Rapport de Projet : Développement d'Applications Réparties

Analyse comparative RPC : XML-RPC, XDR-RPC, JSON-RPC, REST/JSON, gRPC

Module : Développement d'Applications Réparties
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1. Introduction

Ce projet explore cinq protocoles **Remote Procedure Call (RPC)** : XML-RPC, XDR-RPC, JSON-RPC, REST/JSON et gRPC. Pour chaque protocole, nous avons implémenté un serveur et client Python, capturé le trafic réseau avec Wireshark, puis analysé les différences de sérialisation, taille des trames et lisibilité.

Objectifs : Comparer format sur le fil, lisibilité, sécurité transport et cas d'usage pour chaque protocole RPC.

2. Environnement & Configuration

Technologies

- **Python 3.9+**, Wireshark 4.0+
- **Bibliothèques :** xmlrpc (stdlib), struct, Flask, requests, grpcio, grpcio-tools

Ports utilisés

Protocole	Port	Fonction
XML-RPC	9000	Addition de deux entiers
XDR-RPC	9001	Inversion d'une chaîne
JSON-RPC	9001	Minimum de deux valeurs
REST/JSON	9002	POST /reverse (inversion)
gRPC	50051	Longueur d'une chaîne

3. Protocole XML-RPC

Synthèse

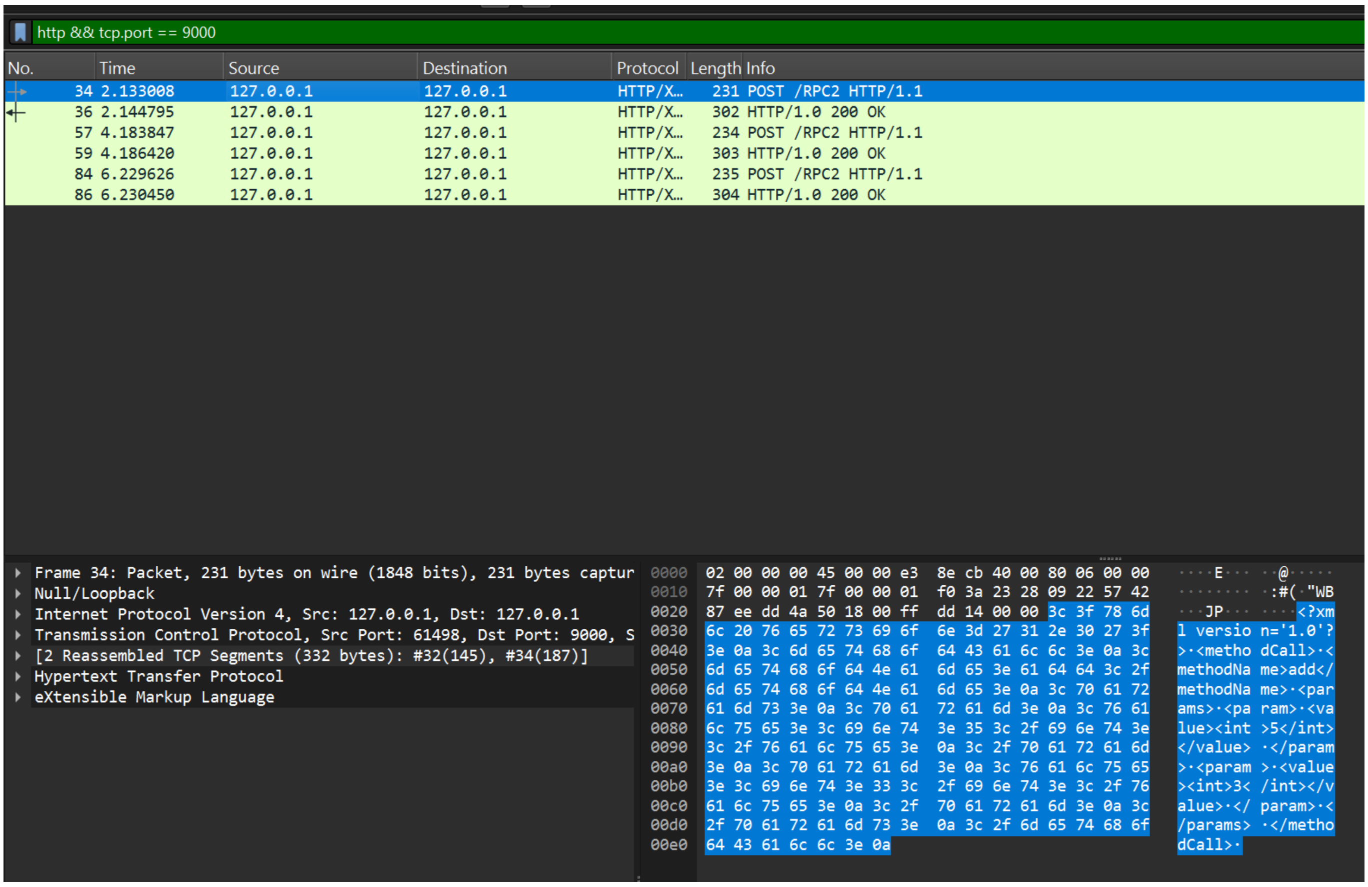
XML-RPC sérialise en XML sur HTTP. Format textuel très lisible mais verbeux.

Implémentation

```python
# Serveur
from xmlrpc.server import SimpleXMLRPCServer
def add(x, y): return x + y
server = SimpleXMLRPCServer(('localhost', 9000))
server.register_function(add, 'add')
server.serve_forever()

# Client
import xmlrpc.client
proxy = xmlrpc.client.ServerProxy('http://localhost:9000')
print(proxy.add(5, 3))  # Output: 8
```

Analyse Wireshark

Requête HTTP POST contenant XML :



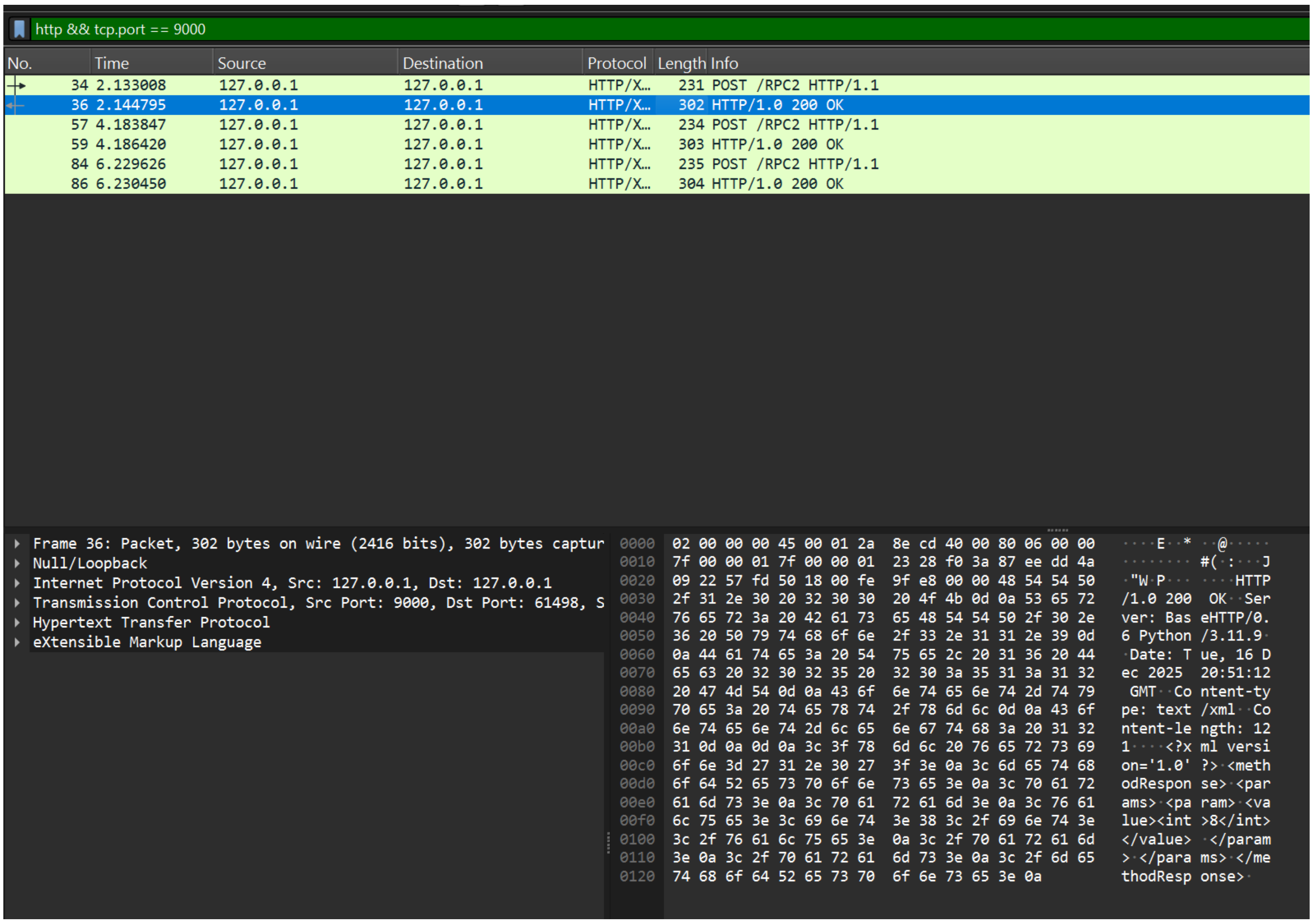
```
http && tcp.port == 9000

No.   Time      Source     Destination  Protocol  Length Info
   34 2.133008  127.0.0.1  127.0.0.1    HTTP/X…   231 POST /RPC2 HTTP/1.1
   36 2.144795  127.0.0.1  127.0.0.1    HTTP/X…   302 HTTP/1.0 200 OK
   57 4.183847  127.0.0.1  127.0.0.1    HTTP/X…   234 POST /RPC2 HTTP/1.1
   59 4.186420  127.0.0.1  127.0.0.1    HTTP/X…   303 HTTP/1.0 200 OK
   84 6.229626  127.0.0.1  127.0.0.1    HTTP/X…   235 POST /RPC2 HTTP/1.1
   86 6.230450  127.0.0.1  127.0.0.1    HTTP/X…   304 HTTP/1.0 200 OK
```

```
Frame 34: Packet, 231 bytes on wire (1848 bits), 231 bytes captur
Null/Loopback
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
Transmission Control Protocol, Src Port: 61498, Dst Port: 9000, S
[2 Reassembled TCP Segments (332 bytes): #32(145), #34(187)]
Hypertext Transfer Protocol
eXtensible Markup Language
```

```
0000  02 00 00 00 45 00 00 e3  8e cb 40 00 80 06 00 00   ····E··· ··@·····
0010  7f 00 00 01 7f 00 00 01  f0 3a 23 28 09 22 57 42   ········ ·:#(·"WB
0020  87 ee dd 4a 50 18 00 ff  dd 14 00 00 3c 3f 78 6d   ···JP··· ····<?xm
0030  6c 20 76 65 72 73 69 6f  6e 3d 27 31 2e 30 27 3f   l versio n='1.0'?
0040  3e 0a 3c 6d 65 74 68 6f  64 43 61 6c 6c 3e 0a 3c   >·<metho dCall>·<
0050  6d 65 74 68 6f 64 4e 61  6d 65 3e 61 64 64 3c 2f   methodNa me>add</
0060  6d 65 74 68 6f 64 4e 61  6d 65 3e 0a 3c 70 61 72   methodNa me>·<par
0070  61 6d 73 3e 0a 3c 70 61  72 61 6d 3e 0a 3c 76 61   ams>·<pa ram>·<va
0080  6c 75 65 3e 3c 69 6e 74  3e 35 3c 2f 69 6e 74 3e   lue><int >5</int>
0090  3c 2f 76 61 6c 75 65 3e  0a 3c 2f 70 61 72 61 6d   </value> ·</param
00a0  3e 0a 3c 70 61 72 61 6d  3e 0a 3c 76 61 6c 75 65   >·<param >·<value
00b0  3e 3c 69 6e 74 3e 33 3c  2f 69 6e 74 3e 3c 2f 76   ><int>3< /int></v
00c0  61 6c 75 65 3e 0a 3c 2f  70 61 72 61 6d 3e 0a 3c   alue>·</ param>·<
00d0  2f 70 61 72 61 6d 73 3e  0a 3c 2f 6d 65 74 68 6f   /params> ·</metho
00e0  64 43 61 6c 6c 3e 0a                               dCall>·
```

Observations : Frame ≈231 bytes. Payload XML `<methodCall><methodName>add</methodName>` totalement lisible.

Réponse HTTP 200 OK avec XML :



```
http && tcp.port == 9000

No.     Time       Source       Destination   Protocol  Length Info
     34 2.133008   127.0.0.1    127.0.0.1     HTTP/X…   231 POST /RPC2 HTTP/1.1
     36 2.144795   127.0.0.1    127.0.0.1     HTTP/X…   302 HTTP/1.0 200 OK
     57 4.183847   127.0.0.1    127.0.0.1     HTTP/X…   234 POST /RPC2 HTTP/1.1
     59 4.186420   127.0.0.1    127.0.0.1     HTTP/X…   303 HTTP/1.0 200 OK
     84 6.229626   127.0.0.1    127.0.0.1     HTTP/X…   235 POST /RPC2 HTTP/1.1
     86 6.230450   127.0.0.1    127.0.0.1     HTTP/X…   304 HTTP/1.0 200 OK
```

```
Frame 36: Packet, 302 bytes on wire (2416 bits), 302 bytes captur
Null/Loopback
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
Transmission Control Protocol, Src Port: 9000, Dst Port: 61498, S
Hypertext Transfer Protocol
eXtensible Markup Language
```

```
0000  02 00 00 00 45 00 01 2a  8e cd 40 00 80 06 00 00   ····E··* ··@·····
0010  7f 00 00 01 7f 00 00 01  23 28 f0 3a 87 ee dd 4a   ········ #(·:···J
0020  09 22 57 fd 50 18 00 fe  9f e8 00 00 48 54 54 50   ·"W·P··· ····HTTP
0030  2f 31 2e 30 20 32 30 30  20 4f 4b 0d 0a 53 65 72   /1.0 200  OK··Ser
0040  76 65 72 3a 20 42 61 73  65 48 54 54 50 2f 30 2e   ver: Bas eHTTP/0.
0050  36 20 50 79 74 68 6f 6e  2f 33 2e 31 31 2e 39 0d   6 Python /3.11.9·
0060  0a 44 61 74 65 3a 20 54  75 65 2c 20 31 36 20 44   ·Date: T ue, 16 D
0070  65 63 20 32 30 32 35 20  32 30 3a 35 31 3a 31 32   ec 2025  20:51:12
0080  20 47 4d 54 0d 0a 43 6f  6e 74 65 6e 74 2d 74 79    GMT··Co ntent-ty
0090  70 65 3a 20 74 65 78 74  2f 78 6d 6c 0d 0a 43 6f   pe: text /xml··Co
00a0  6e 74 65 6e 74 2d 6c 65  6e 67 74 68 3a 20 31 32   ntent-le ngth: 12
00b0  31 0d 0a 0d 0a 3c 3f 78  6d 6c 20 76 65 72 73 69   1····<?x ml versi
00c0  6f 6e 3d 27 31 2e 30 27  3f 3e 0a 3c 6d 65 74 68   on='1.0' ?>·<meth
00d0  6f 64 52 65 73 70 6f 6e  73 65 3e 0a 3c 70 61 72   odRespon se>·<par
00e0  61 6d 73 3e 0a 3c 70 61  72 61 6d 3e 0a 3c 76 61   ams>·<pa ram>·<va
00f0  6c 75 65 3e 3c 69 6e 74  3e 38 3c 2f 69 6e 74 3e   lue><int >8</int>
0100  3c 2f 76 61 6c 75 65 3e  0a 3c 2f 70 61 72 61 6d   </value> ·</param
0110  3e 0a 3c 2f 70 61 72 61  6d 73 3e 0a 3c 2f 6d 65   >·</para ms>·</me
0120  74 68 6f 64 52 65 73 70  6f 6e 73 65 3e 0a         thodResp onse>·
```

Observations : Frame ≈302 bytes. `<methodResponse><int>8</int>` visible en clair. Verbosité XML augmente la taille.

Analyse : Lisibilité ★★★★★, Taille importante, HTTP/HTTPS pour sécurité, idéal pour debugging.

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4. Protocole XDR-RPC

Synthèse

XDR encode en binaire (big-endian). Compact mais illisible sans décodeur.

Implémentation

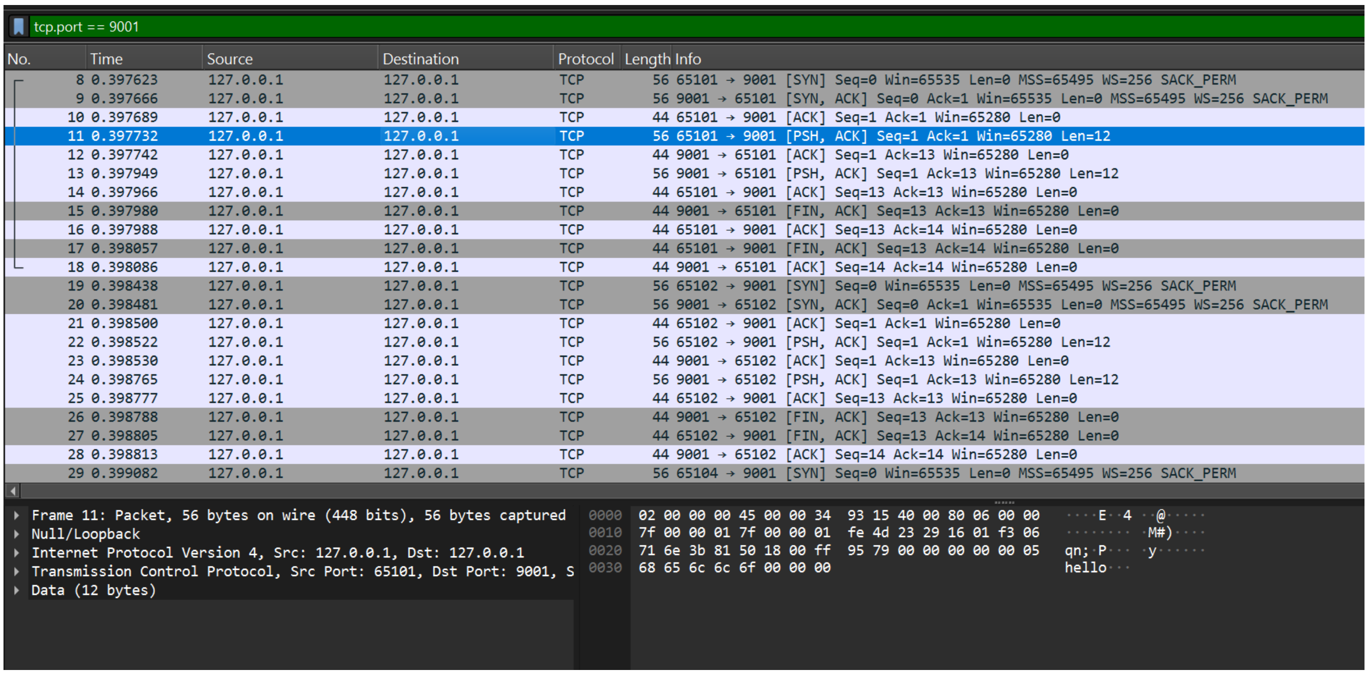
```python
# Serveur
import struct
from http.server import HTTPServer, BaseHTTPRequestHandler

class XDRHandler(BaseHTTPRequestHandler):
    def do_POST(self):
        body = self.rfile.read(int(self.headers['Content-Length']))
        str_len, = struct.unpack('!I', body[:4])
        input_str = body[4:4+str_len].decode('utf-8')
        result = input_str[::-1]  # Inverse
        response = struct.pack('!I', len(result)) + result.encode()
        self.send_response(200)
        self.end_headers()
        self.wfile.write(response)

server = HTTPServer(('localhost', 9001), XDRHandler)
server.serve_forever()
```

Analyse Wireshark

Requête TCP avec payload binaire XDR :



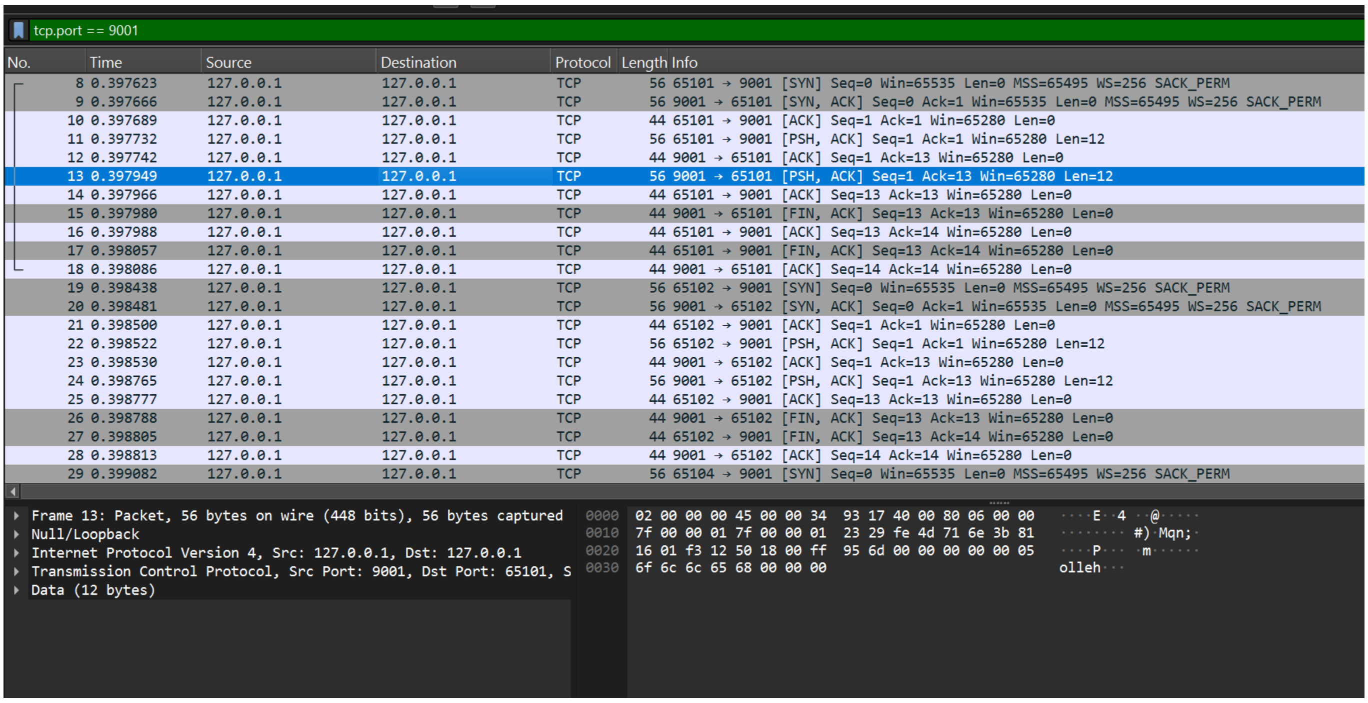
```
tcp.port == 9001
No.  Time       Source     Destination  Protocol  Length Info
  8 0.397623  127.0.0.1  127.0.0.1  TCP  56 65101 → 9001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
  9 0.397666  127.0.0.1  127.0.0.1  TCP  56 9001 → 65101 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
 10 0.397689  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [ACK] Seq=1 Ack=1 Win=65280 Len=0
 11 0.397732  127.0.0.1  127.0.0.1  TCP  56 65101 → 9001 [PSH, ACK] Seq=1 Ack=1 Win=65280 Len=12
 12 0.397742  127.0.0.1  127.0.0.1  TCP  44 9001 → 65101 [ACK] Seq=1 Ack=13 Win=65280 Len=0
 13 0.397949  127.0.0.1  127.0.0.1  TCP  56 9001 → 65101 [PSH, ACK] Seq=1 Ack=13 Win=65280 Len=12
 14 0.397966  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [ACK] Seq=13 Ack=13 Win=65280 Len=0
 15 0.397980  127.0.0.1  127.0.0.1  TCP  44 9001 → 65101 [FIN, ACK] Seq=13 Ack=13 Win=65280 Len=0
 16 0.397988  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [ACK] Seq=13 Ack=14 Win=65280 Len=0
 17 0.398057  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [FIN, ACK] Seq=13 Ack=14 Win=65280 Len=0
 18 0.398086  127.0.0.1  127.0.0.1  TCP  44 9001 → 65101 [ACK] Seq=14 Ack=14 Win=65280 Len=0
 19 0.398438  127.0.0.1  127.0.0.1  TCP  56 65102 → 9001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
 20 0.398481  127.0.0.1  127.0.0.1  TCP  56 9001 → 65102 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
 21 0.398500  127.0.0.1  127.0.0.1  TCP  44 65102 → 9001 [ACK] Seq=1 Ack=1 Win=65280 Len=0
 22 0.398522  127.0.0.1  127.0.0.1  TCP  56 65102 → 9001 [PSH, ACK] Seq=1 Ack=1 Win=65280 Len=12
 23 0.398530  127.0.0.1  127.0.0.1  TCP  44 9001 → 65102 [ACK] Seq=1 Ack=13 Win=65280 Len=0
 24 0.398765  127.0.0.1  127.0.0.1  TCP  56 9001 → 65102 [PSH, ACK] Seq=1 Ack=13 Win=65280 Len=12
 25 0.398777  127.0.0.1  127.0.0.1  TCP  44 65102 → 9001 [ACK] Seq=13 Ack=13 Win=65280 Len=0
 26 0.398788  127.0.0.1  127.0.0.1  TCP  44 9001 → 65102 [FIN, ACK] Seq=13 Ack=13 Win=65280 Len=0
 27 0.398805  127.0.0.1  127.0.0.1  TCP  44 65102 → 9001 [FIN, ACK] Seq=13 Ack=14 Win=65280 Len=0
 28 0.398813  127.0.0.1  127.0.0.1  TCP  44 9001 → 65102 [ACK] Seq=14 Ack=14 Win=65280 Len=0
 29 0.399082  127.0.0.1  127.0.0.1  TCP  56 65104 → 9001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM

› Frame 11: Packet, 56 bytes on wire (448 bits), 56 bytes captured
› Null/Loopback
› Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
› Transmission Control Protocol, Src Port: 65101, Dst Port: 9001, S
› Data (12 bytes)

0000  02 00 00 00 45 00 00 34  93 15 40 00 80 06 00 00   ····E··4 ··@·····
0010  7f 00 00 01 7f 00 00 01  fe 4d 23 29 16 01 f3 06   ········ ·M#)····
0020  71 6e 3b 81 50 18 00 ff  95 79 00 00 00 00 00 05   qn;·P··· ·y······
0030  68 65 6c 6c 6f 00 00 00                            hello···
```

Observations : Frame ≈56 bytes. Data (12 bytes) en binaire, visible seulement en hex dump.

Réponse TCP avec XDR binaire :



```
tcp.port == 9001
No.  Time       Source     Destination  Protocol  Length Info
  8 0.397623  127.0.0.1  127.0.0.1  TCP  56 65101 → 9001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
  9 0.397666  127.0.0.1  127.0.0.1  TCP  56 9001 → 65101 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
 10 0.397689  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [ACK] Seq=1 Ack=1 Win=65280 Len=0
 11 0.397732  127.0.0.1  127.0.0.1  TCP  56 65101 → 9001 [PSH, ACK] Seq=1 Ack=1 Win=65280 Len=12
 12 0.397742  127.0.0.1  127.0.0.1  TCP  44 9001 → 65101 [ACK] Seq=1 Ack=13 Win=65280 Len=0
 13 0.397949  127.0.0.1  127.0.0.1  TCP  56 9001 → 65101 [PSH, ACK] Seq=1 Ack=13 Win=65280 Len=12
 14 0.397966  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [ACK] Seq=13 Ack=13 Win=65280 Len=0
 15 0.397980  127.0.0.1  127.0.0.1  TCP  44 9001 → 65101 [FIN, ACK] Seq=13 Ack=13 Win=65280 Len=0
 16 0.397988  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [ACK] Seq=13 Ack=14 Win=65280 Len=0
 17 0.398057  127.0.0.1  127.0.0.1  TCP  44 65101 → 9001 [FIN, ACK] Seq=13 Ack=14 Win=65280 Len=0
 18 0.398086  127.0.0.1  127.0.0.1  TCP  44 9001 → 65101 [ACK] Seq=14 Ack=14 Win=65280 Len=0
 19 0.398438  127.0.0.1  127.0.0.1  TCP  56 65102 → 9001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
 20 0.398481  127.0.0.1  127.0.0.1  TCP  56 9001 → 65102 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM
 21 0.398500  127.0.0.1  127.0.0.1  TCP  44 65102 → 9001 [ACK] Seq=1 Ack=1 Win=65280 Len=0
 22 0.398522  127.0.0.1  127.0.0.1  TCP  56 65102 → 9001 [PSH, ACK] Seq=1 Ack=1 Win=65280 Len=12
 23 0.398530  127.0.0.1  127.0.0.1  TCP  44 9001 → 65102 [ACK] Seq=1 Ack=13 Win=65280 Len=0
 24 0.398765  127.0.0.1  127.0.0.1  TCP  56 9001 → 65102 [PSH, ACK] Seq=1 Ack=13 Win=65280 Len=12
 25 0.398777  127.0.0.1  127.0.0.1  TCP  44 65102 → 9001 [ACK] Seq=13 Ack=13 Win=65280 Len=0
 26 0.398788  127.0.0.1  127.0.0.1  TCP  44 9001 → 65102 [FIN, ACK] Seq=13 Ack=13 Win=65280 Len=0
 27 0.398805  127.0.0.1  127.0.0.1  TCP  44 65102 → 9001 [FIN, ACK] Seq=13 Ack=14 Win=65280 Len=0
 28 0.398813  127.0.0.1  127.0.0.1  TCP  44 9001 → 65102 [ACK] Seq=14 Ack=14 Win=65280 Len=0
 29 0.399082  127.0.0.1  127.0.0.1  TCP  56 65104 → 9001 [SYN] Seq=0 Win=65535 Len=0 MSS=65495 WS=256 SACK_PERM

› Frame 13: Packet, 56 bytes on wire (448 bits), 56 bytes captured
› Null/Loopback
› Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
› Transmission Control Protocol, Src Port: 9001, Dst Port: 65101, S
› Data (12 bytes)

0000  02 00 00 00 45 00 00 34  93 17 40 00 80 06 00 00   ····E··4 ··@·····
0010  7f 00 00 01 7f 00 00 01  23 29 fe 4d 71 6e 3b 81   ········ #)·Mqn;·
0020  16 01 f3 12 50 18 00 ff  95 6d 00 00 00 00 00 05   ····P··· ·m······
0030  6f 6c 6c 65 68 00 00 00                            olleh···
```

Observations : Frame ≈56 bytes. Chaîne "olleh" encodée en binaire compact.

Analyse : Lisibilité ★☆☆☆☆, Très compact (~75% plus petit qu'XML), difficile à analyser manuellement.

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5. Protocole JSON-RPC

Synthèse

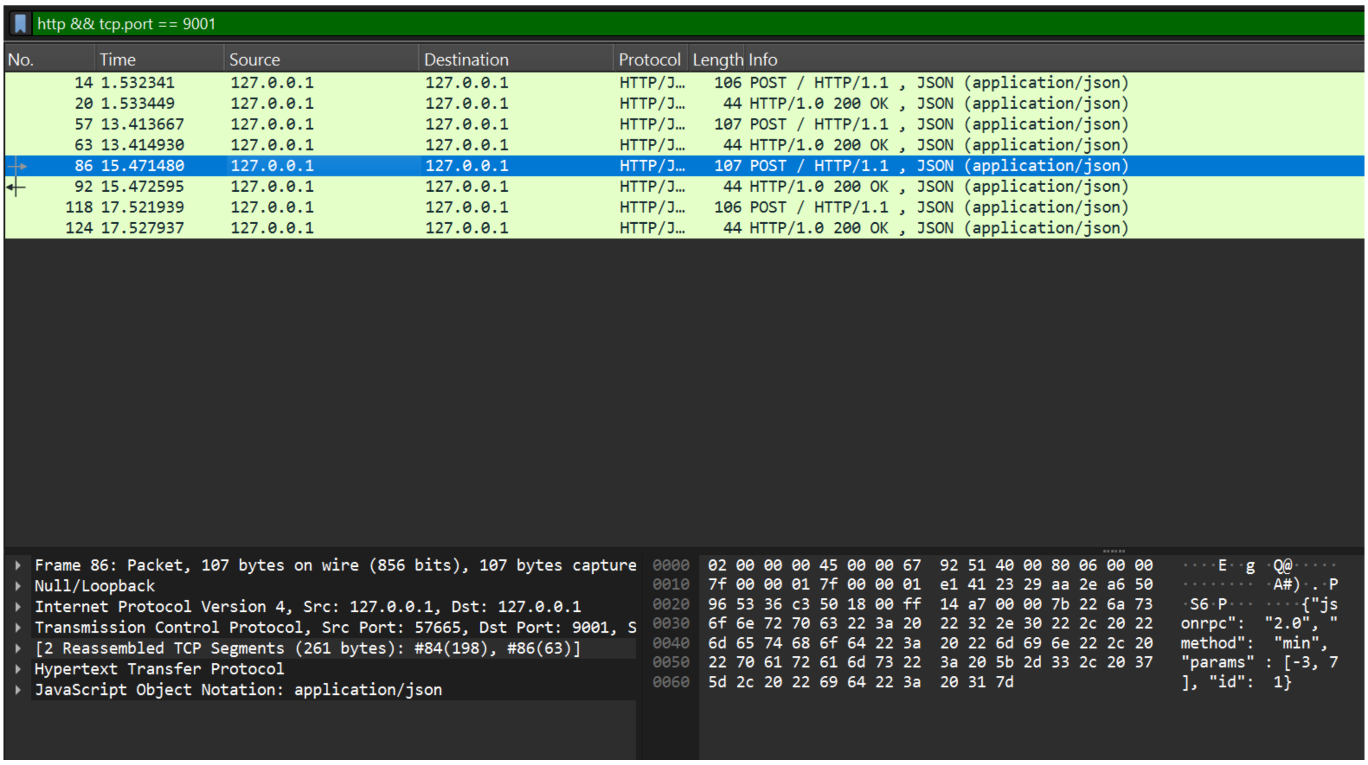
JSON-RPC 2.0 : format structuré JSON avec `jsonrpc`, `method`, `params`, `id`.

Implémentation

```python
# Serveur
from http.server import HTTPServer, BaseHTTPRequestHandler
import json

class JSONRPCHandler(BaseHTTPRequestHandler):
    def do_POST(self):
        body = json.loads(self.rfile.read(int(self.headers['Content-Length'])))
        if body.get('method') == 'min':
            result = min(body.get('params', []))
            response = {"jsonrpc": "2.0", "result": result, "id": body.get('id')}
        self.send_response(200)
        self.end_headers()
        self.wfile.write(json.dumps(response).encode())

server = HTTPServer(('localhost', 9001), JSONRPCHandler)
server.serve_forever()
```

Analyse Wireshark

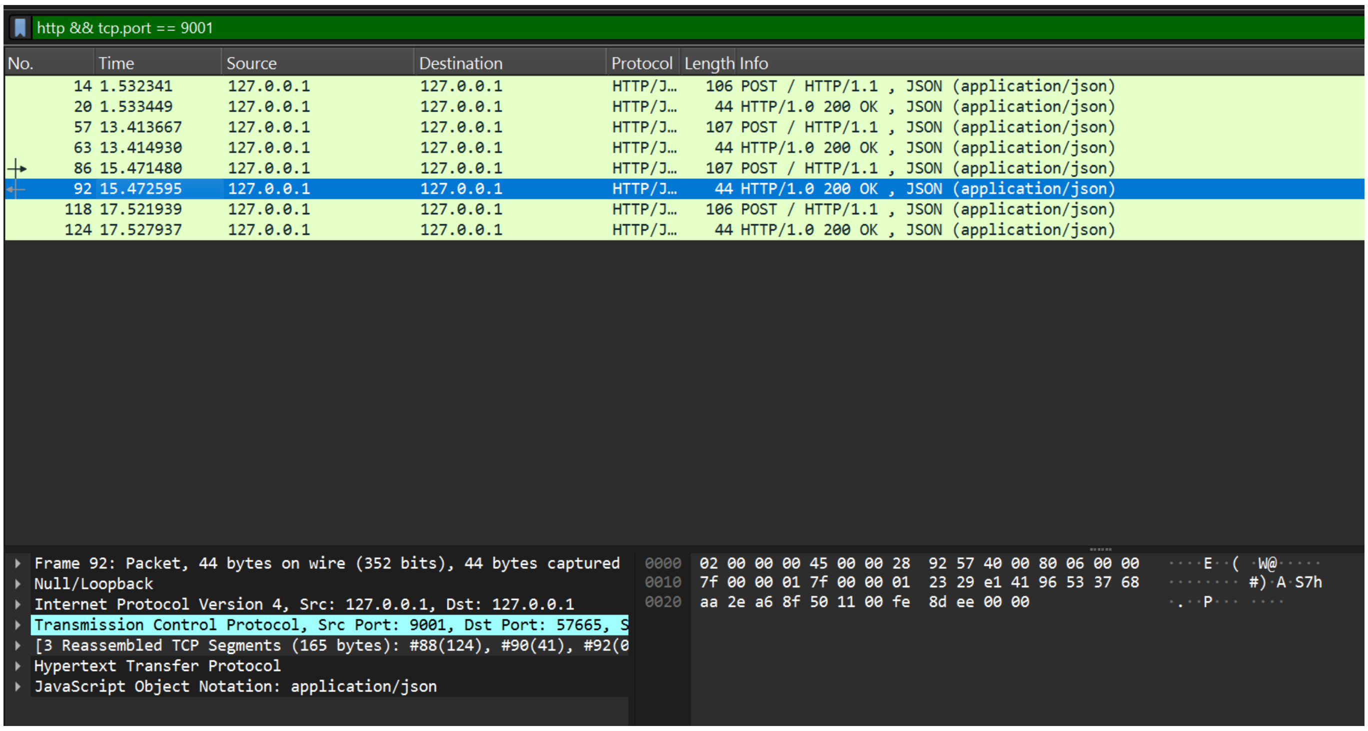
Requête HTTP avec JSON-RPC 2.0 :



```
http && tcp.port == 9001

No.   Time       Source      Destination  Protocol Length Info
  14 1.532341   127.0.0.1   127.0.0.1    HTTP/J…   106 POST / HTTP/1.1 , JSON (application/json)
  20 1.533449   127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)
  57 13.413667  127.0.0.1   127.0.0.1    HTTP/J…   107 POST / HTTP/1.1 , JSON (application/json)
  63 13.414930  127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)
  86 15.471480  127.0.0.1   127.0.0.1    HTTP/J…   107 POST / HTTP/1.1 , JSON (application/json)
  92 15.472595  127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)
 118 17.521939  127.0.0.1   127.0.0.1    HTTP/J…   106 POST / HTTP/1.1 , JSON (application/json)
 124 17.527937  127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)

Frame 86: Packet, 107 bytes on wire (856 bits), 107 bytes capture
Null/Loopback
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
Transmission Control Protocol, Src Port: 57665, Dst Port: 9001, S
[2 Reassembled TCP Segments (261 bytes): #84(198), #86(63)]
Hypertext Transfer Protocol
JavaScript Object Notation: application/json

0000  02 00 00 00 45 00 00 67  92 51 40 00 80 06 00 00   ····E··g ·Q@·····
0010  7f 00 00 01 7f 00 00 01  e1 41 23 29 aa 2e a6 50   ········ ·A#)·.·P
0020  96 53 36 c3 50 18 00 ff  14 a7 00 00 7b 22 6a 73   ·S6·P··· ····{"js
0030  6f 6e 72 70 63 22 3a 20  22 32 2e 30 22 2c 20 22   onrpc":  "2.0", "
0040  6d 65 74 68 6f 64 22 3a  20 22 6d 69 6e 22 2c 20   method":  "min",
0050  22 70 61 72 61 6d 73 22  3a 20 5b 2d 33 2c 20 37   "params" : [-3, 7
0060  5d 2c 20 22 69 64 22 3a  20 31 7d                  ], "id":  1}
```

Observations : Frame ≈107 bytes. JSON `{"jsonrpc":"2.0","method":"min","params":[-3,7]}` lisible.

Réponse HTTP avec result JSON :



```
http && tcp.port == 9001

No.   Time       Source      Destination  Protocol Length Info
  14 1.532341   127.0.0.1   127.0.0.1    HTTP/J…   106 POST / HTTP/1.1 , JSON (application/json)
  20 1.533449   127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)
  57 13.413667  127.0.0.1   127.0.0.1    HTTP/J…   107 POST / HTTP/1.1 , JSON (application/json)
  63 13.414930  127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)
  86 15.471480  127.0.0.1   127.0.0.1    HTTP/J…   107 POST / HTTP/1.1 , JSON (application/json)
  92 15.472595  127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)
 118 17.521939  127.0.0.1   127.0.0.1    HTTP/J…   106 POST / HTTP/1.1 , JSON (application/json)
 124 17.527937  127.0.0.1   127.0.0.1    HTTP/J…    44 HTTP/1.0 200 OK , JSON (application/json)

Frame 92: Packet, 44 bytes on wire (352 bits), 44 bytes captured
Null/Loopback
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
Transmission Control Protocol, Src Port: 9001, Dst Port: 57665, S
[3 Reassembled TCP Segments (165 bytes): #88(124), #90(41), #92(0
Hypertext Transfer Protocol
JavaScript Object Notation: application/json

0000  02 00 00 00 45 00 00 28  92 57 40 00 80 06 00 00   ····E··( ·W@·····
0010  7f 00 00 01 7f 00 00 01  23 29 e1 41 96 53 37 68   ········ #)·A·S7h
0020  aa 2e a6 8f 50 11 00 fe  8d ee 00 00               ·.··P··· ····
```

Observations : Petite frame. JSON `{"result":-3,"id":1}` clair et structuré.

Analyse : Lisibilité ★★★★☆, Taille intermédiaire, bon compromis texte/compacité.

---

6. Protocole REST/JSON

Synthèse

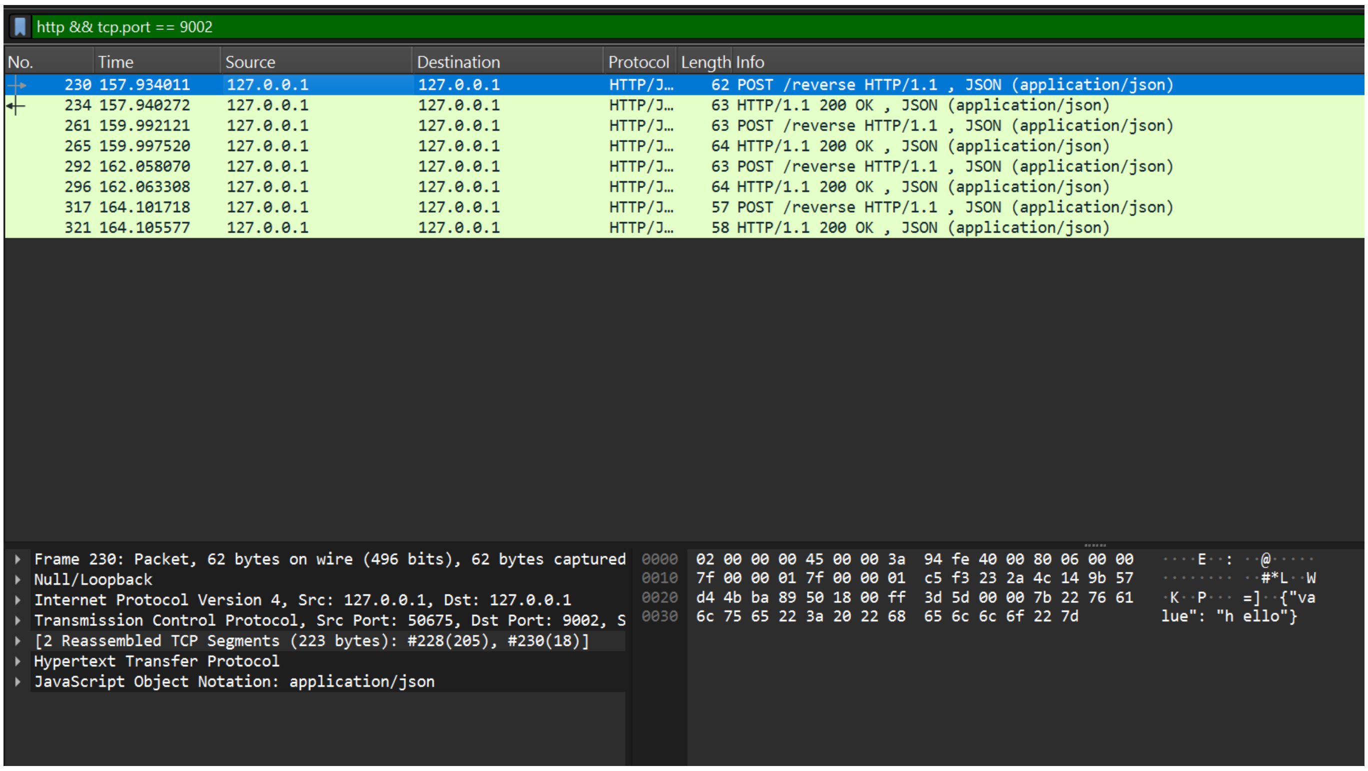
Architecture REST : ressources HTTP + verbes (POST, GET). État échangé en JSON.

Implémentation

```python
# Serveur Flask
from flask import Flask, request, jsonify
app = Flask(__name__)

@app.route('/reverse', methods=['POST'])
def reverse():
    data = request.get_json()
    return jsonify({'result': data['value'][::-1]}), 200

app.run(host='localhost', port=9002)
```

Analyse Wireshark

Requête POST /reverse avec JSON :



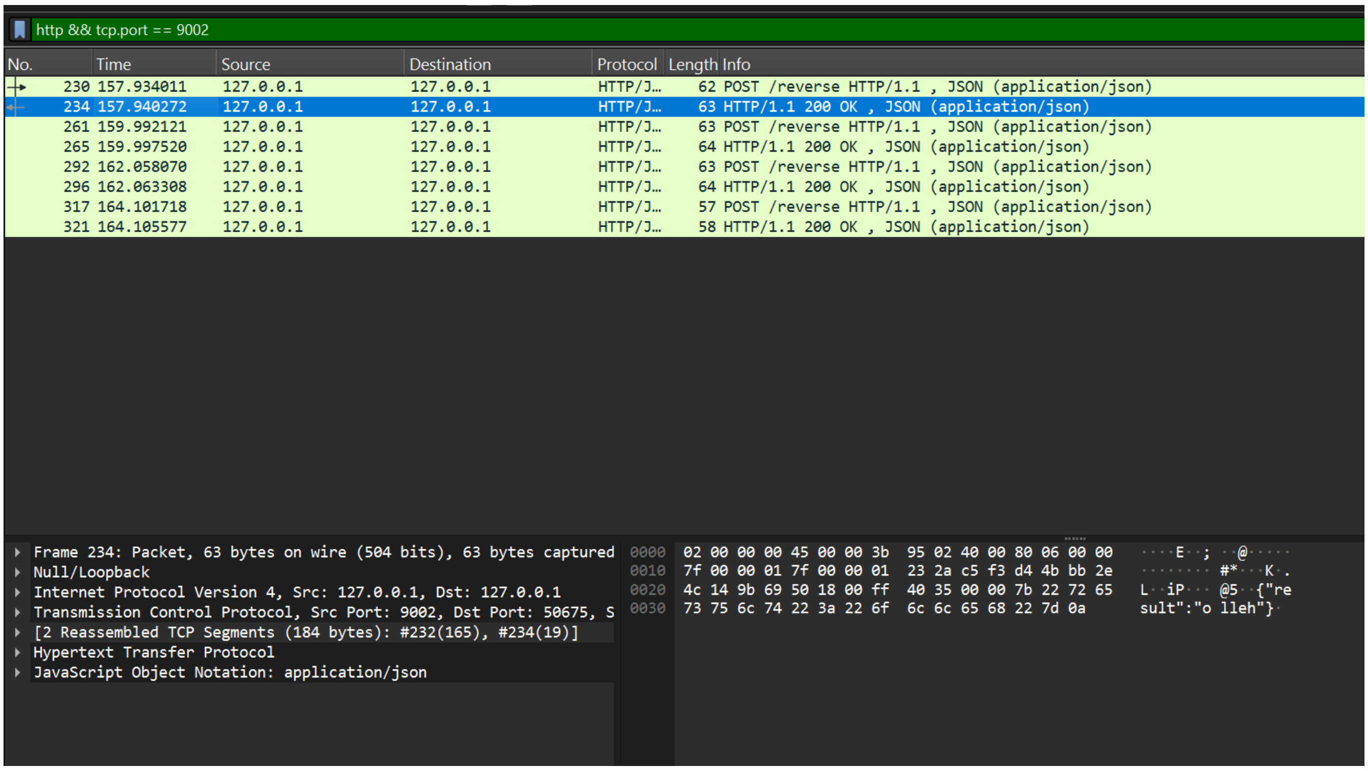
```
No.   Time        Source      Destination  Protocol Length Info
230 157.934011   127.0.0.1   127.0.0.1    HTTP/J…   62 POST /reverse HTTP/1.1 , JSON (application/json)
234 157.940272   127.0.0.1   127.0.0.1    HTTP/J…   63 HTTP/1.1 200 OK , JSON (application/json)
261 159.992121   127.0.0.1   127.0.0.1    HTTP/J…   63 POST /reverse HTTP/1.1 , JSON (application/json)
265 159.997520   127.0.0.1   127.0.0.1    HTTP/J…   64 HTTP/1.1 200 OK , JSON (application/json)
292 162.058070   127.0.0.1   127.0.0.1    HTTP/J…   63 POST /reverse HTTP/1.1 , JSON (application/json)
296 162.063308   127.0.0.1   127.0.0.1    HTTP/J…   64 HTTP/1.1 200 OK , JSON (application/json)
317 164.101718   127.0.0.1   127.0.0.1    HTTP/J…   57 POST /reverse HTTP/1.1 , JSON (application/json)
321 164.105577   127.0.0.1   127.0.0.1    HTTP/J…   58 HTTP/1.1 200 OK , JSON (application/json)
```

```
Frame 230: Packet, 62 bytes on wire (496 bits), 62 bytes captured
Null/Loopback
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
Transmission Control Protocol, Src Port: 50675, Dst Port: 9002, S
[2 Reassembled TCP Segments (223 bytes): #228(205), #230(18)]
Hypertext Transfer Protocol
JavaScript Object Notation: application/json
```

```
0000  02 00 00 00 45 00 00 3a  94 fe 40 00 80 06 00 00   ····E··:··@·····
0010  7f 00 00 01 7f 00 00 01  c5 f3 23 2a 4c 14 9b 57   ··········#*L··W
0020  d4 4b ba 89 50 18 00 ff  3d 5d 00 00 7b 22 76 61   ·K··P···=]··{"va
0030  6c 75 65 22 3a 20 22 68  65 6c 6c 6f 22 7d         lue": "h ello"}
```

Observations : Frame ≈62 bytes. URI `/reverse` + JSON `{"value":"hello"}` explicite.

Réponse HTTP 200 OK avec JSON :



```
http && tcp.port == 9002

No.  Time        Source     Destination  Protocol Length Info
230 157.934011  127.0.0.1  127.0.0.1    HTTP/J…   62 POST /reverse HTTP/1.1 , JSON (application/json)
234 157.940272  127.0.0.1  127.0.0.1    HTTP/J…   63 HTTP/1.1 200 OK , JSON (application/json)
261 159.992121  127.0.0.1  127.0.0.1    HTTP/J…   63 POST /reverse HTTP/1.1 , JSON (application/json)
265 159.997520  127.0.0.1  127.0.0.1    HTTP/J…   64 HTTP/1.1 200 OK , JSON (application/json)
292 162.058070  127.0.0.1  127.0.0.1    HTTP/J…   63 POST /reverse HTTP/1.1 , JSON (application/json)
296 162.063308  127.0.0.1  127.0.0.1    HTTP/J…   64 HTTP/1.1 200 OK , JSON (application/json)
317 164.101718  127.0.0.1  127.0.0.1    HTTP/J…   57 POST /reverse HTTP/1.1 , JSON (application/json)
321 164.105577  127.0.0.1  127.0.0.1    HTTP/J…   58 HTTP/1.1 200 OK , JSON (application/json)

Frame 234: Packet, 63 bytes on wire (504 bits), 63 bytes captured
Null/Loopback
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
Transmission Control Protocol, Src Port: 9002, Dst Port: 50675, S
[2 Reassembled TCP Segments (184 bytes): #232(165), #234(19)]
Hypertext Transfer Protocol
JavaScript Object Notation: application/json

0000  02 00 00 00 45 00 00 3b  95 02 40 00 80 06 00 00   ····E··; ··@·····
0010  7f 00 00 01 7f 00 00 01  23 2a c5 f3 d4 4b bb 2e   ········ #*···K·.
0020  4c 14 9b 69 50 18 00 ff  40 35 00 00 7b 22 72 65   L··iP··· @5··{"re
0030  73 75 6c 74 22 3a 22 6f  6c 6c 65 68 22 7d 0a      sult":"o lleh"}·
```

Observations : Frame ≈63 bytes. `{"result":"olleh"}` compact et clair.

Analyse : Lisibilité ★★★★★, Très compact, HTTP standard universel, idéal pour APIs web.

---

7. Protocole gRPC

Synthèse

gRPC : Protocol Buffers (binaire) + HTTP/2. Haute performance, streaming natif.

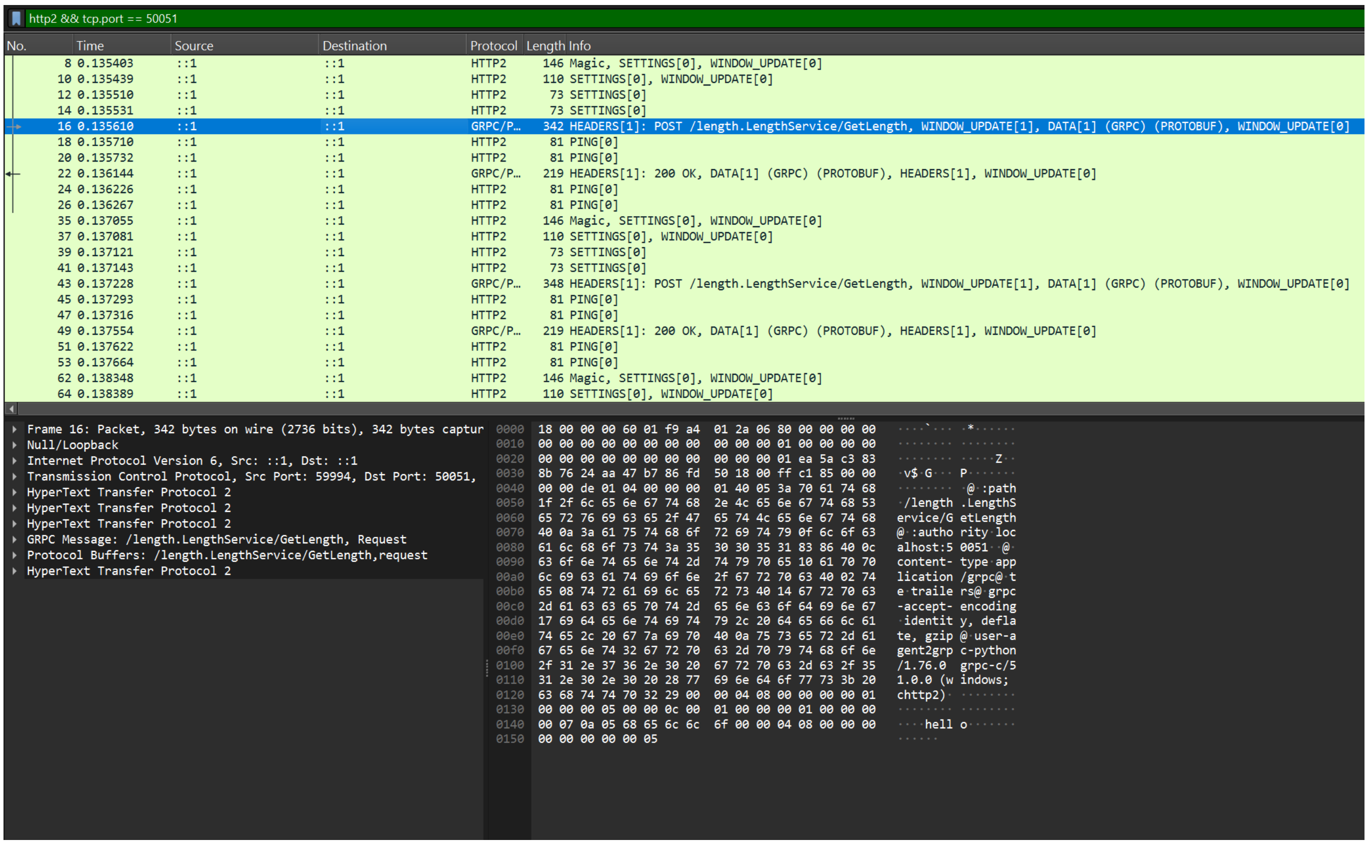
Implémentation

```
// length.proto
syntax = "proto3";
package length;

service LengthService {
  rpc GetLength(StringRequest) returns (StringReply) {}
}
message StringRequest { string value = 1; }
message StringReply { int32 length = 1; }
```

```python
# Serveur
import grpc, length_pb2, length_pb2_grpc
from concurrent import futures

class LengthServicer(length_pb2_grpc.LengthServiceServicer):
    def GetLength(self, request, context):
        return length_pb2.StringReply(length=len(request.value))

server = grpc.server(futures.ThreadPoolExecutor(max_workers=10))
length_pb2_grpc.add_LengthServiceServicer_to_server(LengthServicer(), server)
server.add_insecure_port('[::]:50051')
server.start()
server.wait_for_termination()
```

Analyse Wireshark

Requête HTTP/2 avec Protocol Buffers :



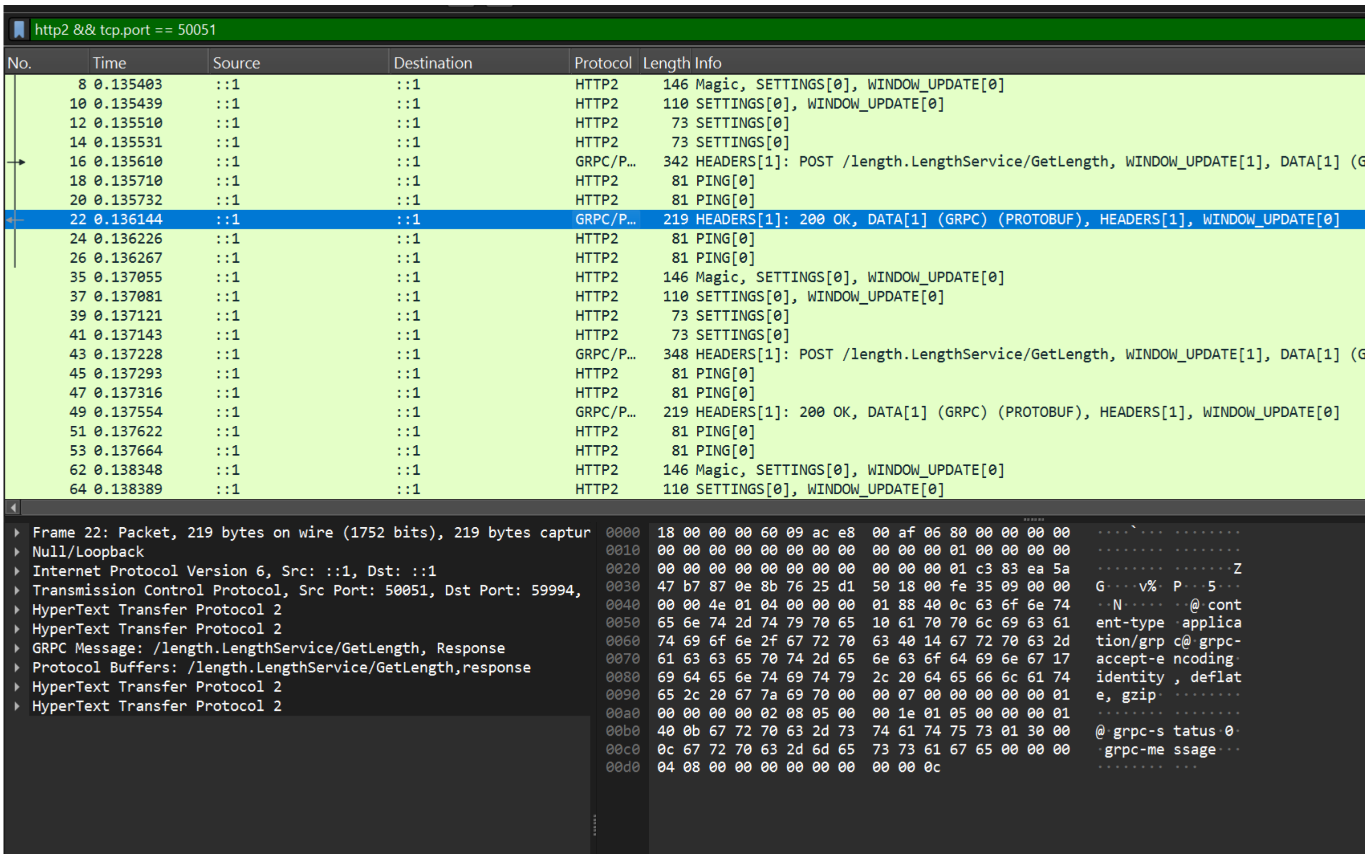
```
http2 && tcp.port == 50051

No.  Time       Source   Destination  Protocol  Length Info
  8 0.135403    ::1      ::1          HTTP2      146 Magic, SETTINGS[0], WINDOW_UPDATE[0]
 10 0.135439    ::1      ::1          HTTP2      110 SETTINGS[0], WINDOW_UPDATE[0]
 12 0.135510    ::1      ::1          HTTP2       73 SETTINGS[0]
 14 0.135531    ::1      ::1          HTTP2       73 SETTINGS[0]
 16 0.135610    ::1      ::1          GRPC/P…    342 HEADERS[1]: POST /length.LengthService/GetLength, WINDOW_UPDATE[1], DATA[1] (GRPC) (PROTOBUF), WINDOW_UPDATE[0]
 18 0.135710    ::1      ::1          HTTP2       81 PING[0]
 20 0.135732    ::1      ::1          HTTP2       81 PING[0]
 22 0.136144    ::1      ::1          GRPC/P…    219 HEADERS[1]: 200 OK, DATA[1] (GRPC) (PROTOBUF), HEADERS[1], WINDOW_UPDATE[0]
 24 0.136226    ::1      ::1          HTTP2       81 PING[0]
 26 0.136267    ::1      ::1          HTTP2       81 PING[0]
 35 0.137055    ::1      ::1          HTTP2      146 Magic, SETTINGS[0], WINDOW_UPDATE[0]
 37 0.137081    ::1      ::1          HTTP2      110 SETTINGS[0], WINDOW_UPDATE[0]
 39 0.137121    ::1      ::1          HTTP2       73 SETTINGS[0]
 41 0.137143    ::1      ::1          HTTP2       73 SETTINGS[0]
 43 0.137228    ::1      ::1          GRPC/P…    348 HEADERS[1]: POST /length.LengthService/GetLength, WINDOW_UPDATE[1], DATA[1] (GRPC) (PROTOBUF), WINDOW_UPDATE[0]
 45 0.137293    ::1      ::1          HTTP2       81 PING[0]
 47 0.137316    ::1      ::1          HTTP2       81 PING[0]
 49 0.137554    ::1      ::1          GRPC/P…    219 HEADERS[1]: 200 OK, DATA[1] (GRPC) (PROTOBUF), HEADERS[1], WINDOW_UPDATE[0]
 51 0.137622    ::1      ::1          HTTP2       81 PING[0]
 53 0.137664    ::1      ::1          HTTP2       81 PING[0]
 62 0.138348    ::1      ::1          HTTP2      146 Magic, SETTINGS[0], WINDOW_UPDATE[0]
 64 0.138389    ::1      ::1          HTTP2      110 SETTINGS[0], WINDOW_UPDATE[0]
```

```
Frame 16: Packet, 342 bytes on wire (2736 bits), 342 bytes captur
Null/Loopback
Internet Protocol Version 6, Src: ::1, Dst: ::1
Transmission Control Protocol, Src Port: 59994, Dst Port: 50051,
HyperText Transfer Protocol 2
HyperText Transfer Protocol 2
HyperText Transfer Protocol 2
GRPC Message: /length.LengthService/GetLength, Request
Protocol Buffers: /length.LengthService/GetLength,request
HyperText Transfer Protocol 2
```

```
0000  18 00 00 00 60 01 f9 a4  01 2a 06 80 00 00 00 00   ····`··· ·*······
0010  00 00 00 00 00 00 00 00  00 00 00 01 00 00 00 00   ········ ········
0020  00 00 00 00 00 00 00 00  00 00 00 01 ea 5a c3 83   ········ ·····Z··
0030  8b 76 24 aa 47 b7 86 fd  50 18 00 ff c1 85 00 00   ·v$·G··· P·······
0040  00 00 de 01 04 00 00 00  01 40 05 3a 70 61 74 68   ········ ·@·:path
0050  1f 2f 6c 65 6e 67 74 68  2e 4c 65 6e 67 74 68 53   ·/length .LengthS
0060  65 72 76 69 63 65 2f 47  65 74 4c 65 6e 67 74 68   ervice/G etLength
0070  40 0a 3a 61 75 74 68 6f  72 69 74 79 0f 6c 6f 63   @·:autho rity·loc
0080  61 6c 68 6f 73 74 3a 35  30 30 35 31 83 86 40 0c   alhost:5 0051··@·
0090  63 6f 6e 74 65 6e 74 2d  74 79 70 65 10 61 70 70   content- type·app
00a0  6c 69 63 61 74 69 6f 6e  2f 67 72 70 63 40 02 74   lication /grpc@·t
00b0  65 08 74 72 61 69 6c 65  72 73 40 14 67 72 70 63   e·traile rs@·grpc
00c0  2d 61 63 63 65 70 74 2d  65 6e 63 6f 64 69 6e 67   -accept- encoding
00d0  17 69 64 65 6e 74 69 74  79 2c 20 64 65 66 6c 61   ·identit y, defla
00e0  74 65 2c 20 67 7a 69 70  40 0a 75 73 65 72 2d 61   te, gzip @·user-a
00f0  67 65 6e 74 32 67 72 70  63 2d 70 79 74 68 6f 6e   gent2grp c-python
0100  2f 31 2e 37 36 2e 30 20  67 72 70 63 2d 63 2f 35   /1.76.0  grpc-c/5
0110  31 2e 30 2e 30 20 28 77  69 6e 64 6f 77 73 3b 20   1.0.0 (w indows; 
0120  63 68 74 74 70 32 29 00  00 04 08 00 00 00 00 01   chttp2)· ········
0130  00 00 00 05 00 00 0c 00  01 00 00 00 01 00 00 00   ········ ········
0140  00 07 0a 05 68 65 6c 6c  6f 00 00 04 08 00 00 00   ····hell o·······
0150  00 00 00 00 00 05                                  ······
```

Observations : Frame ≈342 bytes. HTTP/2 POST `/length.LengthService/GetLength`, DATA protobuf binaire illisible.

Réponse HTTP/2 avec protobuf :



```
http2 && tcp.port == 50051

No. Time      Source  Destination  Protocol Length Info
  8 0.135403  ::1     ::1          HTTP2    146 Magic, SETTINGS[0], WINDOW_UPDATE[0]
 10 0.135439  ::1     ::1          HTTP2    110 SETTINGS[0], WINDOW_UPDATE[0]
 12 0.135510  ::1     ::1          HTTP2     73 SETTINGS[0]
 14 0.135531  ::1     ::1          HTTP2     73 SETTINGS[0]
 16 0.135610  ::1     ::1          GRPC/P…  342 HEADERS[1]: POST /length.LengthService/GetLength, WINDOW_UPDATE[1], DATA[1] (G
 18 0.135710  ::1     ::1          HTTP2     81 PING[0]
 20 0.135732  ::1     ::1          HTTP2     81 PING[0]
 22 0.136144  ::1     ::1          GRPC/P…  219 HEADERS[1]: 200 OK, DATA[1] (GRPC) (PROTOBUF), HEADERS[1], WINDOW_UPDATE[0]
 24 0.136226  ::1     ::1          HTTP2     81 PING[0]
 26 0.136267  ::1     ::1          HTTP2     81 PING[0]
 35 0.137055  ::1     ::1          HTTP2    146 Magic, SETTINGS[0], WINDOW_UPDATE[0]
 37 0.137081  ::1     ::1          HTTP2    110 SETTINGS[0], WINDOW_UPDATE[0]
 39 0.137121  ::1     ::1          HTTP2     73 SETTINGS[0]
 41 0.137143  ::1     ::1          HTTP2     73 SETTINGS[0]
 43 0.137228  ::1     ::1          GRPC/P…  348 HEADERS[1]: POST /length.LengthService/GetLength, WINDOW_UPDATE[1], DATA[1] (G
 45 0.137293  ::1     ::1          HTTP2     81 PING[0]
 47 0.137316  ::1     ::1          HTTP2     81 PING[0]
 49 0.137554  ::1     ::1          GRPC/P…  219 HEADERS[1]: 200 OK, DATA[1] (GRPC) (PROTOBUF), HEADERS[1], WINDOW_UPDATE[0]
 51 0.137622  ::1     ::1          HTTP2     81 PING[0]
 53 0.137664  ::1     ::1          HTTP2     81 PING[0]
 62 0.138348  ::1     ::1          HTTP2    146 Magic, SETTINGS[0], WINDOW_UPDATE[0]
 64 0.138389  ::1     ::1          HTTP2    110 SETTINGS[0], WINDOW_UPDATE[0]

Frame 22: Packet, 219 bytes on wire (1752 bits), 219 bytes captur
Null/Loopback
Internet Protocol Version 6, Src: ::1, Dst: ::1
Transmission Control Protocol, Src Port: 50051, Dst Port: 59994,
HyperText Transfer Protocol 2
HyperText Transfer Protocol 2
GRPC Message: /length.LengthService/GetLength, Response
Protocol Buffers: /length.LengthService/GetLength,response
HyperText Transfer Protocol 2
HyperText Transfer Protocol 2

0000  18 00 00 00 60 09 ac e8  00 af 06 80 00 00 00 00   ····`··· ········
0010  00 00 00 00 00 00 00 00  00 00 00 01 00 00 00 00   ········ ········
0020  00 00 00 00 00 00 00 00  00 00 00 01 c3 83 ea 5a   ········ ·······Z
0030  47 b7 87 0e 8b 76 25 d1  50 18 00 fe 35 09 00 00   G····v%· P···5···
0040  00 00 4e 01 04 00 00 00  01 88 40 0c 63 6f 6e 74   ··N····· ··@·cont
0050  65 6e 74 2d 74 79 70 65  10 61 70 70 6c 69 63 61   ent-type ·applica
0060  74 69 6f 6e 2f 67 72 70  63 40 14 67 72 70 63 2d   tion/grp c@·grpc-
0070  61 63 63 65 70 74 2d 65  6e 63 6f 64 69 6e 67 17   accept-e ncoding·
0080  69 64 65 6e 74 69 74 79  2c 20 64 65 66 6c 61 74   identity , deflat
0090  65 2c 20 67 7a 69 70 00  00 07 00 00 00 00 00 01   e, gzip· ········
00a0  00 00 00 00 02 08 05 00  00 1e 01 05 00 00 00 01   ········ ········
00b0  40 0b 67 72 70 63 2d 73  74 61 74 75 73 01 30 00   @·grpc-s tatus·0·
00c0  0c 67 72 70 63 2d 6d 65  73 73 61 67 65 00 00 00   ·grpc-me ssage···
00d0  04 08 00 00 00 00 00 00  00 00 0c                  ········ ···
```

Observations : Frame ≈219 bytes. Réponse binaire compacte, nécessite .proto pour interpréter.

Analyse : Lisibilité ★☆☆☆☆, Très compact, HTTP/2 performant, idéal pour microservices.

---

8. Analyse Comparative

Tableau de synthèse

Critère	XML-RPC	XDR-RPC	JSON-RPC	REST/JSON	gRPC
Lisibilité	★★★★★	★☆☆☆☆	★★★★☆	★★★★★	★☆☆☆☆
Taille (bytes)	230-300	50-100	100-150	60-100	100-350
Format	HTTP+XML	TCP+XDR binaire	HTTP+JSON	HTTP+JSON	HTTP/2+Protobuf
Transport sécurisé	HTTPS	HTTPS	HTTPS	HTTPS	TLS/mTLS
Multi-langage	Excellent	Bon	Excellent	Universel	Excellent
Streaming	Non	Non	Non	Non	Oui (natif)
Cas d'usage	Legacy web	Contraintes bande passante	APIs simples	APIs web modernes	Microservices haute perf

Recommandations par cas d'usage

- **API web publique** → REST/JSON : standard, caching HTTP, universellement supporté

- **Microservices internes** → gRPC : performance, streaming, type-safe
- **Prototype rapide** → REST/JSON ou JSON-RPC : setup minimal, testable immédiatement
- **Système legacy** → XML-RPC ou XDR-RPC : compatibilité existante
- **IoT/embedded** → JSON-RPC : léger, simple, support universel

---

9. Méthodologie Wireshark

Procédure de capture

1. Ouvrir Wireshark, interface Loopback
2. Filtre par port : `tcp.port == 9000` (XML-RPC), `tcp.port == 9001` (XDR/JSON-RPC), `tcp.port == 9002` (REST), `tcp.port == 50051` (gRPC)
3. Lancer serveur, puis client
4. Enregistrer capture : `File > Export Specified Packets` → `.pcapng`
5. Stocker dans `wireshark-captures/`

Tests réalisés

Protocole	Fonction	Input	Output attendu	Status
XML-RPC	add	(5, 3)	8	✓ PASS
XDR-RPC	reverse	"hello"	"olleh"	✓ PASS
JSON-RPC	min	[-3, 7]	-3	✓ PASS
REST/JSON	/reverse	{"value":"hello"}	{"result":"olleh"}	✓ PASS
gRPC	GetLength	"hello"	5	✓ PASS

Structure du dépôt Git

```
Projet-RPC/
├── xml-rpc/
│   ├── server.py
│   └── client.py
├── xdr-rpc/
│   ├── server.py
│   └── client.py
├── json-rpc/
│   ├── server.py
│   └── client.py
├── rest-json/
│   ├── server.py
│   └── client.py
├── grpc/
│   ├── length.proto
│   ├── server.py
│   └── client.py
├── wireshark-captures/
│   ├── xml-rpc-request.png
│   ├── xml-rpc-response.png
│   ├── xdr-rpc-request.png
│   ├── xdr-rpc-response.png
│   ├── json-rpc-request.png
│   ├── json-rpc-response.png
│   ├── rest-json-request.png
│   ├── rest-json-response.png
│   ├── grpc-request.png
│   └── grpc-response.png
└── rapport_final.md
```

---

10. Conclusion

Ce projet a démontré les différences fondamentales entre cinq approches RPC. **XML-RPC** et **XDR-RPC** sont historiques mais dépassés. **JSON-RPC** offre un bon compromis. **REST/JSON** domine les APIs web modernes grâce à sa simplicité et son universalité. **gRPC** s'impose pour les microservices nécessitant haute performance et streaming.

Les captures Wireshark ont validé les caractéristiques théoriques : XML/JSON sont lisibles mais plus volumineux, XDR/Protobuf sont compacts mais opaques, HTTP/2 optimise le transport.

Perspectives

- Implémenter sécurité (TLS/mTLS, OAuth2)
- Benchmark performance (latence, throughput)
- Containerisation Docker + orchestration
- Monitoring avec Prometheus/Jaeger

Auteur : [Votre Nom]
Dépôt Git : [URL GitHub/GitLab]
Date : 16 Décembre 2025