Distributed Computing

Lesson 6: Data Types and Marshalling

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Outline

1. Data Types and Marshalling

website

Overview

- What to consider when exchanging data between hosts in a heterogeneous system?

Introduction

- Heterogeneous distributed system can consist of computers that...

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- Marshalling [1]: Transforming data into a representation that can be sent to a different computer/process

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- The bit-representation of a `double` on one computer may make no sense at all at another one
- Marshalling [1]: Transforming data into a representation that can be sent to a different computer/process
- Unmarshalling: Transforming received marshalled data into the internal representation used in a given computer/process

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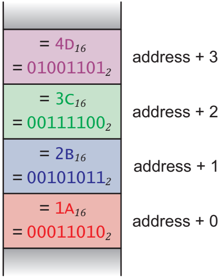
$$
\begin{aligned}
x &= 439\,041\,101_{10}\\
&= 1A\ 2B\ 3C\ 4D_{16}\\
&= 00011010\ 00101011\ 00111100\ 01001101_{2}
\end{aligned}
$$



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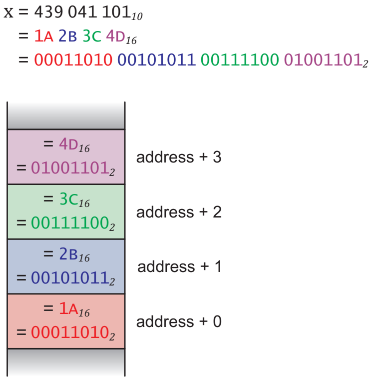
  - e.g., MIPS, SPARC, PowerPC, Motorola 6800/68k, Atmel AVR32, and TMS9900 processors



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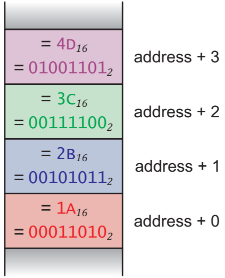

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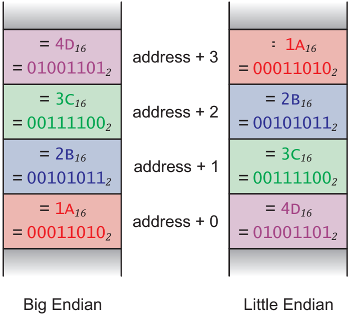

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  - e.g., 80x86-compatible, Alpha, Altera Nios, Atmel AVR, some SH3/SH4-Systems, and VAX

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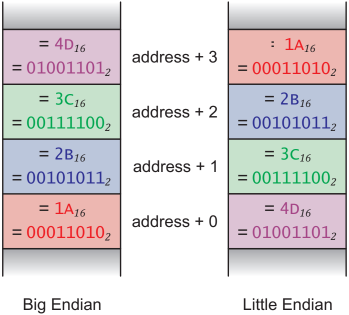

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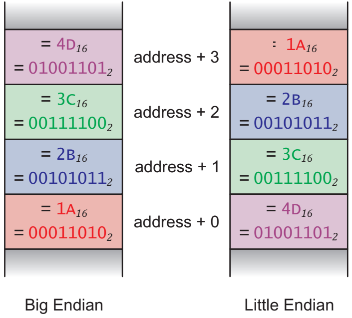

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- It is usually unknown what endianness a communication partner has

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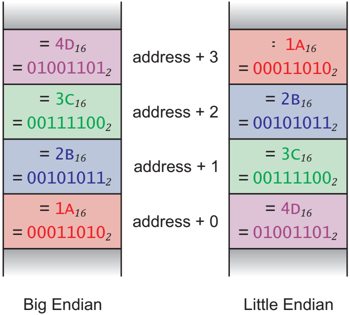

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- Upon arrival, data is translated from network byte order to host byte order
- Internet protocol stack: network byte order = Big Endian

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- These functions translate between host byte order and Big Endian
- Not for 64bit `int`s, as such long integers were not available when API was designed [2]

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- UDP sockets: create the packets in memory:
  - `ByteArrayOutputStream`s are output streams which store all data written to them as `byte`
  - `ByteArrayInputStream`s are input streams which take their data from an array of bytes

Listing: TCPServerStructuredData.java Structured Data: TCP Server / Java

```java
import java.io.DataInputStream;   import java.io.DataOutputStream;
import java.net.ServerSocket;     import java.net.Socket;

public class TCPServerStructuredData {
  public static final void main(final String[] args) {
    ServerSocket      server;       Socket            client;
    DataOutputStream  dos;          DataInputStream   dis;
    String            s;            long              a, b,r;

    try {
      server = new ServerSocket(9996);//1 + 2)

      for (int j = 5; (--j) >= 0;) { //process only 5 clients, so I can show 5) below
        client = server.accept();    //3)

        dis = new DataInputStream(client.getInputStream()); //4 + 3
        s   = dis.readUTF();       //read an UTF-encoded string: the operation
        r   = a = dis.readLong(); //read a 64 bit long integer
        b   = dis.readLong();     //read another 64 bit long int
        if ("add".equalsIgnoreCase(s)) { r += b; } else { // add
          if ("sub".equalsIgnoreCase(s)) { r -= b;  }     // subtract
        }  //4 + 3)

        System.out.println(s + "(" + a + ", " + b + ") = " + r + " to " + client.getRemoteSocketAddress());

        dos = new DataOutputStream(client.getOutputStream()); //marshall output
        dos.writeLong(r); //write 64bit long integer: 4 + 3)
        dos.close(); // flush and close

        client.close(); //4)
      }
      server.close(); //5)
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

Structured Data: TCP Client / Java

Listing: TCPClientStructuredData.java Structured Data: TCP Client / Java

```
import java.io.DataInputStream;    import java.io.DataOutputStream;
import java.net.InetAddress;       import java.net.Socket;

public class TCPClientStructuredData {

  public static final void main(final String[] args) {
    Socket            client;     InetAddress      ia;
    DataOutputStream  dos;        DataInputStream  dis;

    try {
      ia = InetAddress.getByName("localhost");

      client = new Socket(ia, 9996); //1+2)

      dos = new DataOutputStream(client.getOutputStream()); //marshall data
      dos.writeUTF("sub"); //send operation name 3)
      dos.writeLong(9876); //send 64bit long integer
      dos.writeLong(1234); //send another 64bit long integer
      dos.flush();  //flush is important, otherwise stuff may just be buffered!

      dis = new DataInputStream(client.getInputStream()); // unmashall input
      System.out.println("Result: " + dis.readLong());    //3)

      client.close(); //4)
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

Structured Data: UDP Server / Java

Listing: UDPServerStructuredData.java Structured Data: UDP Server / Java

```
import java.io.ByteArrayInputStream;  import java.io.DataInputStream;  import java.io.OutputStream; import
    java.net.DatagramPacket;
import java.io.ByteArrayOutputStream; import java.io.DataOutputStream; import java.net.InetAddress; import
    java.net.DatagramSocket;

public class UDPServerStructuredData {
  public static final void main(final String[] args) {
    DatagramSocket         server;  DatagramPacket    p, answer;
    ByteArrayOutputStream bos;      DataOutputStream  dos;
    ByteArrayInputStream  bis;      DataInputStream   dis;
    byte[]                data;     String            s;
    long                  a, b,r;

    try {
      server = new DatagramSocket(9997); //1)
      data = new byte[2048];

      for (int j = 5; (--j) >= 0;) {
        p = new DatagramPacket(data, data.length); // create package
        server.receive(p);  // receive data 2)

        bis = new ByteArrayInputStream(data, 0, p.getLength());  //wrap in stream 3)
        dis = new DataInputStream(bis); //wrap again for unmarshalling
        s   = dis.readUTF();      //read string with operation id
        r   = a = dis.readLong(); //read 64bit long integer
        b   = dis.readLong();     //read 64bit long integer
        if ("add".equalsIgnoreCase(s)) { r += b; } else { //add
          if ("sub".equalsIgnoreCase(s)) { r -= b;  }     //subtract
        }  //end 3)

        System.out.println(s + "(" + a + ", " + b + ") = " + r + " to " + p.getSocketAddress());

        bos = new ByteArrayOutputStream(); //create buffered stream for answer
        dos = new DataOutputStream(bos); //marshall
        dos.writeLong(r); //write 64bit long with result
        dos.close(); //flush to buffer and close

        answer = new DatagramPacket(bos.toByteArray(), bos.size(), p.getSocketAddress()); //4)
        server.send(answer); //send marshalled answer data
      }
      server.close(); //5)
    } catch (Throwable t) {
      t.printStackTrace();
    }
```

Structured Data: UDP Client / Java

Listing: UDPClientStructuredData.java Structured Data: UDP Client / Java

```
import java.io.ByteArrayInputStream;  import java.io.DataInputStream;  import java.io.OutputStream;
import java.io.ByteArrayOutputStream; import java.io.DataOutputStream; import java.net.InetAddress;
import java.net.DatagramPacket;       import java.net.DatagramSocket;

public class UDPClientStructuredData {
  public static final void main(final String[] args) {
    DatagramSocket  client;         InetAddress           ia;
    ByteArrayOutputStream bos;      DataOutputStream      dos;
    ByteArrayInputStream  bis;      DataInputStream       dis;
    DatagramPacket        p;        byte[]                data;

    try {
      ia = InetAddress.getByName("localhost");
      client = new DatagramSocket();  //create socket 1)

      bos = new ByteArrayOutputStream(); //create buffered stream for building message
      dos = new DataOutputStream(bos);   //mashall data
      dos.writeUTF("add");               //write operation name
      dos.writeLong(1234);               //write 64bit long: 1st operand
      dos.writeLong(9876);               //write 64bit long: 2nd operand
      dos.close();              //flush to buffer and close
      data = bos.toByteArray(); //get array with marshalled data to send

      p = new DatagramPacket(data, data.length, ia, 9997); //create package
      client.send(p);      //send package to server 2)

      client.receive(p); // receive answer
      bis = new ByteArrayInputStream(p.getData(), 0, p.getLength());
      dis = new DataInputStream(bis); //unmarshall
      System.out.println("Result: " + dis.readLong()); //3)

      client.close(); //4)
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

Summary

- All data exists as a sequence of bits and bytes in the memory of a computer.
- Data types and formats are basically contracts regarding how a certain sequence of such bits and bytes is to be interpreted.
- Different programming languages might have different formats for numbers, text (next lesson), and even Boolean values.
- Different CPU architectures might define different formats as well.
- Thus, a sequence of bytes might be interpreted as different number on different computers.
- If data is exchanged, it is thus first marshalled from the sending computer's local format into a network-wide accepted format before sending and then unmarshalled into the receiving computer's local format upon receipt.

谢谢
Thank you

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Caspar David Friedrich, “Der Wanderer über dem Nebelmeer”, 1818
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Bibliography

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