Lab2: send and receive packets with DPDK

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1. 问题解答

- Q1: What's the purpose of using hugepage?
  - 减少 TLB 缓存项的使用，从而大大降低 TLB Miss 的概率。
  - 减少页表的级数，从而提升查询页表的效率。

- Q2: Take examples/helloworld as an example, describe the execution flow of DPDK programs?

  答：helloworld 代码如下所示。

  ```
  int main(int argc, char **argv)
  {
      int ret;
      unsigned lcore_id;

      ret = rte_eal_init(argc, argv);
      if (ret < 0)
          rte_panic("Cannot init EAL\n");

      /* call lcore_hello() on every worker lcore */
      RTE_LCORE_FOREACH_WORKER(lcore_id) {
          rte_eal_remote_launch(lcore_hello, NULL, lcore_id);
      }

      /* call it on main lcore too */
      lcore_hello(NULL);
      rte_eal_mp_wait_lcore();

      /* clean up the EAL */
      rte_eal_cleanup();
      return 0;
  }
  ```

  控制流如下：

  1. 调用`rte_eal_init`，初始化基础运行环境，若初始化失败则报错。
  2. 对多核运行初始化。即遍历 EAL 指定可以使用的 lcore，然后通过`rte_eal_remote_launch`在每个 lcore 上，启动被指定的线程。
  3. 运行当前线程的函数 locore_hello。
  4. 主线程等待从线程结束执行。
  5. 执行`rte_eal_cleanup`，释放资源，防止 hugepage 内存泄漏。

- Q3: Read the codes of examples/skeleton, describe DPDK APIs related to sending and receiving packets.

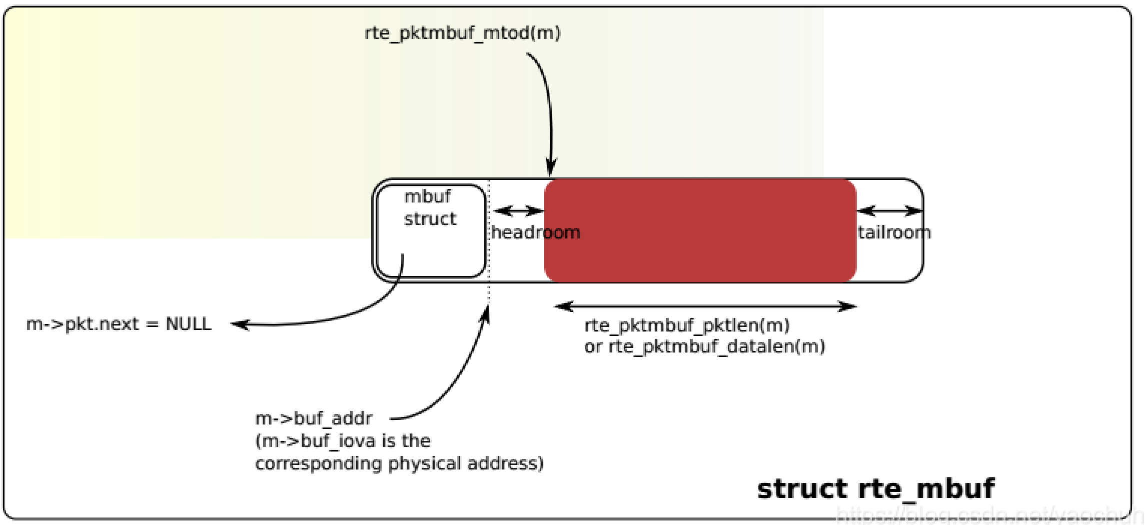
  答：以下分别为收包、发包所对应的 API。通过指定的端口与队列，收/发缓存区中的数据。

```
    其中，最后一个参数`nb_pkts`为指定一次函数调用来处理的包的个数。当设置为1时，每次收/发一个包。

    dpdk在样例程序，例如skeleton中，使用了burst模式，即收/发包数量为32个。这样可以减少内存访问，提高性能。
```

```
static inline uint16_t rte_eth_rx_burst(uint8_t port_id, uint16_t queue_id, struct rte_mbuf **rx_pkts, const uint16_t nb_pkts)
```

```
static inline uint16_t rte_eth_tx_burst(uint8_t port_id, uint16_t queue_id, struct rte_mbuf **tx_pkts, uint16_t nb_pkts)
```

- Q4: Describe the data structure of ‘rte_mbuf’.
- 答：`rte_mbuf`的结构如下所示。



- `headroom`为`mbuf`头部与实际包数据的一段空间，存储控制信息、帧内容、事件等。`headroom`的起始地址保存在`buff_addr`指针中。
- 在`headroom`后为实际数据所占空间。数据帧的长度可通过调用`pkt_len(m)`或`data_len(m)`获得。
- 实际数据后剩余的空间为`tailroom`。通过`headroom`与`tailroom`，可方便应用解封报文。
- `pkt`的`next`字段指向下一个 segment 的地址；`buf_addr`指向`headroom`的起始地址；`rte_pktmbuf_mtod(m)`指向实际 data 的起始地址。
- 此外，还记录了所属的 mempool，时间戳，端口，私有数据大小等信息。

2. 检验正确性

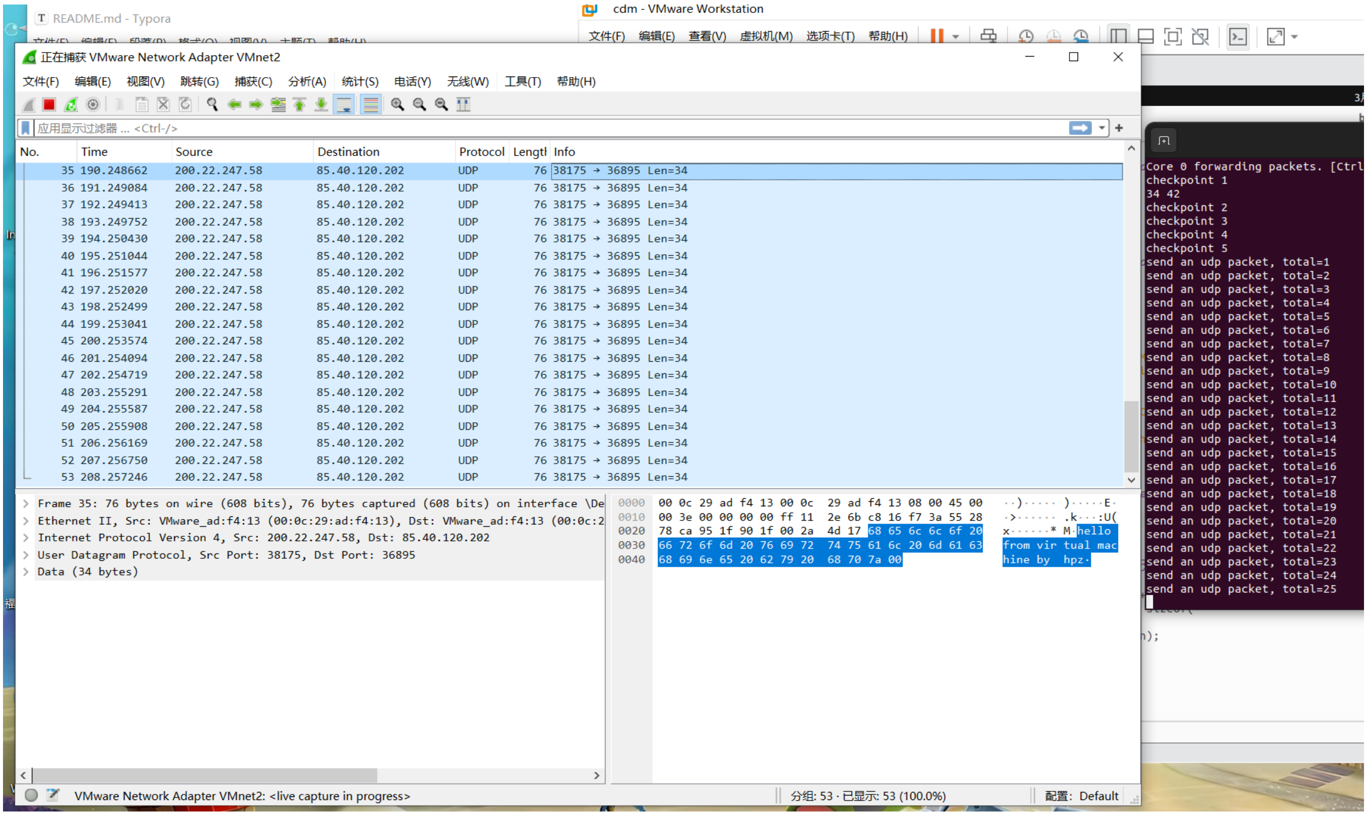
主要代码如下：

```
uint16_t port;

    /*
     * Check that the port is on the same NUMA node as the polling thread
     * for best performance.
     */
    RTE_ETH_FOREACH_DEV(port)
    if (rte_eth_dev_socket_id(port) >= 0 &&
        rte_eth_dev_socket_id(port) !=
        (int) rte_socket_id())
        printf("WARNING, port %u is on remote NUMA node to "
               "polling thread.\n\tPerformance will "
               "not be optimal.\n", port);

    printf("\nCore %u forwarding packets. [Ctrl+C to quit]\n", rte_lcore_id());

    char *package_data = "hello from virtual machine by hpz";
    int data_len = strlen(package_data) + 1;


    /* Run until the application is quit or killed. */

    port = 0; // only use port 0

    struct rte_mbuf *buf[1];
    buf[0] = rte_pktmbuf_alloc(mbuf_pool); //分配空间
    int hdr_len = sizeof(
                      struct rte_ether_hdr) + sizeof(
                      struct rte_ipv4_hdr) + sizeof(
                      struct rte_udp_hdr);
    rte_pktmbuf_append(buf[0], data_len + hdr_len);

    puts("checkpoint 1");
    printf("%d %d\n", data_len, hdr_len);

    /* 构造包 ether+ip+udp*/
    struct rte_ether_hdr *eth_hdr = rte_pktmbuf_mtod(buf[0],
    struct rte_ether_hdr *);
    struct rte_ipv4_hdr *ip_hdr = rte_pktmbuf_mtod_offset(buf[0],
    struct rte_ipv4_hdr *, sizeof(struct rte_ether_hdr));
    struct rte_udp_hdr *udp_hdr = rte_pktmbuf_mtod_offset(buf[0],
    struct rte_udp_hdr *, sizeof(struct rte_ether_hdr) + sizeof(struct
rte_ipv4_hdr));

    puts("checkpoint 2");

    /* 构造ethernet header */
    struct rte_ether_addr mac_addr;
    rte_eth_macaddr_get(0, &mac_addr);
    eth_hdr->ether_type = rte_cpu_to_be_16(RTE_ETHER_TYPE_IPV4);
    eth_hdr->s_addr = mac_addr;
    eth_hdr->d_addr = mac_addr;
    puts("checkpoint 3");

    /* 构造ip header */
    ip_hdr->version_ihl = RTE_IPV4_VHL_DEF;
    ip_hdr->type_of_service = 0; // unused
    ip_hdr->total_length = 62 << 8; // calc by data length
    ip_hdr->packet_id = 0;
    ip_hdr->fragment_offset = 0;
    ip_hdr->time_to_live = 255;
    ip_hdr->next_proto_id = 17; // udp
    ip_hdr->src_addr = IPv4(58, 247, 22, 200);
    ip_hdr->dst_addr = IPv4(202, 120, 40, 85);
    ip_hdr->hdr_checksum = rte_ipv4_cksum(ip_hdr);

    puts("checkpoint 4");

    /* 构造udp header */
    udp_hdr->src_port = 8085;
    udp_hdr->dst_port = 8080;
    udp_hdr->dgram_len = (data_len + sizeof(struct rte_udp_hdr)) << 8;
    udp_hdr->dgram_cksum = rte_ipv4_udptcp_cksum(ip_hdr, udp_hdr);

    puts("checkpoint 5");

    void *tmp = rte_pktmbuf_mtod_offset(buf[0],
    void *, hdr_len);
    memcpy(tmp, package_data, data_len);

    int total = 0;
    int interval = 1;
    for (;;) {
        const uint16_t nb_rx = rte_eth_tx_burst(port, 0, buf, 1); //每次发一个包
        total++;
        printf("send an udp packet, total=%d\n", total);
        sleep(interval);
    }

    /* Free packets. */
    rte_pktmbuf_free(buf[0]);
```

执行命令：

```
cd dpdk
sudo meson -D examples=all build
cd build
sudo ninja install
cd examples
sudo ./dpdk-skeleton
```

通过 wireshark，我们可以监听来自虚拟机的 UDP 包，且 UDP 包可以正常解析，内容正确。


README.md - Typora
cdm - VMware Workstation
文件(F) 编辑(E) 查看(V) 虚拟机(M) 选项卡(T) 帮助(H)
正在捕获 VMware Network Adapter VMnet2
文件(F) 编辑(E) 视图(V) 跳转(G) 捕获(C) 分析(A) 统计(S) 电话(Y) 无线(W) 工具(T) 帮助(H)
应用显示过滤器 ... <Ctrl-/>

```
No.   Time        Source         Destination    Protocol Lengtl Info
   35 190.248662  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   36 191.249084  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   37 192.249413  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   38 193.249752  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   39 194.250430  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   40 195.251044  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   41 196.251577  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   42 197.252020  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   43 198.252499  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   44 199.253041  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   45 200.253574  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   46 201.254094  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   47 202.254719  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   48 203.255291  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   49 204.255587  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   50 205.255908  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   51 206.256169  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   52 207.256750  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
   53 208.257246  200.22.247.58  85.40.120.202  UDP      76 38175 → 36895 Len=34
```

```
> Frame 35: 76 bytes on wire (608 bits), 76 bytes captured (608 bits) on interface \De
> Ethernet II, Src: VMware_ad:f4:13 (00:0c:29:ad:f4:13), Dst: VMware_ad:f4:13 (00:0c:2
> Internet Protocol Version 4, Src: 200.22.247.58, Dst: 85.40.120.202
> User Datagram Protocol, Src Port: 38175, Dst Port: 36895
> Data (34 bytes)
```

```
0000  00 0c 29 ad f4 13 00 0c  29 ad f4 13 08 00 45 00   ··)····· )·····E·
0010  00 3e 00 00 00 00 ff 11  2e 6b c8 16 f7 3a 55 28   ·>······ .k···:U(
0020  78 ca 95 1f 90 1f 00 2a  4d 17 68 65 6c 6c 6f 20   x······* M·hello 
0030  66 72 6f 6d 20 76 69 72  74 75 61 6c 20 6d 61 63   from vir tual mac
0040  68 69 6e 65 20 62 79 20  68 70 7a 00               hine by  hpz·
```

```
VMware Network Adapter VMnet2: <live capture in progress>    分组: 53 · 已显示: 53 (100.0%)    配置: Default
```

```
Core 0 forwarding packets. [Ctrl
checkpoint 1
34 42
checkpoint 2
checkpoint 3
checkpoint 4
checkpoint 5
send an udp packet, total=1
send an udp packet, total=2
send an udp packet, total=3
send an udp packet, total=4
send an udp packet, total=5
send an udp packet, total=6
send an udp packet, total=7
send an udp packet, total=8
send an udp packet, total=9
send an udp packet, total=10
send an udp packet, total=11
send an udp packet, total=12
send an udp packet, total=13
send an udp packet, total=14
send an udp packet, total=15
send an udp packet, total=16
send an udp packet, total=17
send an udp packet, total=18
send an udp packet, total=19
send an udp packet, total=20
send an udp packet, total=21
send an udp packet, total=22
send an udp packet, total=23
send an udp packet, total=24
send an udp packet, total=25
```

References

[1] 深入浅出 dpdk chapter1.7 实例讲解

[2] 深入浅出 dpdk chapter6.6 Mbuf 与 Mempool

[3] https://blog.csdn.net/XuVowkin/article/details/117064512

[4] DPDK 总结之常用 API https://blog.csdn.net/gerald_jones/article/details/106600175

[5] DPDK 基础模块之 rte_mbuf 详解 https://www.cnblogs.com/ziding/p/4214499.html

[6] https://en.wikipedia.org/wiki/IPv4