Using Data Compression to Improve Application Server Performance

Peter Haggar
Senior Software Engineer
Emerging Technology
IBM Corporation
Research Triangle Park, NC
haggar@us.ibm.com

About Me

- Practicing Software Engineer for 17+ years
- Focus on high performance Web Services
- IBM Representative to W3C XML Binary Characterization Working Group
- Work with Web Services on mobile devices
- Please email me with any questions about this presentation

Agenda

- Desire/Need for Compression
- Compression Techniques
- Sample Application and Data
- Sample GZIP Compression Ratios
- Performance with GZIP Compression
- Performance Conclusions
- Enabling GZIP Compression
- W3C XML Binary Characterization Working Group
- References

Desire/Need for Compression

- According to a May 2003 study:
  - 13% of U.S. has broadband
  - 87% of U.S. has narrowband (dial-up)
    - Majority at 56kbps
  - http://www.internetworldstats.com/am/us.htm
- Broadband growing rapidly
  - But, most people don't have optimal connections
- Not all businesses can operate over optimal connections

Desire/Need for Compression

- As computing grows
  - More and more data being sent
- Computers are more sparsely connected
- Connections are not always optimal
- Making matters worse (for performance)
  - Many new(er) technologies are ASCII based
    - HTTP, XML, HTML, *etc*.
    - More verbose than binary counterparts
      - ✓ Typically compress very well, however

Desire/Need for Compression

- New(er) ASCII based technologies
  - Less brittle
  - Easier to program and maintain
  - But…
  - More verbose
  - Require more processing power
  - Require more bandwidth

Desire/Need for Compression

- Many existing applications use brittle binary protocols
  - Over less than optimal connections
  - Acceptable performance achieved due to
    - Efficient processing of binary data
    - Efficient use of existing bandwidth

Desire/Need for Compression

- Challenge:
  - Upgrade existing applications to less brittle ASCII based technologies such as XML and Web Services
    - Maintain performance
      - ✓ At least make it acceptable
    - Don't require upgrade to network
      - ✓ Expensive…sometimes impossible
    - Don't use remaining bandwidth
      - ✓ Chokes off other applications

Desire/Need for Compression

- Can't expect people/businesses to upgrade connections when you deploy "better" technology

Compression Techniques

- Alternate encodings
  - proprietary
- Non-proprietary compression algorithms
  - GZIP
  - deflate
  - compress
- Technique doesn't matter
  - Goal is to send less bytes

Compression Techniques

- GZIP supported by most modern browsers
  - *via* "Accept-Encoding" HTTP header
  - EX:
    - Accept-Encoding: gzip, deflate
    - Means browser can accept data encoded in indicated forms and decompress those forms
- However, most application servers don't support compression by default
  - Therefore, adding "Accept-Encoding" header has no effect

Compression Techniques

- Solution is to add compression to server
  - If client is not a browser… add it there too
- GZIP compression is solid and pervasive
  - We will use it in examples later

Sample Application and Data

- Web Services application
  - Client
  - Server
    - Application Server == WebSphere
      - ✓ Could be any other Application Server though
  - Four different payload sizes
    - 1K
    - 10K
    - 100K
    - 1Meg

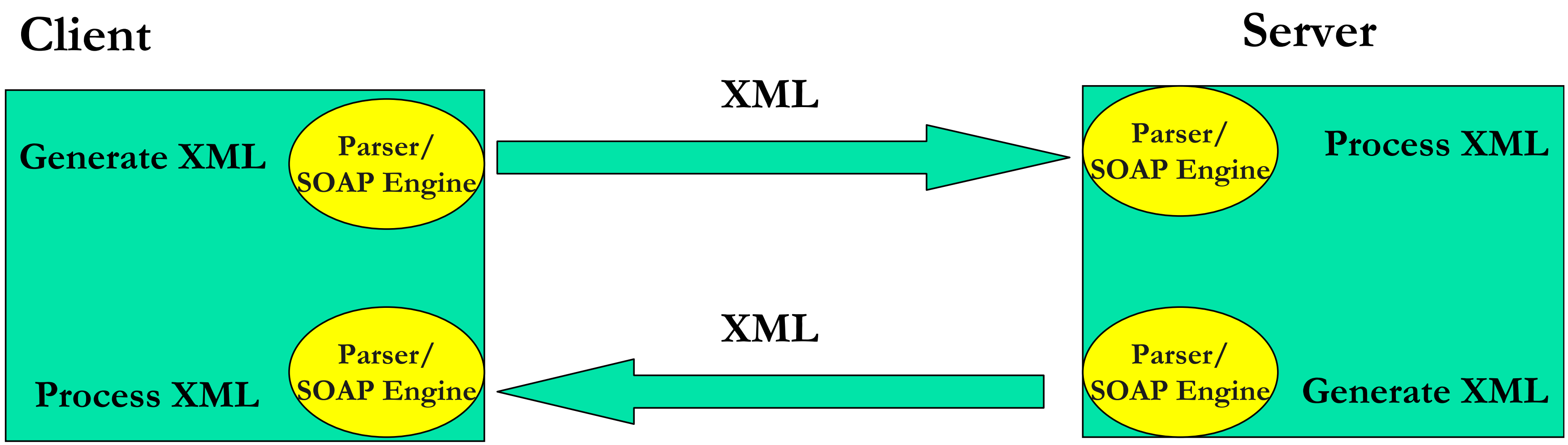
Sample Application and Data

- Data is comprised of banking messages
- Conforms to IFX Schema
- Data is sufficiently randomized to give realistic compression and performance numbers
  - Larger payloads were not created with copy/paste

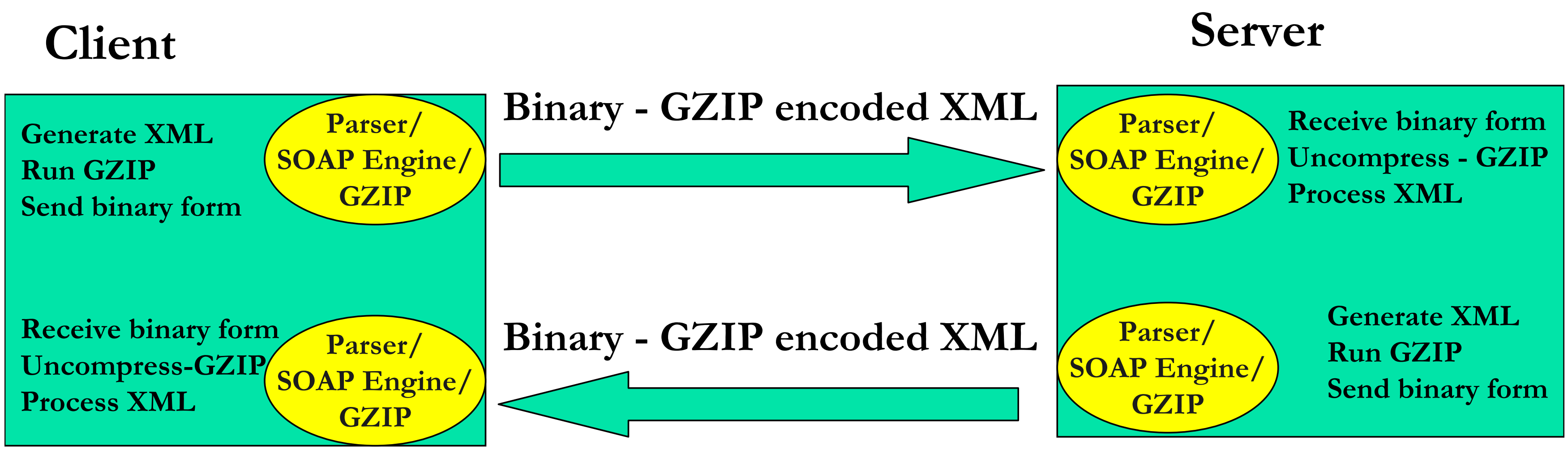
Sample Application and Data

- Determine how differing payloads perform using varying line speeds
  - 100 Mbps
    - Excellent network
  - 2.4 Mbps
    - ~ Cable Modem speed
  - 56 kbps
    - Dial-up speed

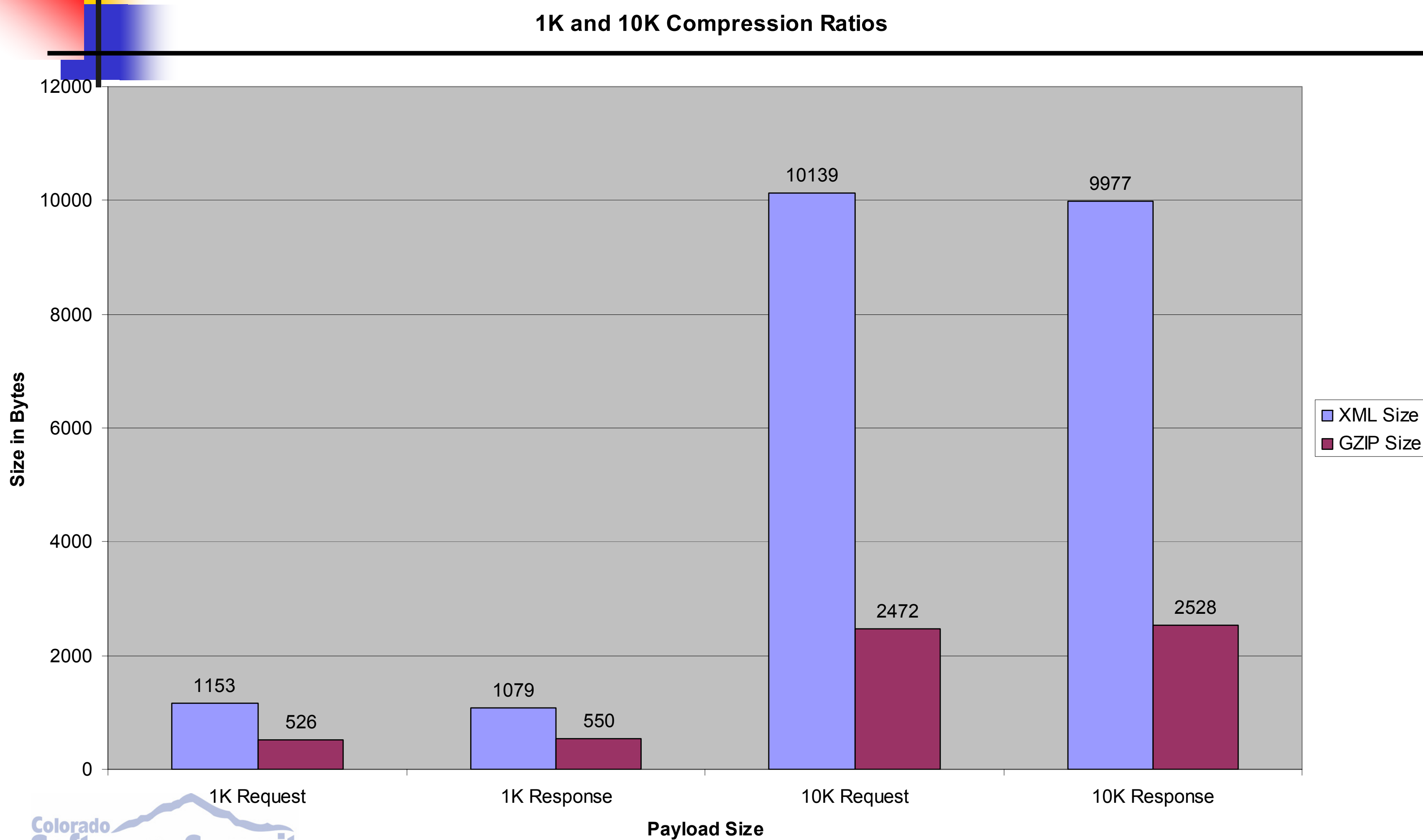
XML Based Flow



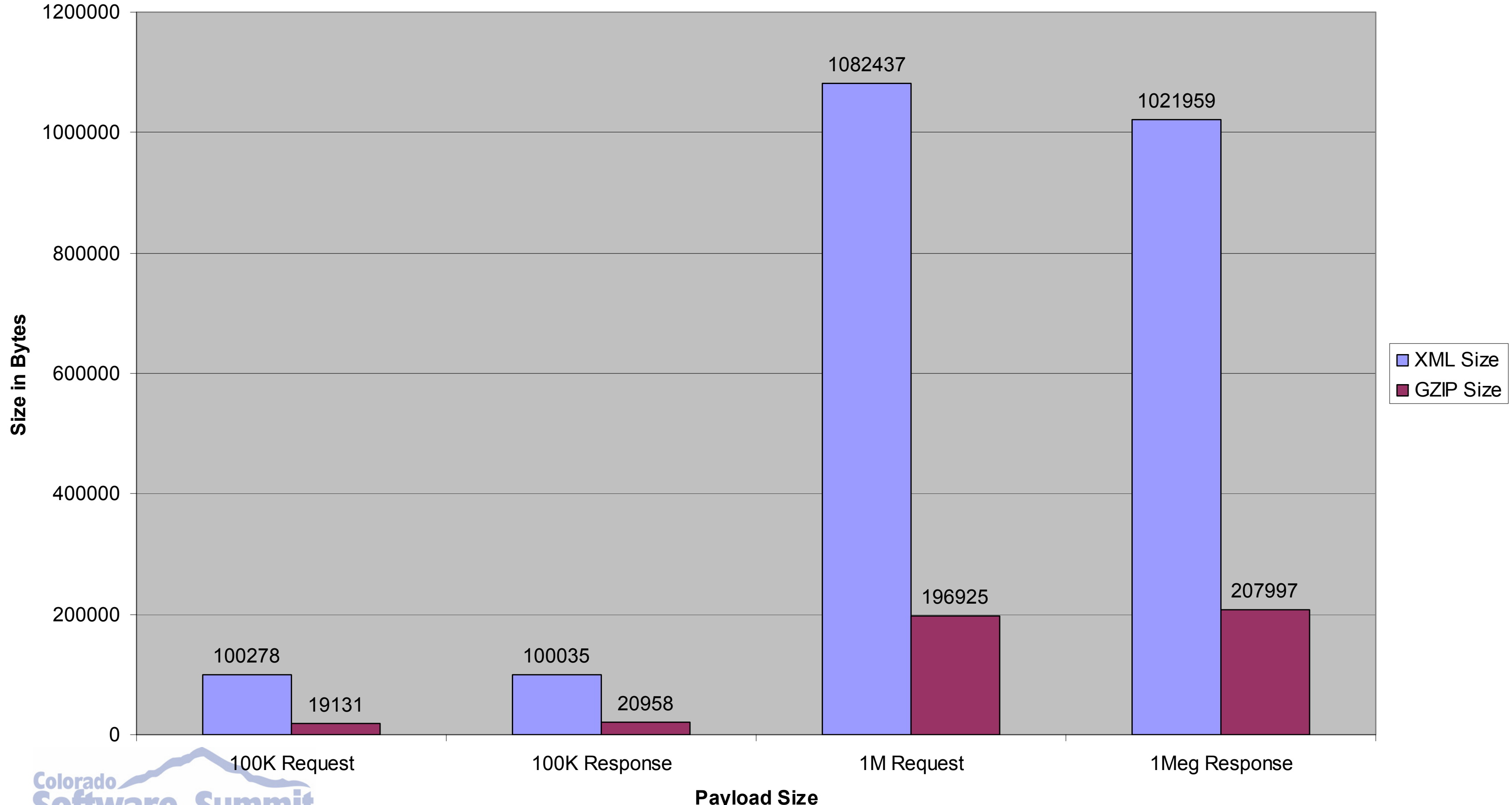
GZIP Based Flow



Sample GZIP Compression Ratios


1K and 10K Compression Ratios
12000
10000
8000
6000
4000
2000
0
Size in Bytes
1153
526
1079
550
10139
2472
9977
2528
1K Request
1K Response
10K Request
10K Response
Payload Size
XML Size
GZIP Size

100K and 1Meg Compression Ratios



Data Compression Analysis

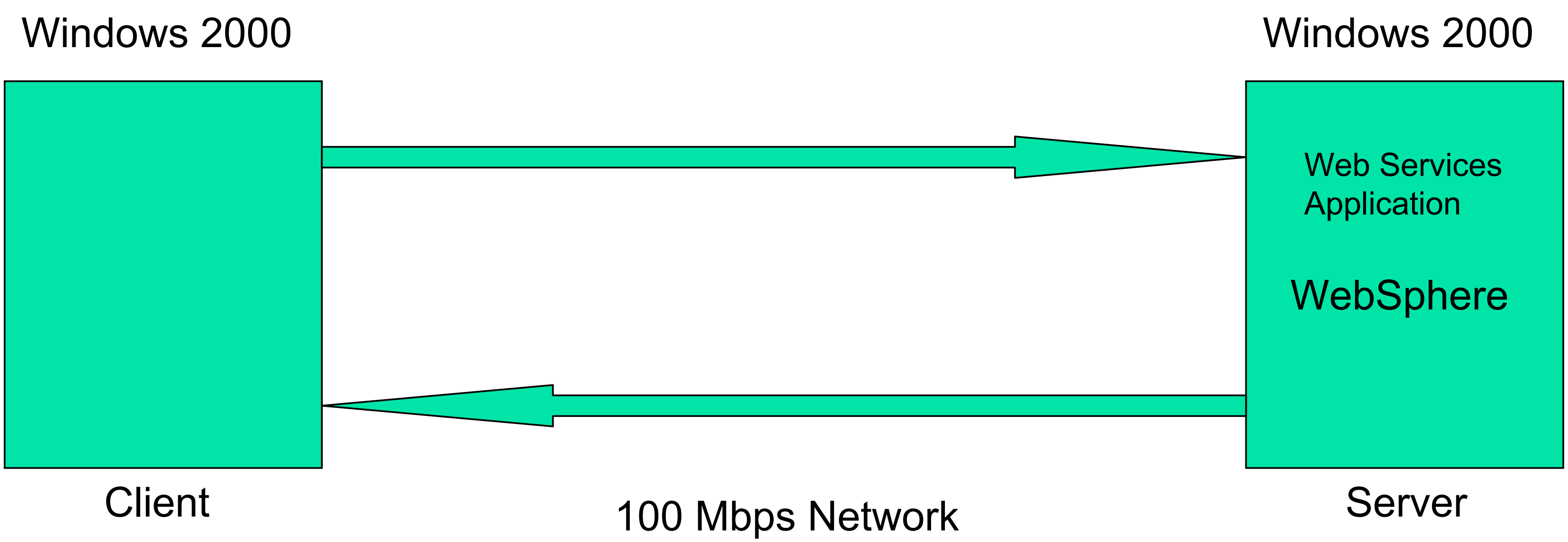
- GZIP achieves excellent compression
  - 82% reduction best case
  - 72% reduction average
- Not unexpected since XML messages are ASCII based
- GZIP doesn't always work this well
  - Example: large sets of floating point numbers don't compress very well

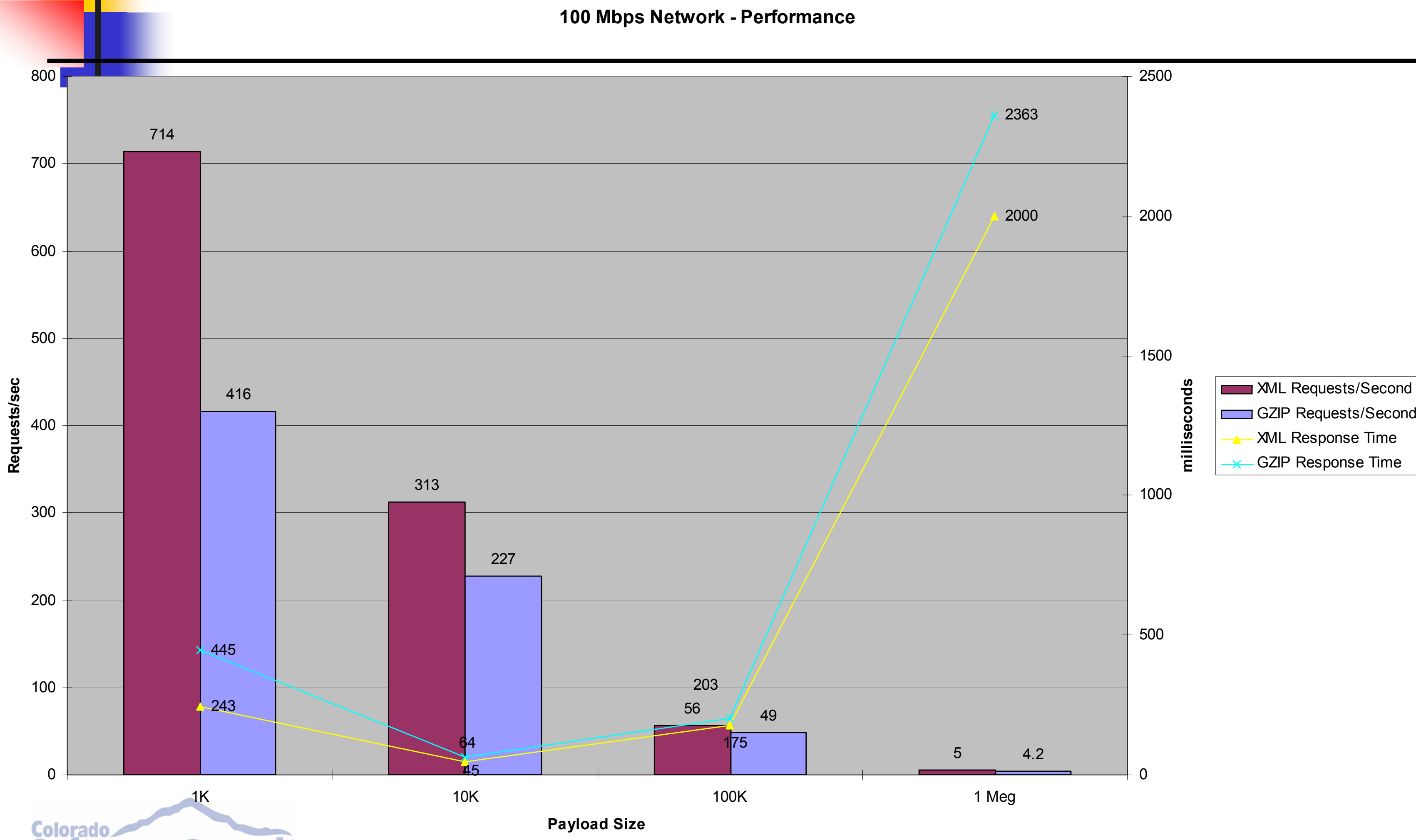
Performance with GZIP Compression

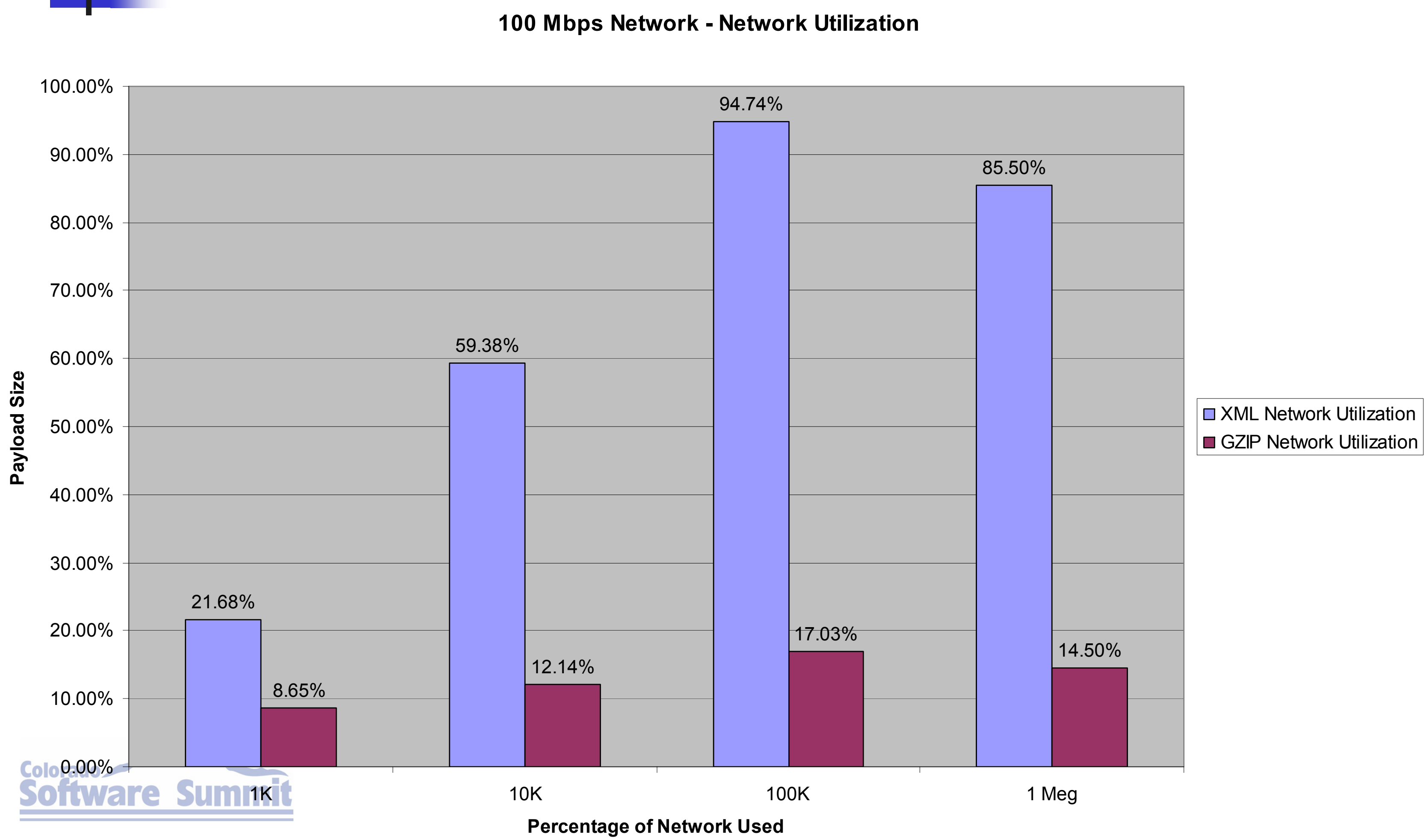
Topology

- 2 Windows Machines
- 1 Linux machine
- Private network

Topology – 100 Mbps Network




100 Mbps Network - Performance
Requests/sec
milliseconds
Payload Size
1K
10K
100K
1 Meg
714
416
313
227
56
49
5
4.2
445
243
64
45
203
175
2363
2000
XML Requests/Second
GZIP Requests/Second
XML Response Time
GZIP Response Time

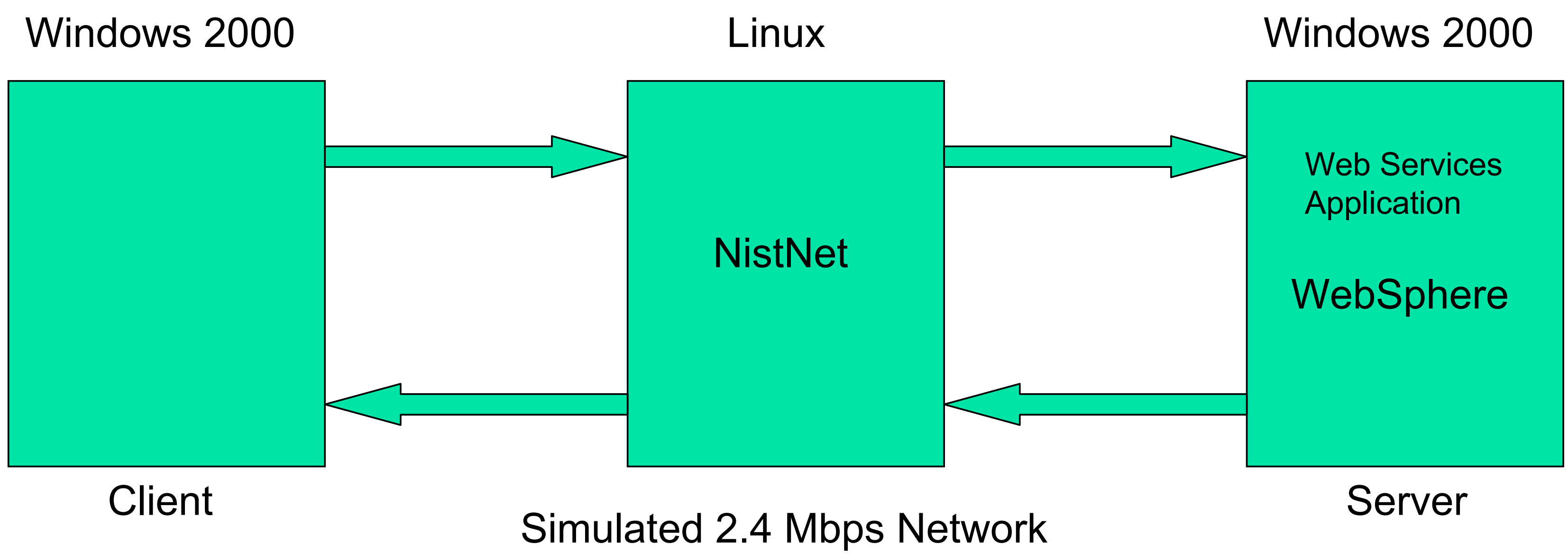


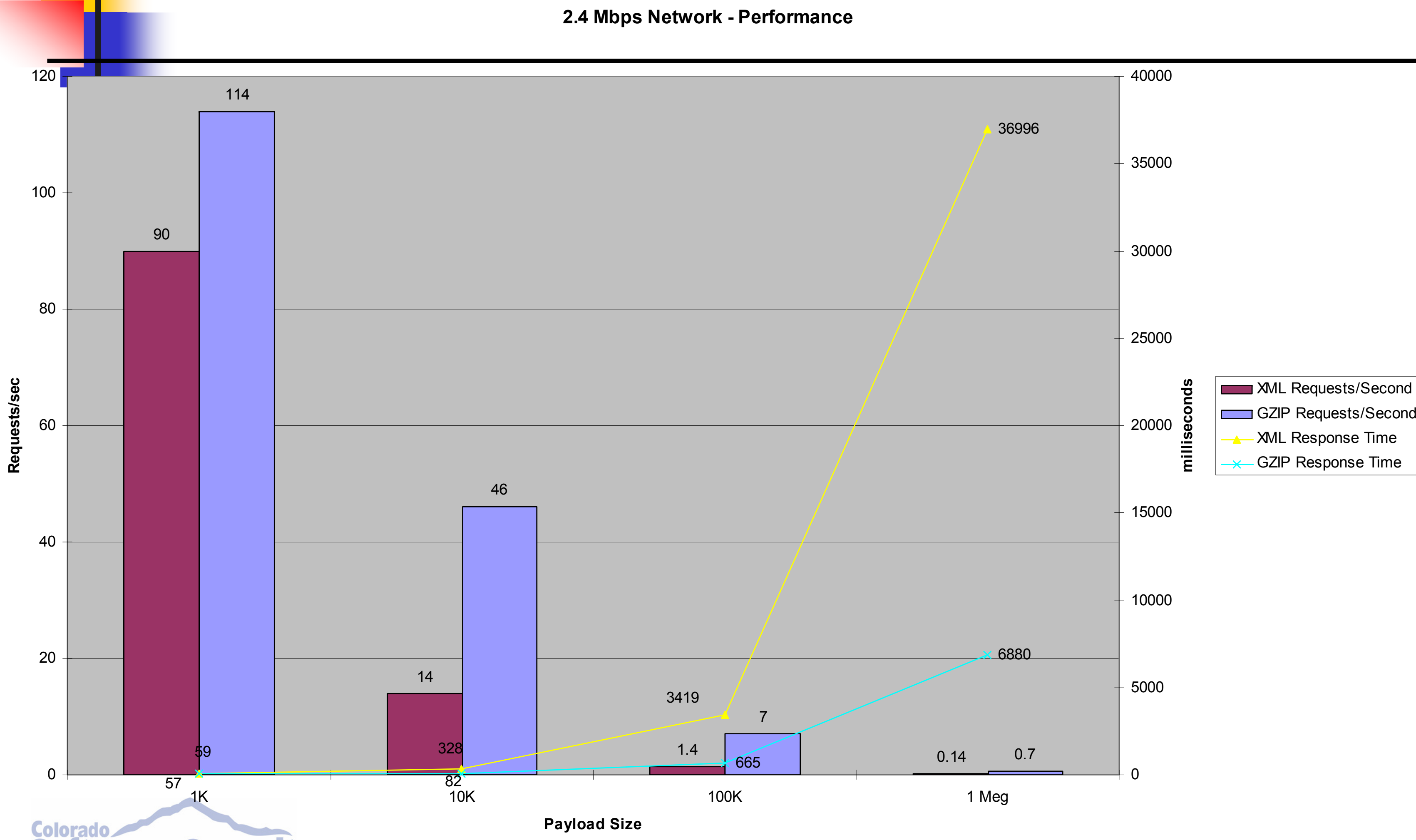
100 Mbps Network - Network Utilization
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Payload Size
21.68%
8.65%
59.38%
12.14%
94.74%
17.03%
85.50%
14.50%
1K
10K
100K
1 Meg
Percentage of Network Used
XML Network Utilization
GZIP Network Utilization

100 Mbps Network Summary

- GZIP is slower because the network is not the bottleneck
  - The cost of compressing and uncompressing the data does not pay off
- GZIP uses the least network due to its excellent compression
- XML uses almost the entire 100 Mbps network for 100K and 1Meg payloads
  - 12,500,000 bytes

Topology – 2.4 Mbps Network

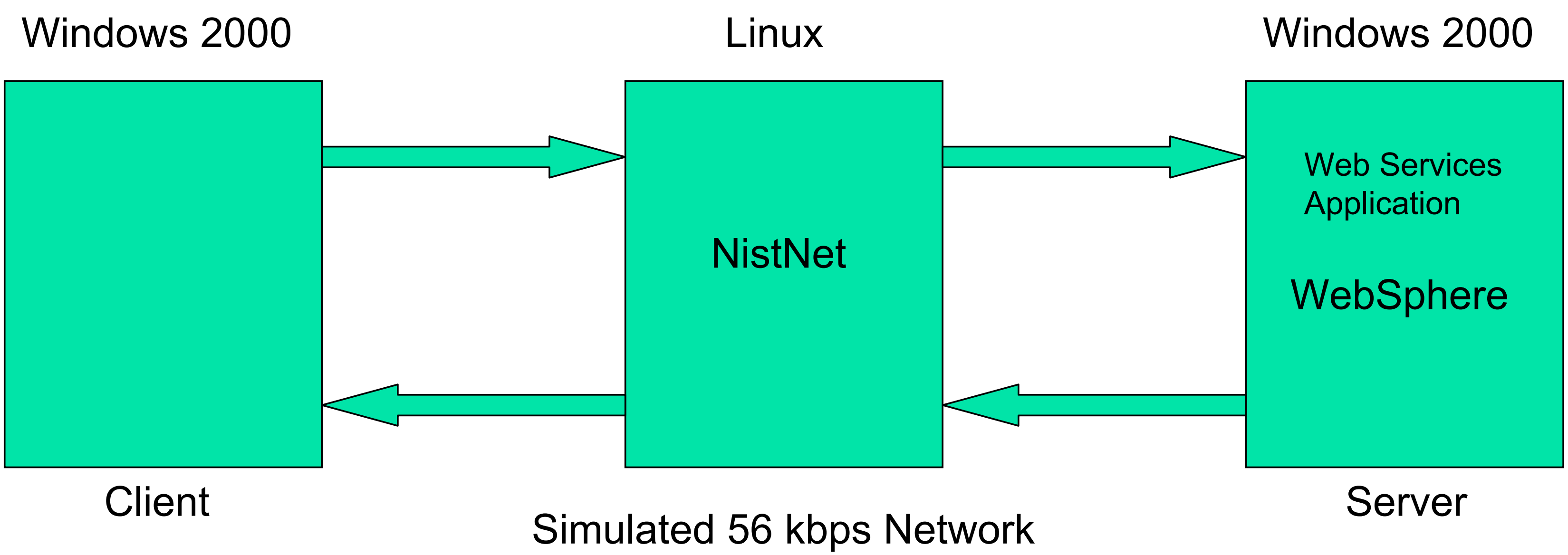


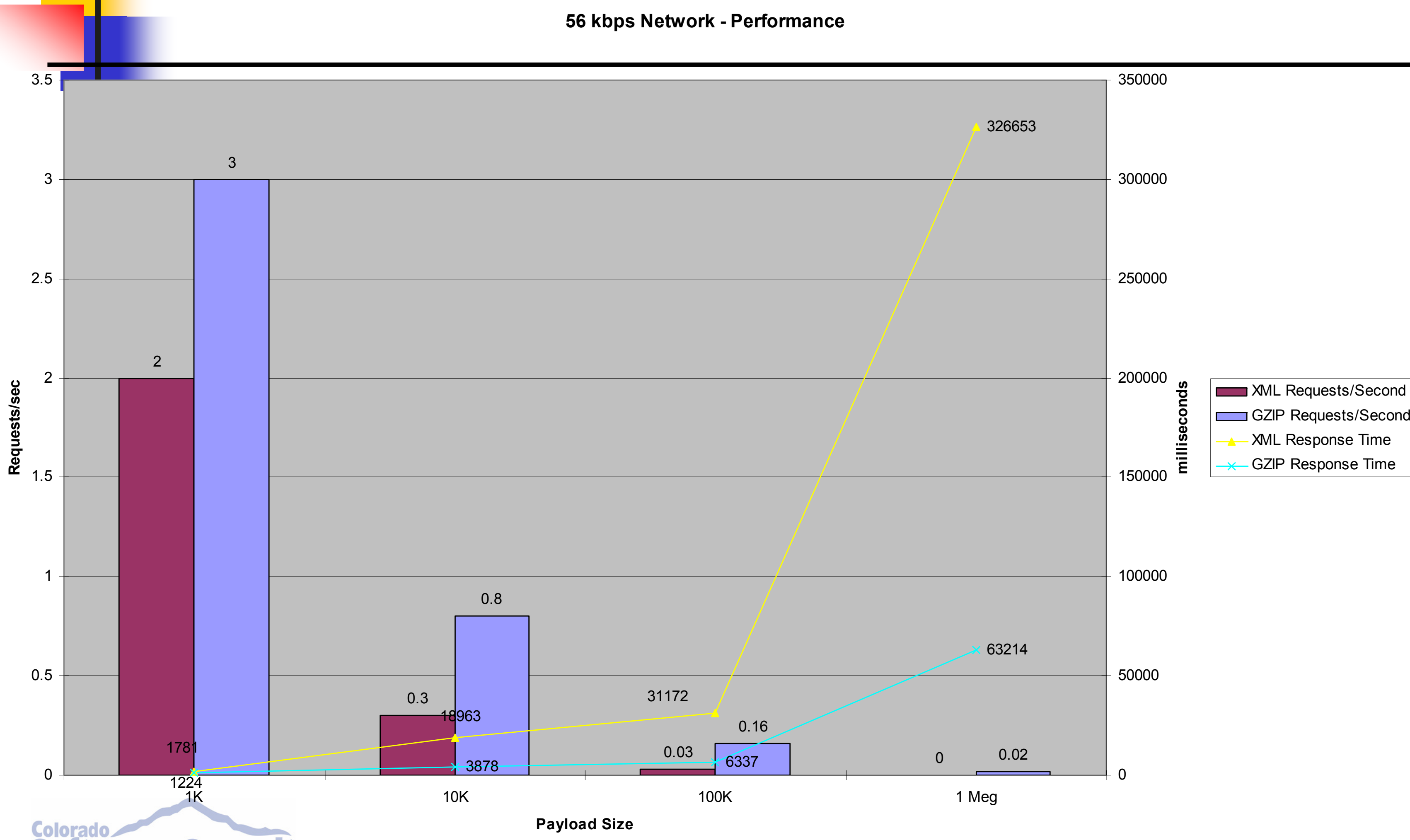

2.4 Mbps Network - Performance
Requests/sec
milliseconds
Payload Size
1K
10K
100K
1 Meg
90
114
14
46
1.4
7
0.14
0.7
57
59
82
328
3419
665
36996
6880
XML Requests/Second
GZIP Requests/Second
XML Response Time
GZIP Response Time

2.4 Mbps Network Summary

- GZIP faster in all cases with the lower response time
  - Better compression enables this as the network becomes the bottleneck
- GZIP
  - Up to 5x faster than XML
  - 3x faster than XML on average

Topology – 56 kbps Network



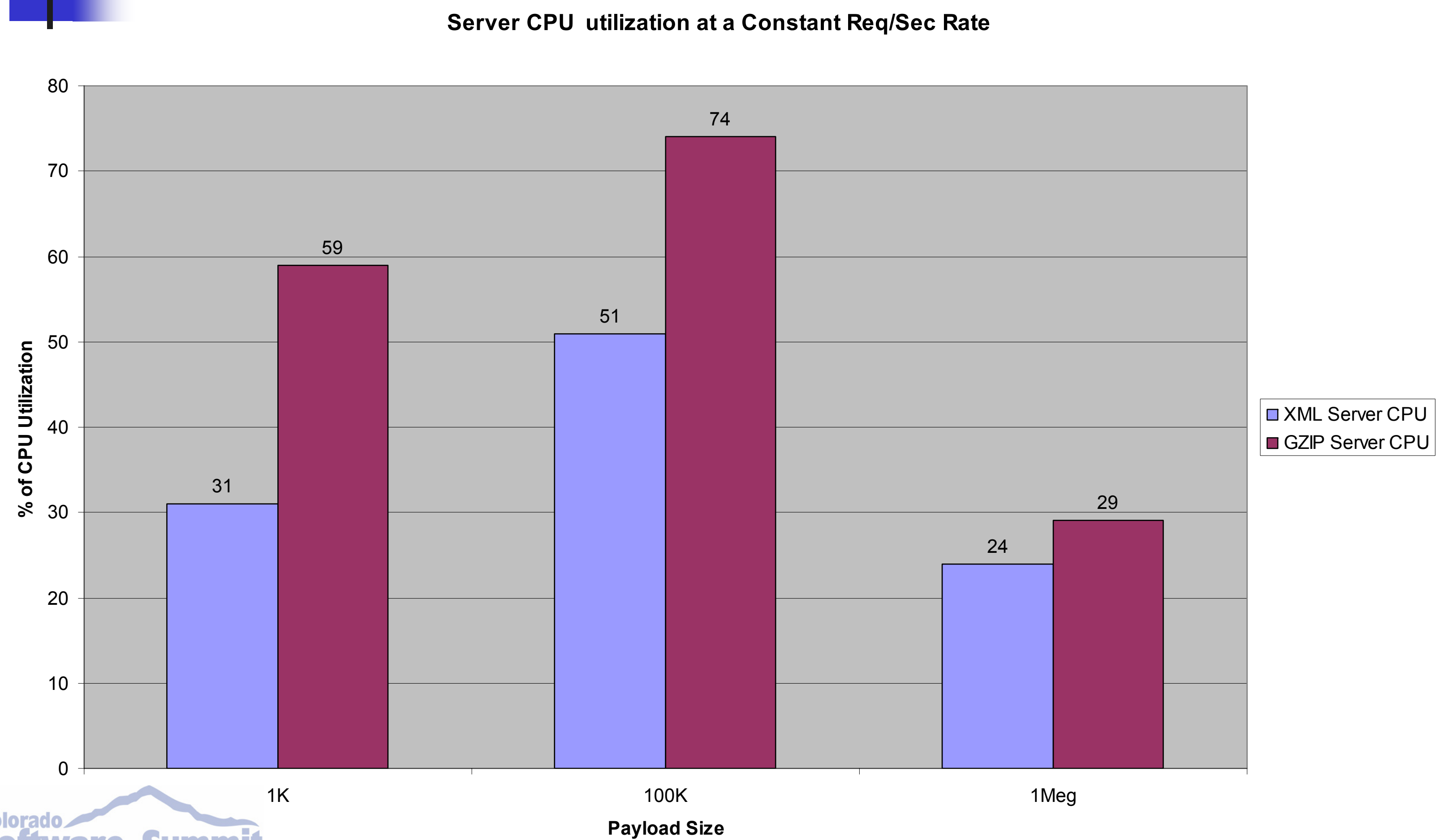

56 kbps Network - Performance
Requests/sec
milliseconds
Payload Size
1K
10K
100K
1 Meg
XML Requests/Second
GZIP Requests/Second
XML Response Time
GZIP Response Time
2
3
0.3
0.8
0.03
0.16
0
0.02
1781
1224
18963
3878
31172
6337
326653
63214

56 kbps Network Summary

- Similar to 2.4 Mbps case
  - GZIP better performer
  - Up to 5x faster than XML
  - About 3x faster than XML on average

XML and GZIP CPU Cost

- Quantify the server CPU utilization for both at the same transaction rate


Server CPU utilization at a Constant Req/Sec Rate
% of CPU Utilization
0
10
20
30
40
50
60
70
80
31
59
51
74
24
29
1K
100K
1Meg
Payload Size
XML Server CPU
GZIP Server CPU

Performance Conclusions

- When the network is not the bottleneck
  - GZIP is slower
- When the network is the bottleneck
  - GZIP is significantly faster than XML
  - GZIP the better performer
    - 3x faster than XML on average

Performance Conclusions

- GZIP uses more CPU at the same tran rate
  - 1K
    - 90% more Server CPU
  - 100K
    - 45% more Server CPU
  - 1Meg
    - 21% more Server CPU

Enabling GZIP Compression

- Need to enable it on client and server
- If client is browser and it supports GZIP
  - Just worry about server
- Otherwise, need to handle GZIP on both client and server

HTTP Headers

- Accept-Encoding:
  - Tells receiver that you accept the comma separated list of encodings
- Content-Encoding:
  - Tells receiver the encoding of what you sent
- Content-Type:
  - Tells receiver the type of data being sent
    - Ex: text/xml

HTTP Headers

- When you add code to your server to handle GZIP
  - Only encode response with GZIP if the request header contains
    - Accept-Encoding: gzip
      - Means requester supports GZIP
    - If you encode the response with GZIP, include
      - Content-Encoding: gzip
        - Alerts requester of the encoding used

HTTP Headers

- Also add to the response header:
  - Accept-Encoding: gzip
  - This notifies the requester that the server handles gzip
- For XML, Content-Type is “text/xml”
  - For gzip, set it to “binary/gzip”
- For performance, add additional header:
  - Uncompressed-Content-Length:
    - Tells receiver the size of the buffer they need to create to store the message after they uncompress it

Enabling GZIP Compression

- For Server, implement a Servlet Filter
  - Performs GZIP decompression on requests
  - Performs GZIP compression on responses
- Implement the javax.servlet.Filter interface
  - public void init()
  - public void destroy()
  - public void doFilter()

Servlet Filter

- Implement the doFilter() method
  - Check and set HTTP headers
  - Uncompress the request
  - Compress the response

Uncompress the Request

```
//Read the uncompressed content length from the header
int length = 0;
int bytesread;
String uncompressedContentLength = req.getHeader("Uncompressed-Content-Length");
if (uncompressedContentLength != null)
   length = Integer.parseInt(uncompressedContentLength.trim());

//create a buffer to hold the uncompressed data
byte[] uncompressedData = new byte[length];
try {
   //unzip the message
   GZIPInputStream gzipIS = new GZIPInputStream(req.getInputStream(), length);
   bytesread = gzipIS.read(uncompressedData, 0, length);
   while (bytesread != length)  //1
   {
      int numbytes = gzipIS.read(uncompressedData, bytesread, (length - bytesread));
      if (numbytes == -1)
         break;
      bytesread += numbytes;
   }
}
catch (Exception e) {
   System.out.println("Exception caught: ");
   e.printStackTrace();
}
```

Compress Response

```
//Get the uncompressed data and its length
byte[] uncompressedData = getBytes();
uncompressedContentLength = uncompressedData.length;

//Create a byte array buffer to hold the compressed content
ByteArrayOutputStream baos = new ByteArrayOutputStream(uncompressedContentLength);
try {
   //zip the data and write it to the stream
   GZIPOutputStream gzipOS = new GZIPOutputStream(baos, uncompressedContentLength);
   gzipOS.write(uncompressedData, 0, uncompressedContentLength);  //1
   gzipOS.finish();  //2
}
catch (IOException ioe) { ioe.printStackTrace(); }
compressedData = baos.toByteArray();

//Use length when you set the Content-Length header
length = compressedData.length;
res.addHeader(HTTPConstants.HEADER_UNCOMPRESSED_CONTENT_LENGTH,
                    String.valueOf(uncompressedContentLength));
java.io.OutputStream out = res.getOutputStream();
//Write the compressed data to the stream
out.write(compressedData);
```

Uncompressed-Content-Length

- Important to use this
- Without it, code must guess at buffer size
  - If wrong:
    - Waste memory if too big
    - Waste time creating new buffers and copying data if too small
  - Usage of Uncompressed-Content-Length avoids both issues

JDK GZIP Streams

- java.util.zip package
- Works differently than other streams
  - Don't know why
- When writing data to a GZIPOutputStream
  - You MUST call finish(); after calling write();
    - See //1 and //2 on previous slide
  - finish() completes writing data to the stream and writes the trailer
    - Does not close the underlying stream

GZIPOutputStream – 3 steps to make it work as you want

- 1) Invoke constructor
  - Creates stream
  - Writes header
- 2) Invoke write()
  - Writes data
- 3) Invoke finish()
  - Completes the write (it's buffered)
  - Writes trailer

JDK GZIP Streams

- When reading into a GZIPInputStream
  - Make sure you call read() in a loop until it returns -1
    - -1 indicates you are done
    - See //1 on "Uncompress the Request" slide

W3C XML Binary Characterization Working Group

- Formed in March 2004 to investigate the benefits and drawbacks to a binary representation of XML
  - http://www.w3.org/XML/Binary/
  - Not chartered to write a spec
  - Chartered to make a recommendation on whether another group should be commissioned to produce a spec

W3C XML Binary Characterization Working Group

- Group has one year charter
  - Work ends March 2005
- Output
  - Use Case Document
  - Properties Document
  - Measurements Document
  - Recommendation for creating a standard

W3C XML Binary Characterization Working Group

- Current draft of Use Case document
  - http://www.w3.org/XML/Binary/UseCases/xbc-use-cases.html
- Current draft of Properties document
  - http://www.w3.org/XML/Binary/Properties/xbc-properties.html
- Current draft of Measurements document
  - Not available at the time of this writing

W3C XML Binary Characterization Working Group

- Diverse interests represented
  - Business to Business
  - 3D Graphics
  - Mobile devices
  - Huge sets of scientific data (floating point)
- Will a binary representation satisfy the needs of everyone?
  - And still accomplish goals?

W3C XML Binary Characterization Working Group

- Everyone agrees:
  - Need smaller representation of XML
  - Need a representation that is faster to
    - Transmit
    - Process
- Unclear whether you can optimize small footprint and fast parse speed at the same time
- When you attempt to increase parsing speed
  - You often also increase generation speed

W3C XML Binary Characterization Working Group

- IBM has experimented with an alternate encoding of XML
  - Mixed results
  - Not a clear winner
  - More work needed

W3C XML Binary Characterization Working Group

- Differing needs/desires
  - Server
    - Fast generation
    - Fast parsing/processing
  - Client
    - Small message size due to power constraints and/or connection
    - Cheap to process due to power constraints
- Can one solution address all needs and desires and still meet goals?

References

- http://www.internetworldstats.com/am/us.htm – broadband statistics
- http://www.w3.org/XML/Binary/ – W3C XML Binary Working Group homepage
- http://www.w3.org/XML/Binary/UseCases/xbc-use-cases.html – W3C XML Binary Working Group Use Case Document draft
- http://www.w3.org/XML/Binary/Properties/xbc-properties.html – W3C XML Binary Working Group Properties Document draft