High-level Portable Programming Language for Optimized Memory Use of Network Processors

Yasusi Kanada
Hitachi, Ltd., Central Research Laboratory

1. Introduction

► **Network-processor (NP) programming is important for high-performance networking and in-network processing.**
  - NPs enable quick development of arbitrary protocols and functions.

► **Problems of NP programming:**
  - **No portability** because of hardware/vendor-dependent proprietary tools are required.
  - **Difficulty in development** because of required specialized skill and knowledge (which are not widely available).

► **Focus: Programmers must distinguish SRAM and DRAM to achieve 10-100 Gbps wire-rate packet processing.**
  - Whole packet must be stored in DRAM.
  - Operations on data in DRAM may disable wire-rate processing.
  - NPs might not have cache, or cache mishit may cause serious problems in NPs.

► **Means for solving these problems:**
  - **Phonepl**: an open, high-level, and portable programming language.
  - **Four packet-data representations**, which programmers can be mostly unaware of.

2. Phonepl language design

► Syntax and semantics are close to Java.

- Java/C++ programmers can use Phonepl easily.

► Packets are immutable byte-strings.

- Basic operations on packets are substring, concatenation, etc.
- Non-IP protocols can be programmed easily.
- Immutability enables data sharing among (input/output) packets.

► Byte strings and packets are different types of objects.

- They are handled by quire different methods.

► Assumptions on packet and string data

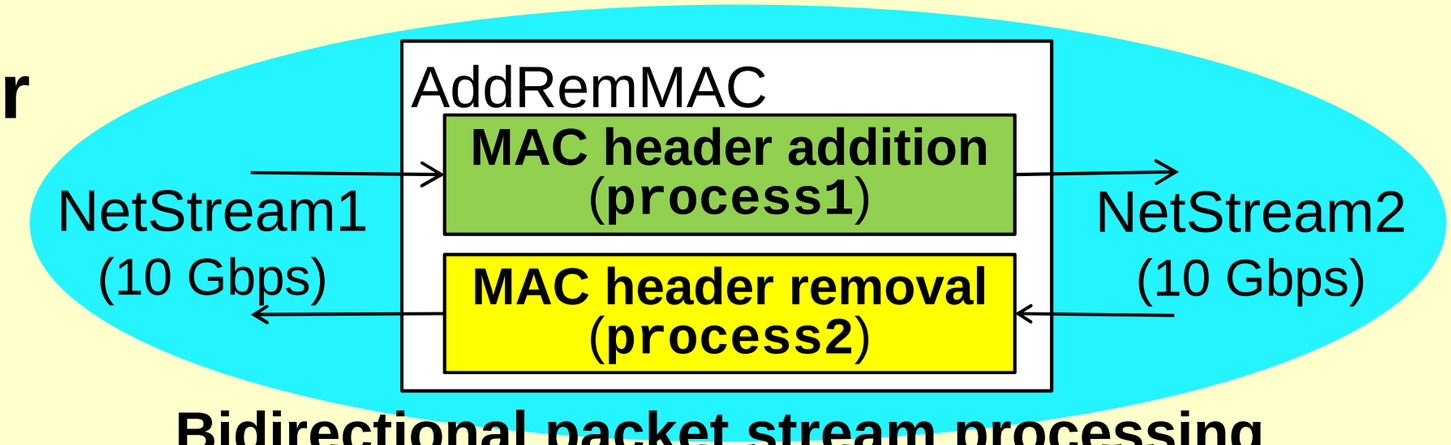
- Whole packet is stored only in DRAM, but the header is in SRAM (cached).
- Whole byte string is cached (in SRAM and maybe stored in DRAM).

► Packet and byte string operations

- **`substring`** and **`subpacket`** operations
  - **`subpacket`** generates a packet from part of a packet.
  - **`substring`** generates a byte string from part of a packet or string.
- Concatenation operations
  - **`concat`** generates a byte string from byte strings.
  - **`“new Packet”`** generates a packet from byte strings and a packet.
  - No methods for concatenating two or more packets.

3. Phonepl program example

► **Simple MAC header addition/removal**



Bidirectional packet stream processing

```
001 import NetStream1;
002 import NetStream2;
003 class AddRemMAC {
004    NetStream out1;
005    NetStream out2;
006    public AddRemMAC(NetStream port1 > process1,
007                     NetStream port2 > process2) {
008       out1 = port1;
009       out2 = port2;
010    }
011    void process1(Packet i) {    // Port 1 to 2 (no VLAN -> no VLAN)
012       Packet o = new Packet(i.substring(0,14),i); // MAC header of original packet
013       out2.put(o);
014    }
015    void process2(Packet i) {    // Port 2 to 1 (no VLAN -> no VLAN)
016       Packet o = i.subpacket(14); // remove MAC header (no VLAN)
017       out1.put(o);
018    }
019    void main() {
020       new AddRemMAC(new NetStream1(), new NetStream2());
022    }
023 }
```

Two packet I/O streams

Input to port1 is passed to process1

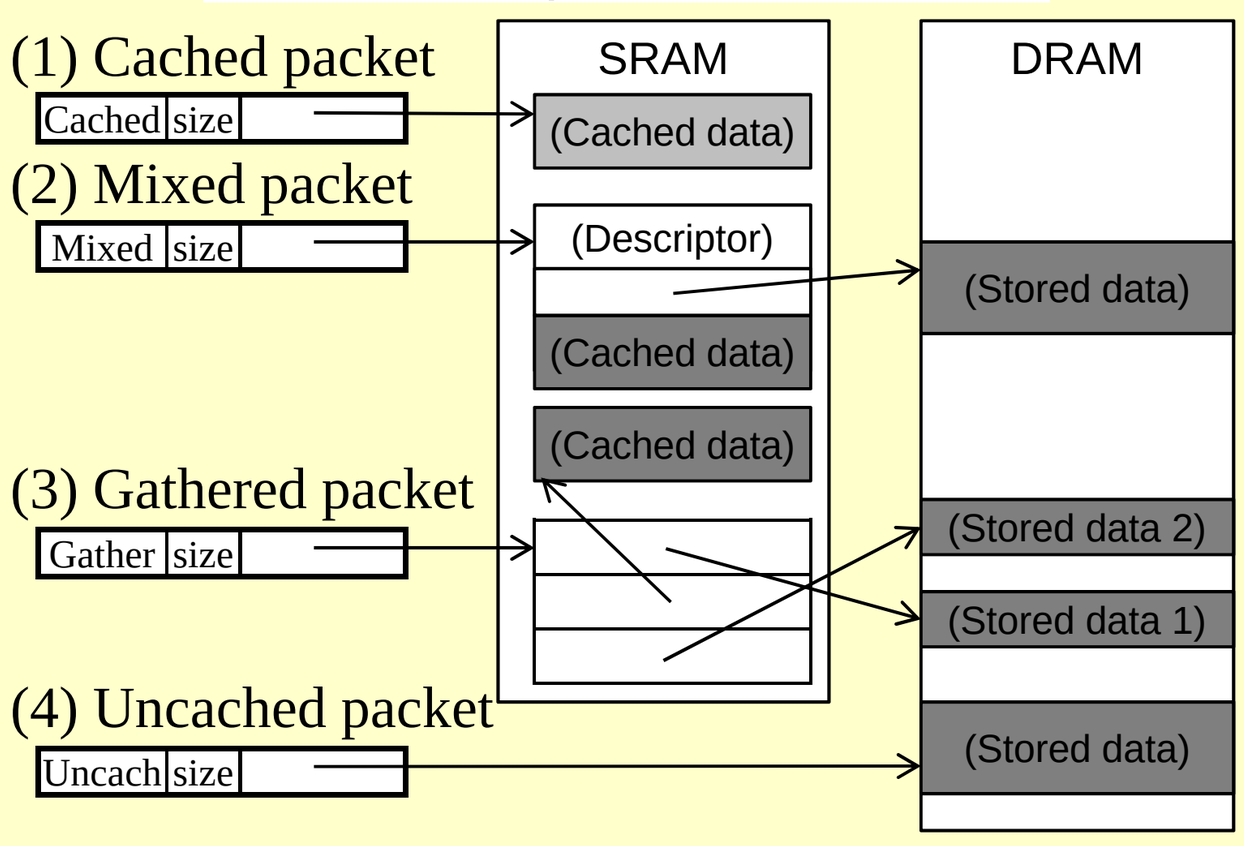
Input to port2 is passed to process2

Object that process packets (singleton) is created.

4. Implementation method

- **A Phonepl implementation selects four packet representations statically or dynamically.**
- **Four representations of `packet` type**
  - **Cached**: whole packet is in SRAM.
    - No copy is assumed to be in DRAM.
  - **Mixed**: whole packet is in DRAM and packet header is in SRAM.
    - Header size is variable.
  - **Gathered**: packet consists of multiple fragments.
    - Represented by an array or list of fragments.
  - **Uncached**: whole packet is in DRAM
    - No copy is assumed to be in SRAM.

Outline of packet data structure: Four representations



5. Prototyping and Evaluation

► Prototype

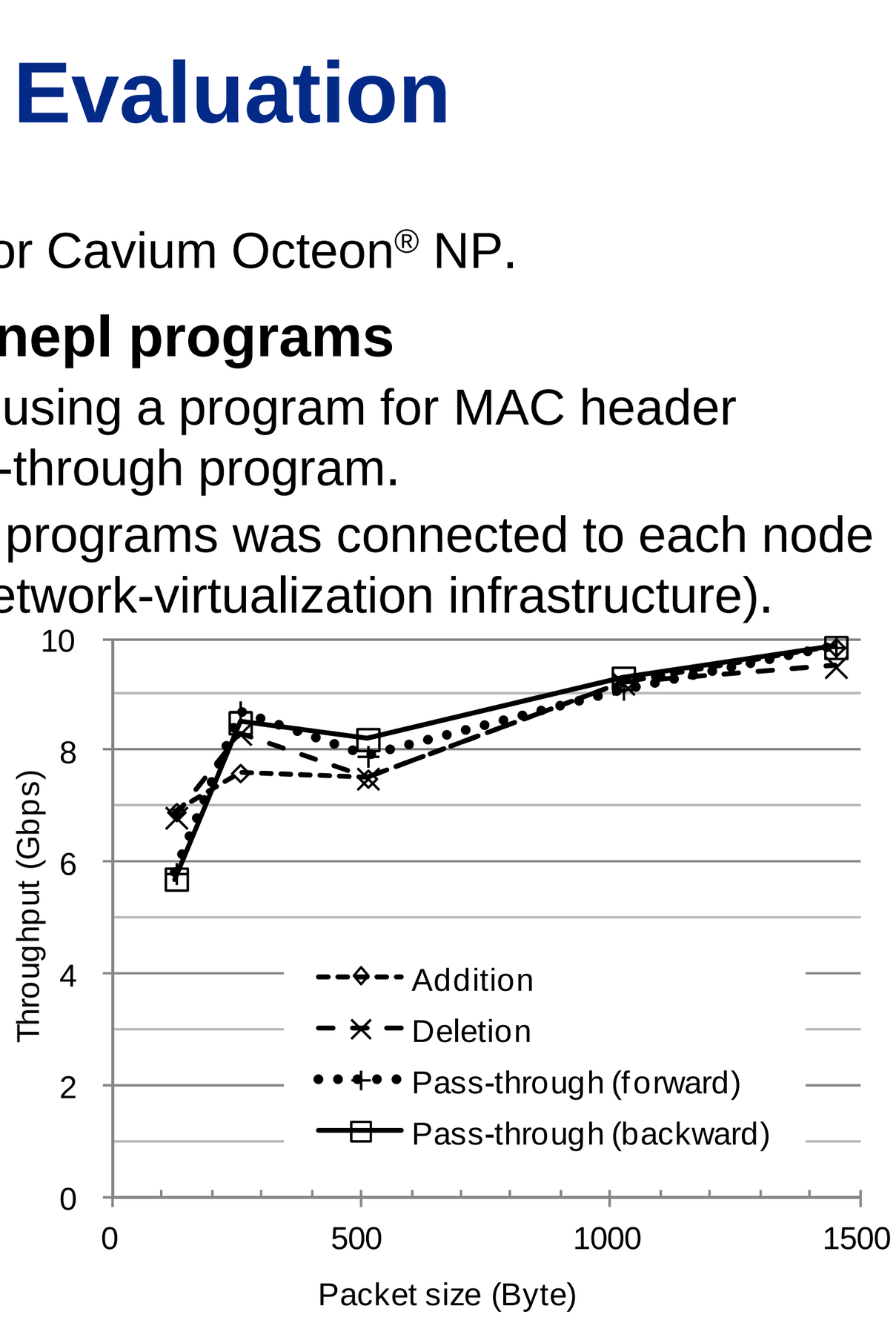
- Phonepl was implemented for Cavium Octeon® NP.

► Evaluation using two Phonepl programs

- Prototype was evaluated by using a program for MAC header addition/deletion and a pass-through program.
- An Octeon board with these programs was connected to each node in VNode Infrastructure (a network-virtualization infrastructure).
  - NP Board: GE WANic 56512

► Evaluation result

- The throughput was over 7.5 Gbps (close to 10-Gbps wire-rate).

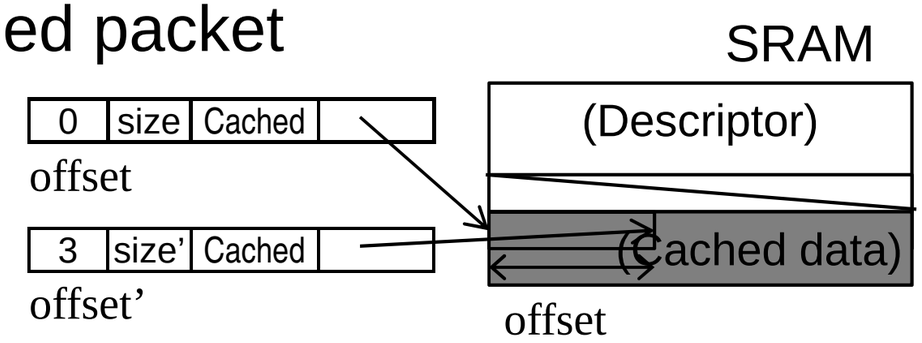


6. Conclusion

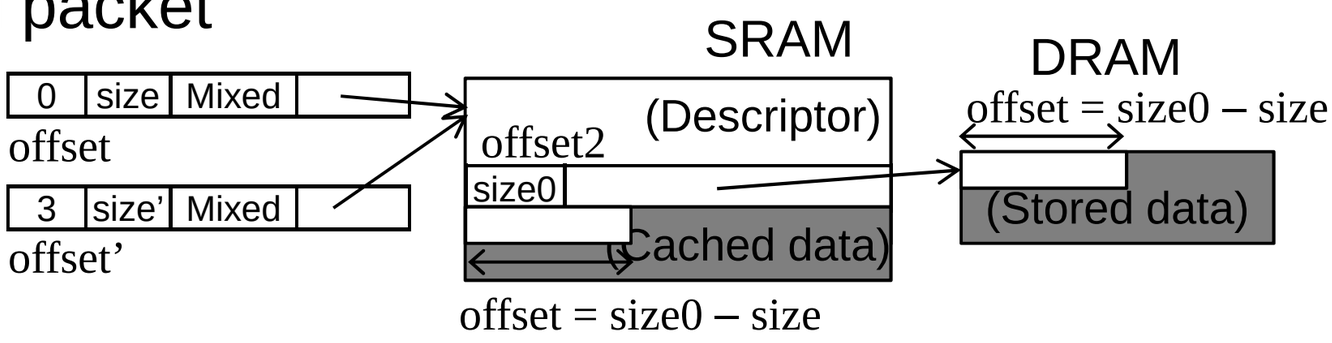
- **To make NP programming easier, Phonepl language and a method for implementing Phonepl are proposed.**
  - Programmers can use SRAM and DRAM appropriately without distinguishing them.
  - Four representations of packet type and usage of them were proposed.
- **The evaluation result shows Phonepl for Octeon NP enables high throughput (close to 10-Gbps wire-rate) in simple packet processing.**

Appendix: Detailed packet data structures

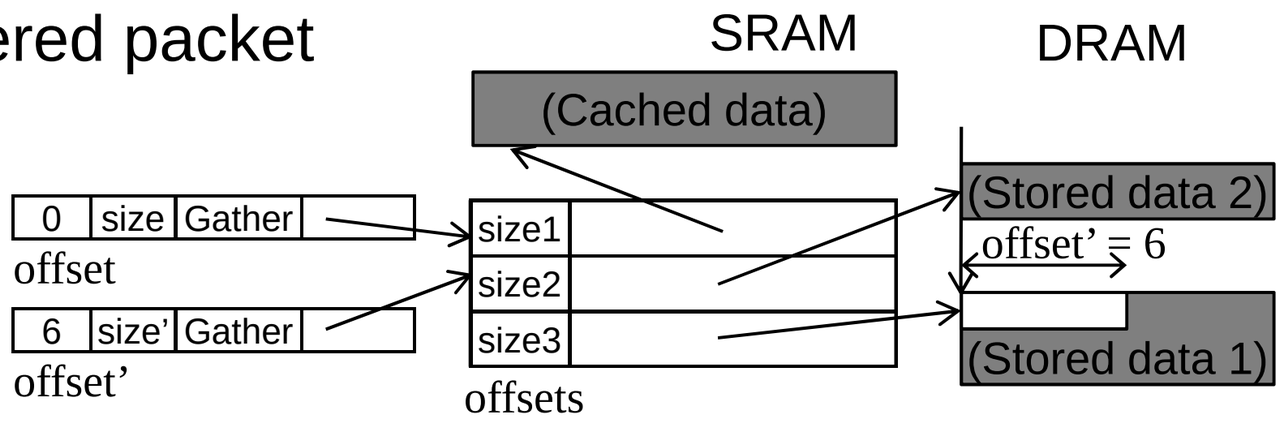
(1) Cached packet



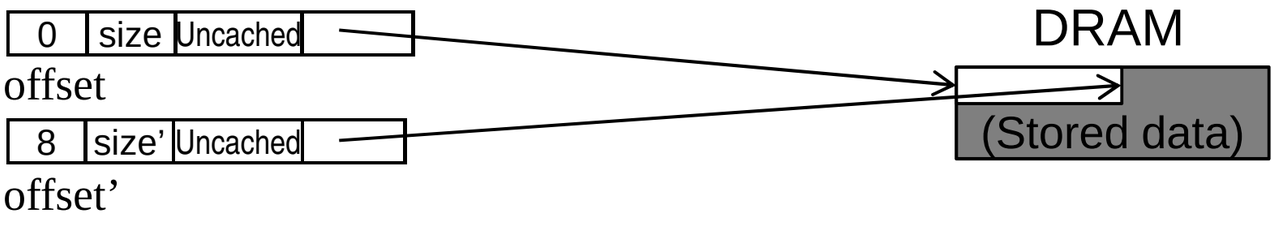
(2) Mixed packet



(3) Gathered packet



(4) Uncached packet



Appendix: Detailed usage of four representations

► Mixed representation is required.

- In packet processing, only packet headers are usually processed.
- In such cases, it is better to store only packet headers to SRAM and tails to DRAM.

► Gathered representation is required.

- This representation is useful when generating a packet by concatenating multiple data in DRAM or SRAM.
- If trying to collect whole data into contiguous area in DRAM, DRAM to DRAM copy, which requires much time, is required.

► State transition between four representations