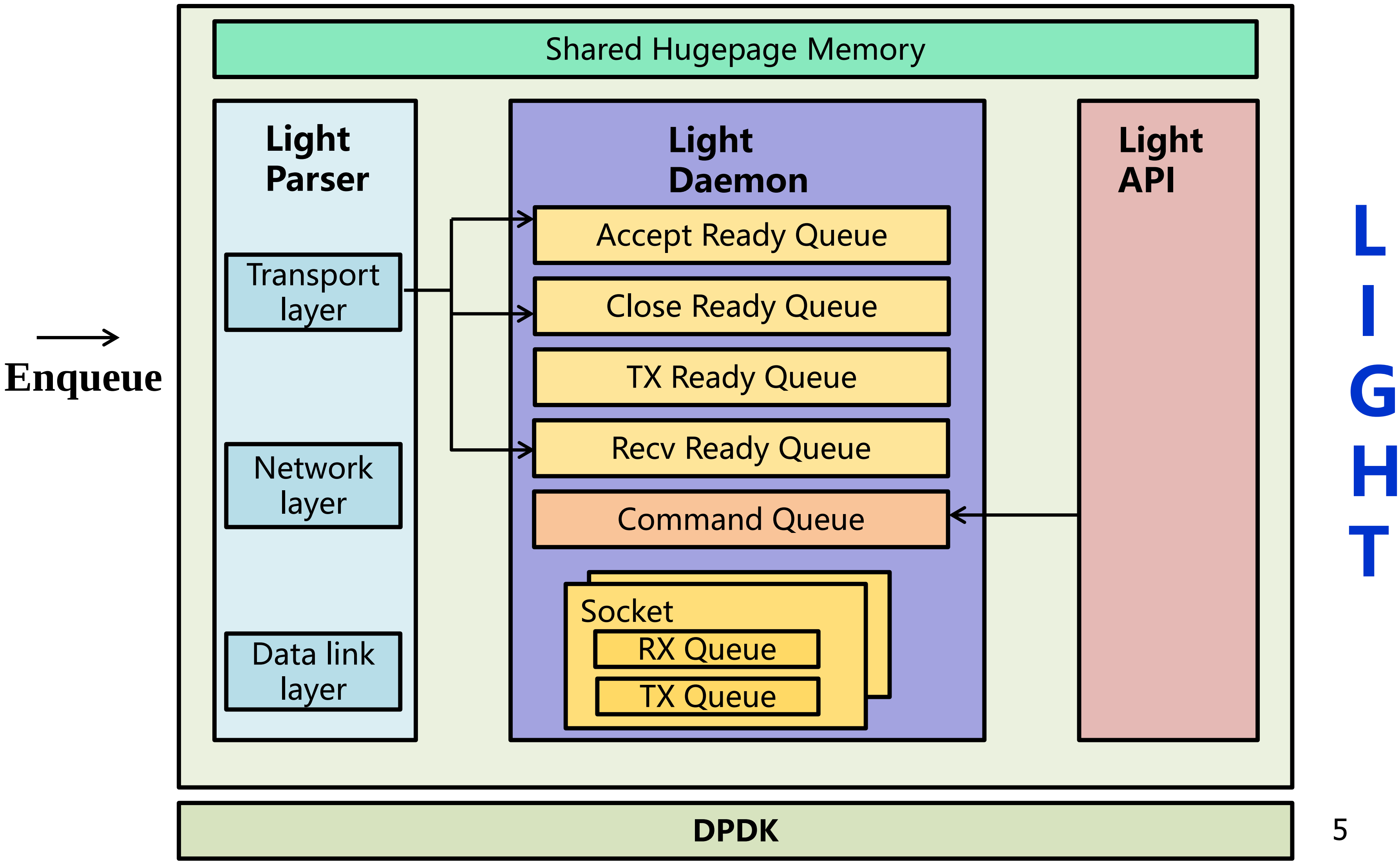
State-of-the-Art

- **Improving the performance of Linux network stack**
  - **Too many works…**
- **mTCP**
  - **Based on DPDK**
  - **Realizing network operations as a thread in application**
- **6wind**
  - **Do not know the technical details**
- **What we want**
  - **A DPDK-based network stack that can provide the functionality of network operating system**

Light: a Polling-based, General-purpose, User-space, High-performance Network Stack



Light Architecture



Design Goals

- **Goal #1: minimize the modification of applications**
  - **Ease the development of new applications**
  - **Benefit the porting of legacy applications**

- **Goal #2: minimize the performance affect to applications**
  - **The purpose of DPDK is to increase the I/O performance**
  - **We do not want that the performance of application is sacrificed due to DPDK**

Goal #1: Minimizing the Modification of Apps.

- **Light provides network-related APIs as a lib to apps.**
  - socket(), listen(), bind(), accept(), connect(), shutdown(), close(), socketpair()
  - send(), receive(), sendto(), recvfrom(), sendmsg(), recvmsg(), read(), write(), readv(),writev()
  - setsockopt(), getsockopt(), ioctl(), fcntl()
  - epoll (), select(), poll()
- **Challenges**
  - How to mask the same network APIs of the kernel?
  - How to differentiate the two FD spaces (Light and kernel) in the application?
- **Now we need to add several lines of codes in app.**
  - DPDK initialization, DLL management

API Mask

- **Applications uses dlsym() to redirect the function address to Light**
  - **Thus the same network APIs in the kernel are masked**
- **Do not need to modify the API calls of the application**
  - **Light's APIs follow the same format of POSIX APIs**
- **Do not need to modify the kernel**
  - **Help the system stability**

Two FD Spaces: Problems

- **FD confusion**
  - **Both sockets and files are referred to by FDs**
  - **E.g., read(), write(), epoll()**
- **Problems of Epoll**
  - **Epoll in the application can wait for the events of network sockets, file events, as well as inter-process sockets**
    - **Epoll for network sockets is supported in Light**
    - **Epoll for file events is supported by kernel**
    - **Epoll for inter-process sockets can be either realized in Light or supported by kernel**
  - **The two Epolls cannot work in blocking mode simultaneously**
    - **Logic problem**

Two FD Spaces: Our Solution

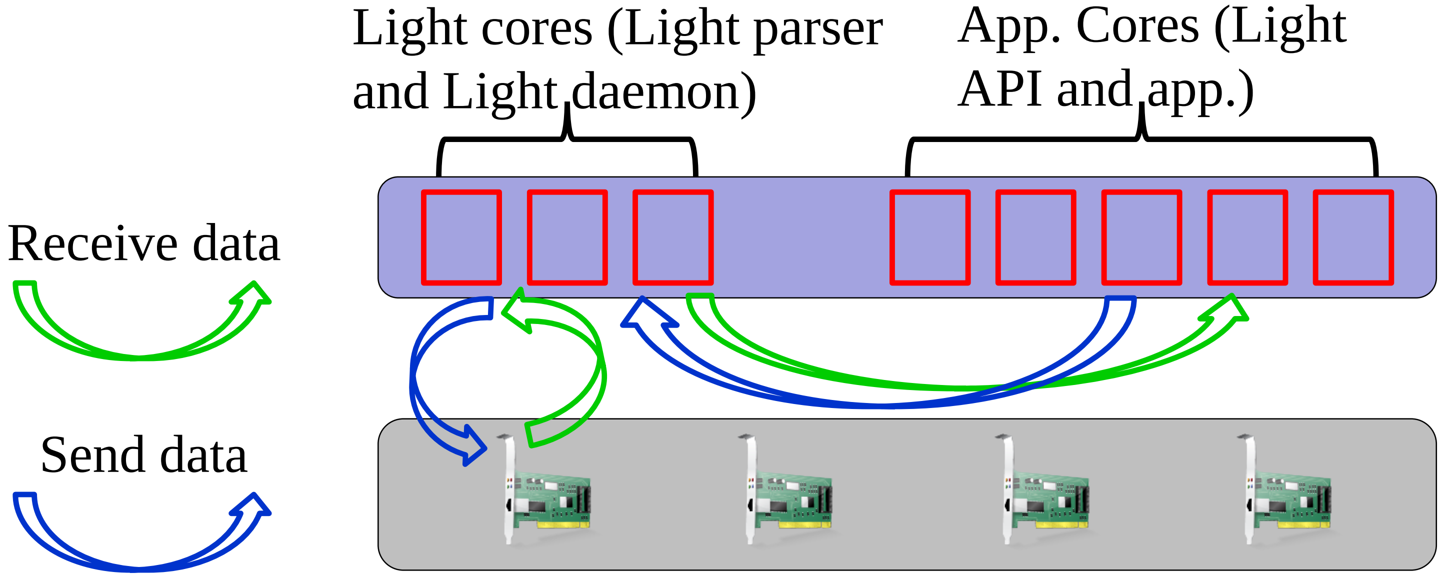
- **For the FD confusion problem**
  - **Light assigns FDs from the upper bound of FD space, because the Kernel assigns FDs from the lower bound of the space**
- **For the two Epoll problem**
  - **If we want to detect the events of both FD spaces**
    - **Intercept Epoll and let it always work in non-blocking mode**
    - **Cons.: app. cannot be suspended, CPU resource waste**
  - **If we want to save CPU resource for blocking calls in app.**
    - **Realize network sockets and inter-process sockets in Light**
    - **Cons.: Cannot detect file events**

Goal #2: Minimizing the Performance Affect to App.

- **Challenge 1: DPDK I/O polling in Light occupies 100% CPU resource**
  - **App. might compete with Light for the CPU resource**
- **Challenge 2: How to minimize the overhead of inter-process communication**
  - **Both Light and application are user-space processes**
  - **The inter-process communication between Light and app. may incur high overhead to apps.**
    - **Compared with if app. uses kernel network stack**

CPU Competition between Light & APPs

- **Solution**
  - **Run Light Parser and Light Daemon in Light cores**
  - **Run App. and Light API in App. cores**
  - **Light cores and App. cores are physically separated**
- **I/O polling only occurs in Light cores, not in App. cores**



Inter-process Communication between App. & Light

- **Basic mechanism**
  - **Lockless queue based on shared memory**
  - **RTE-ring in DPDK**
- **Blocking API calls in app.**
  - **Epoll(), recv(), send(), accept(), connect()**
  - **Kernel can suspend the app. process and wake it up after data arrives, which saves the CPU resource**
  - **Light is a user-space process and cannot do what kernel does**

Possible Methods

- **Method 1:**
  - If there is no event in the queue, the (Light API in) app. process goes to sleep
  - When an event comes, Light daemon uses signal to wakeup the process (batch process to further reduce the overhead)
  - Problem: if the last event fails to wake up the app. process
    - Signal can be lost
    - Time sequence error due to process management: an app. process receives the wakeup signal before it goes to sleep
- **Method 2:**
  - Similar way as in hybrid spinlock
  - While() and sleep for some time inside
  - Problem: still add some CPU overhead to app.

Our Solution

- **Method 1 for Epoll()**
- **Method 2 for send(), receive(), connect(), accept()**
- **Reasons**
  - **The Epoll queue maintains all the events for all sockets of the process**
    - **Any kind of event from any socket can wakeup the app. Process**
  - **The queue of the other 4 APIs only maintains a certain kind of events for a certain socket**
    - **The probability exists that the last event fails to wakeup the app. process**

Features of Light

- **Minimal modification of applications**
  - **Run as a general-purpose service for applications**
  - **Currently app. only has to add several lines of codes**
- **Significant performance improvement**
  - **Inherit the advantage of DPDK**
  - **Minimize the performance affect to apps. due to DPDK**
- **Complete protocol stack**
  - **TCP (including congestion control), UDP, ICMP, IP, UDP, ARP, Ethernet…**

Demonstration

- We run Nginx on Light and Linux kernel separately
  - Single process for Nginx
  - Apache benchmark
- Concurrent requests processed on Light more than doubles that in Linux

Thanks!

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