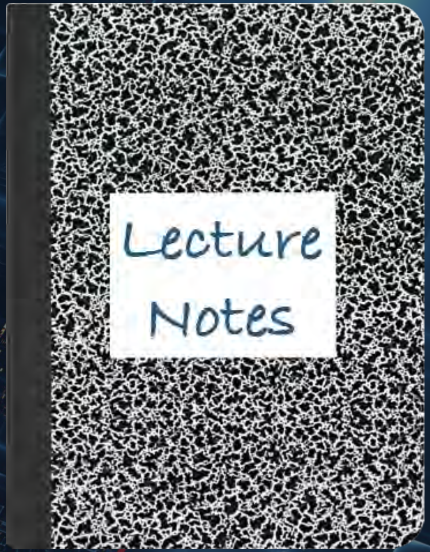
CS 417 – DISTRIBUTED SYSTEMS

Week 2: Part 2

Data Encoding in Remote Procedure Calls



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Sending data over the network

Stream of bytes

```
struct item {
    char name[64];
    unsigned long id;
    int number_in_stock;
    float rating;
    double price;
} scratcher = {
    "Bear Claw Black Telescopic Back Scratcher",
    00120,
    332,
    4.6,
    5.99
}
```

gets stored in memory as:

```
42 65 61 72 20 43 6c 61 77 20 42 6c 61 63 6b 20 54 ...
```

Representing data

No such thing as
incompatibility problems on local system

Remote machine may have:

- Different byte ordering
- Different sizes of integers and other types
- Different floating-point representations
- Different character sets
- Alignment requirements

Integer sizes:

- 8, 16, 32, 64, and 128 bits

Floating point formats:

- IEEE 754 (FP16, P32, FP64, quadruple: 127-bit; octuple: 256 bit)
- Google BFloat16 (Google Brain, supported by NVIDIA)
- NVIDIA TensorFloat (TF32)

String formats:

- ASCII, UTF-8, UTF-16, UTF-32
- Terminated by a 0 byte (C/C++)
- Various object headers (Go, Java, Python)

Representing data

IP (headers) forced all to use **big endian** byte ordering for 16- and 32-bit values

Big endian: Most significant byte in low memory ← *IP headers use big endian*

- Jave Virtual Machine, OpenRISC, Atmel AVR32, IBM z-series, SPARC < V9, Motorola 680x0, older PowerPC

Little endian: Most significant byte in high memory

- Intel/AMD IA-32, x64

Bi-endian: Processor may operate in either mode

- ARM, PowerPC, MIPS, SPARC V9, IA-64 (Intel Itanium)

```
main() {
    unsigned int n;
    char *a = (char *)&n;

    n = 0x11223344;
    printf("%02x, %02x, %02x, %02x\n",
            a[0], a[1], a[2], a[3]);
}
```

Output on an Intel CPU:

```
44, 33, 22, 11
```

Output on a PowerPC:

```
11, 22, 33, 44
```

Representing data: serialization

We need a standard encoding to enable communication between heterogeneous systems

- Serialization
  - Convert data into a pointerless format: *an array of bytes*

- Examples
  - XDR (eXternal Data Representation), used by ONC RPC
  - JSON (JavaScript Object Notation)
  - W3C XML Schema Language
  - ASN.1 (ISO Abstract Syntax Notation)
  - Google Protocol Buffers

Serializing data

Implicit typing

- only values are transmitted, not data types or parameter info
- e.g., ONC XDR (RFC 4506)

Explicit typing

- Type is transmitted with each value
- e.g., ISO's ASN.1, XML, protocol buffers, JSON

Marshaling vs. serialization – almost synonymous – *serialization* is used in *marshaling*:

Serialization: converting an object into a sequence of bytes that can be sent over a network

Marshaling: bundling parameters into a form that can be reconstructed (unmarshaled) by another process. May include object ID or other state. Marshaling uses serialization.

XML: eXtensible Markup Language

```
<ShoppingCart>
    <Items>
        <Item>
            <ItemID> 00120 </ItemID>
            <Item> Bear Claw Black Telescopic Back Scratcher </Item>
            <Price> 5.99 </Price>
        </Item>
        <item>
            <ItemID> 00121 </ItemID>
            <Item> Scalp Massager </Item>
            <Price> 5.95 </Price>
        </Item>
    </Items>
</ShoppingCart>
```

Benefits:

- Human-readable
- Human-editable
- Interleaves structure with text (data)

Problems:

- Verbose: transmit more data than needed
- Longer parsing time
- Data conversion always required for numbers

JSON: JavaScript Object Notation

- Lightweight (relatively efficient) data interchange format
  - Introduced as the "*fat-free alternative to XML*"
  - Based on JavaScript
- Human writeable and readable
- Self-describing (explicitly typed)
- Language independent
- Easy to parse
- Currently converters for 50+ languages
- Includes support for RPC invocation via JSON-RPC

JSON Data Encoding Example

```
{
        "items": [
                {
                        "item_id": 00120,
                        "item:": " Bear Claw Black Telescopic Back Scratcher",
                        "cost": "5.99"
                }
                {
                        "item_id": 00121,
                        "item:": " Scalp Massager r",
                        "cost": "5.95"
                }
        ]
}
```

Google Protocol Buffers

- Efficient mechanism for serializing structured data
  - Much simpler, smaller, and faster than XML or JSON
- Language independent
- Define messages
  - Each message is a set of names and types
- Compile the messages to generate data access classes for your language
- Used extensively within Google
  - Currently over 48,000 different message types defined
  - Used both for RPC and for persistent storage

Example (from the Developer Guide)

```
message Person {
  required string name = 1;
  required int32 id = 2;
  optional string email = 3;

  enum PhoneType {
    MOBILE = 0;
    HOME = 1;
    WORK = 2;
  }

  message PhoneNumber {
    required string number = 1;
    optional PhoneType type = 2 [default = HOME];
  }

  repeated PhoneNumber phone = 4;
}
```

http://code.google.com/apis/protocolbuffers/docs/overview.html

Example (from the Developer Guide)

```
Person person;
person.set_name("John Doe");
person.set_id(1234);
person.set_email("jdoe@example.com");
fstream output("myfile", ios::out | ios::binary);
person.SerializeToOstream(&output);
```

http://code.google.com/apis/protocolbuffers/docs/overview.html

Efficiency example (from the Developer Guide)

```
<person>
    <name>John Doe</name>
    <email>jdoe@example.com</email>
</person>
```

XML version

```
person {
   name: "John Doe"
   email: "jdoe@example.com"
}
```

Text (uncompiled) protocol buffer

- Binary encoded message: ~28 bytes long, 100-200 ns to parse
- XML version: ≥ 69 bytes, 5,000-10,000 ns to parse
- In general,
  - 3-10x smaller data
  - 20-100 times faster to marshal/unmarshal
  - Easier to use programmatically

http://code.google.com/apis/protocolbuffers/docs/overview.html

The End