Network Applications: DNS Details; UDP Network App Programming

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http://zoo.cs.yale.edu/classes/cs433/

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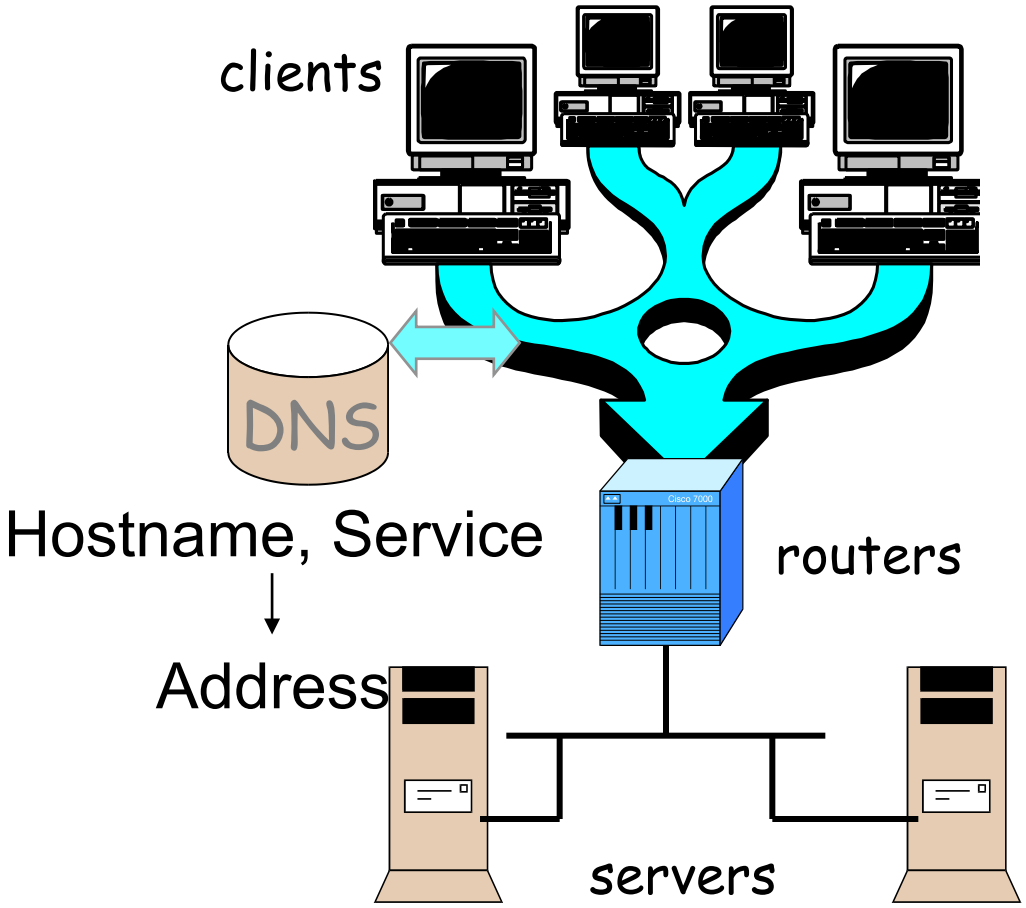
Outline

- Admin and recap
- Network app programming

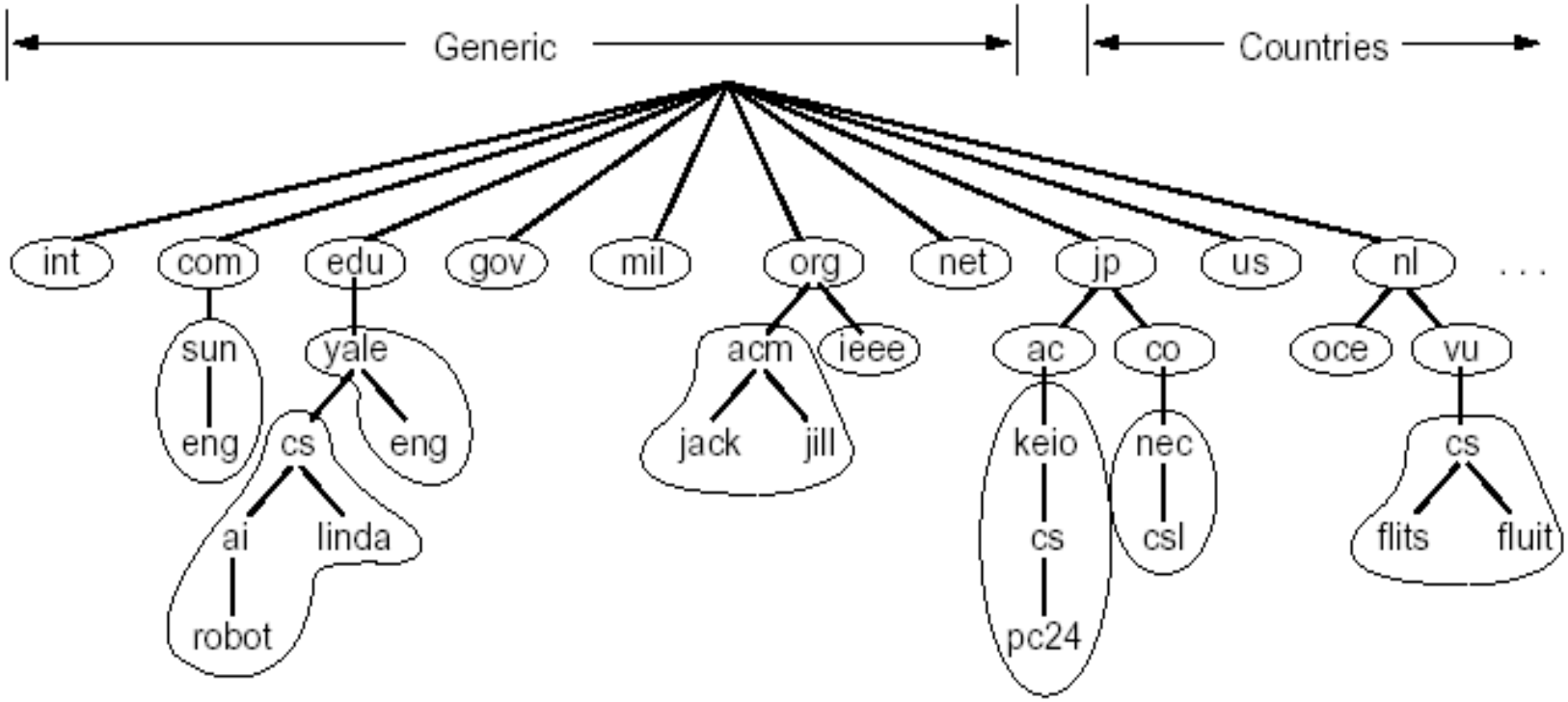
Recap: Domain Name System (DNS)

- Function
  - map between (domain name, service) to value, e.g.,
    - (www.cs.yale.edu, Addr) -> 128.36.229.30
    - (cs.yale.edu, Email) -> netra.cs.yale.edu



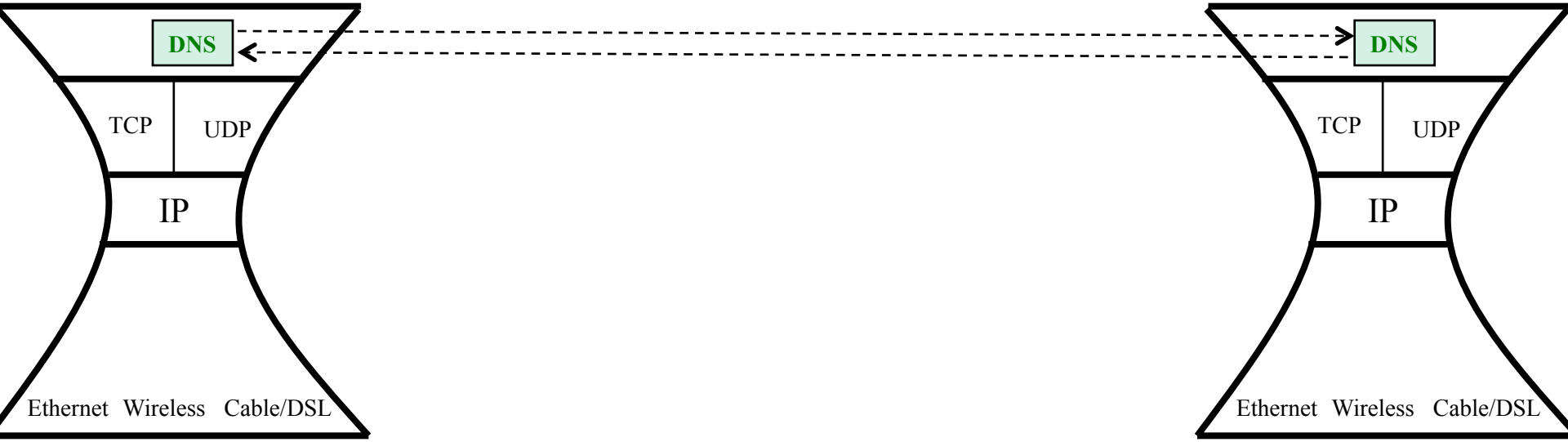
Recap: DNS

- Key design features of DNS
  - Hierarchical domain name space allowing delegation
  - Recursive or iterative queries



DNS Message Format?

Basic encoding decisions: UDP/TCP, how to encode domain name, how to encode answers…



Observing DNS Messages

- Issue DNS query using the command dig:
  - force iterated query to see the trace:

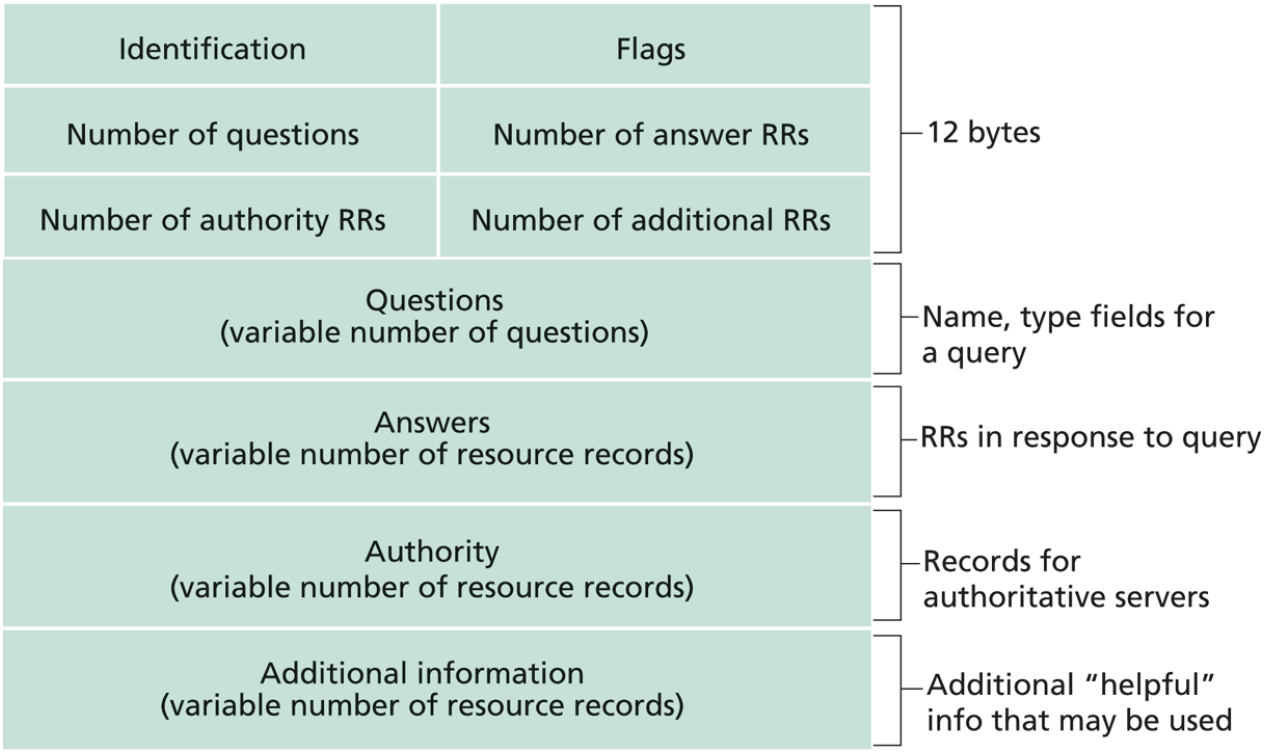
    `%dig +trace www.cnn.com`
    - see the manual for more details

- Capture the messages
  - DNS server is at port 53
    - Display and clear DNS cache
      - https://support.apple.com/en-us/HT202516 (e.g., MAC)
  - Try to load the dns-capture file from class Schedule page, if you do not want live capture

https://www.ietf.org/rfc/rfc1035.txt

DNS Protocol, Messages

DNS protocol : typically over UDP (can use TCP); *query* and *reply* messages, both with the same *message format*



DNS Details

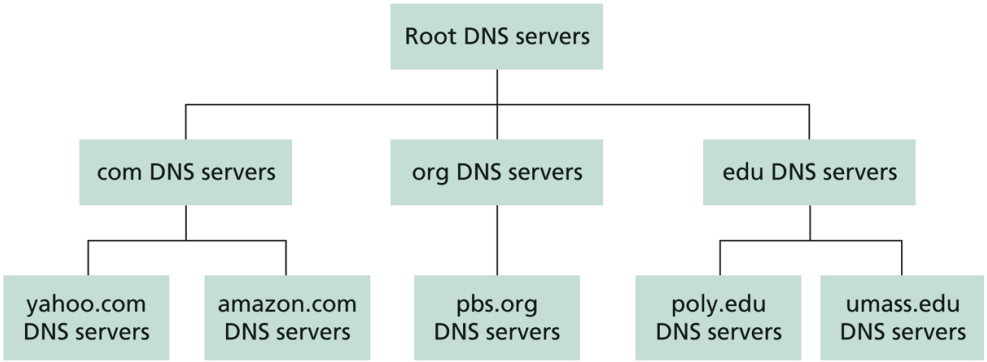
- Header (Sec. 4.1.1 of https://www.ietf.org/rfc/rfc1035.txt)
- Encoding of questions (Sec. 4.1.2):
  - [Label-length label-chars]
- Encoding of answers (Sec. 4.1.3)
  - Pointer format (http://www.iana.org/assignments/dns-parameters/dns-parameters.xhtml)

- See example DNS packets

Evaluation of DNS

Key questions to ask about a C-S application

- **extensible**?
- **scalable**?
- **robust**?
- **security**?



What DNS did Right?

- Hierarchical delegation avoids central control, improving manageability and scalability
- Redundant servers improve robustness
  - see http://www.internetnews.com/dev-news/article.php/1486981 for DDoS attack on root servers in Oct. 2002 (9 of the 13 root servers were crippled, but only slowed the network)
- Caching reduces workload and improves robustness

Problems of DNS

- Domain names may not be the best way to name other resources, e.g. files
- Simple query model makes it hard to implement advanced query
- Relatively static resource types make it hard to introduce new services or handle mobility
- Although theoretically you can update the values of the records, it is rarely enabled
- Early binding (separation of DNS query from application query) does not work well in mobile, dynamic environments
  - e.g., load balancing, locate the nearest printer

Outline

- Recap
- Network app programming

Socket Programming

Socket API

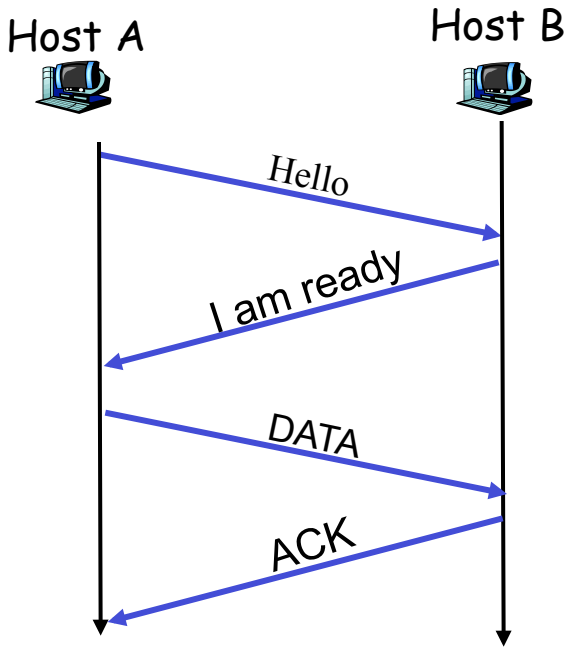
- introduced in BSD4.1 UNIX, 1981
- Two types of sockets
  - Connectionless (UDP)
  - connection-oriented (TCP)

socket

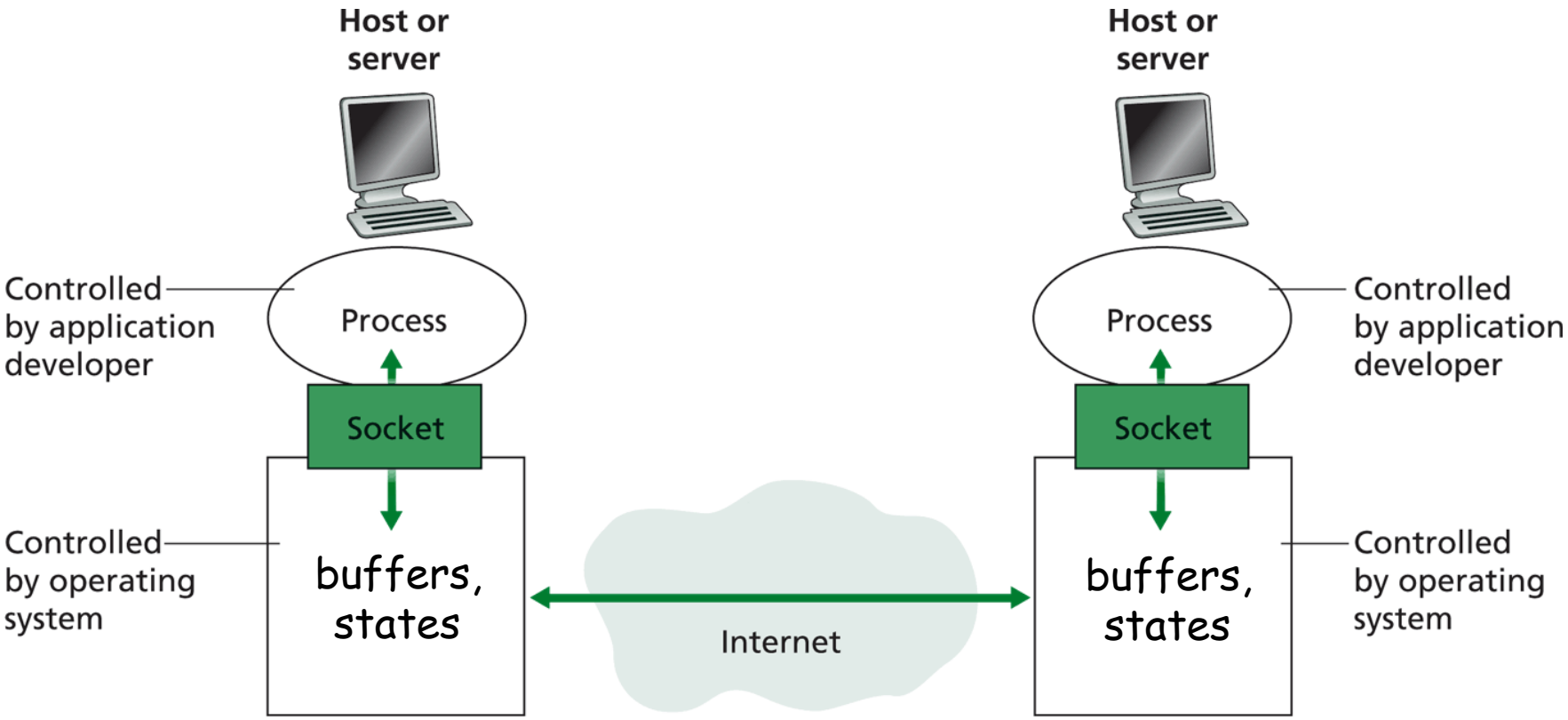
an interface (a "door") into which one application process can both send and receive messages to/from another (remote or local) application process

Services Provided by Transport

- User data protocol (UDP)
  - multiplexing/demultiplexing
- Transmission control protocol (TCP)
  - multiplexing/demultiplexing
  - reliable data transfer
  - rate control: flow control and congestion control



Big Picture: Socket



Outline

- Recap
- Basic network application programming
  - Overview
  - UDP (Datagram Socket)

DatagramSocket(Java) (Basic)

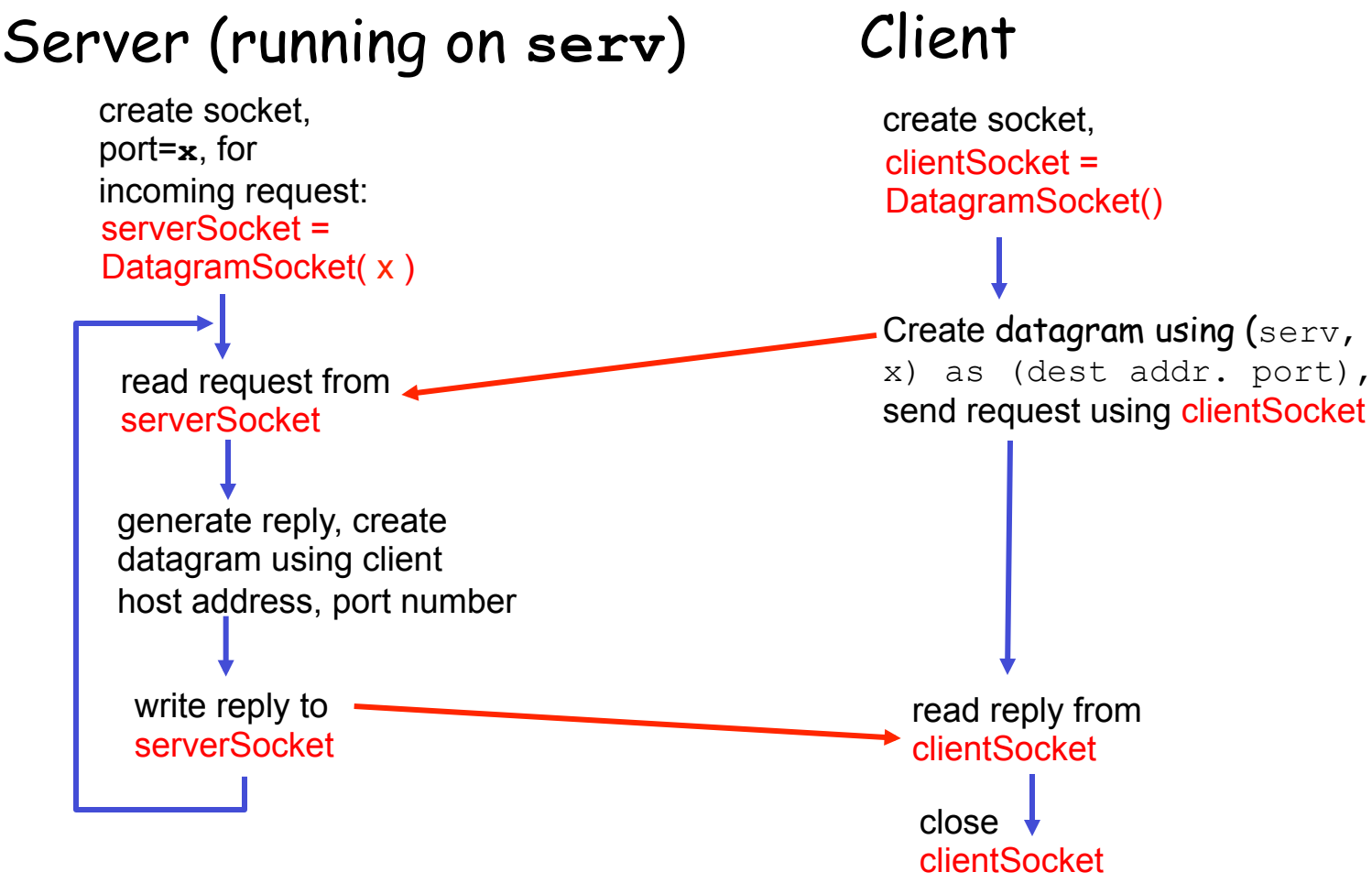
- **DatagramSocket**()
  constructs a datagram socket and binds it to any available port on the local host
- **DatagramSocket**(int lport)
  constructs a datagram socket and binds it to the specified port on the local host machine.

- **DatagramPacket**(byte[] buf, int length)
  constructs a DatagramPacket for receiving packets of length length.
- **DatagramPacket**(byte[] buf, int length, InetAddress address, int port)
  constructs a datagram packet for sending packets of length length to the specified port number on the specified host.

- **receive**(DatagramPacket p)
  receives a datagram packet from this socket.
- **send**(DatagramPacket p)
  sends a datagram packet from this socket.

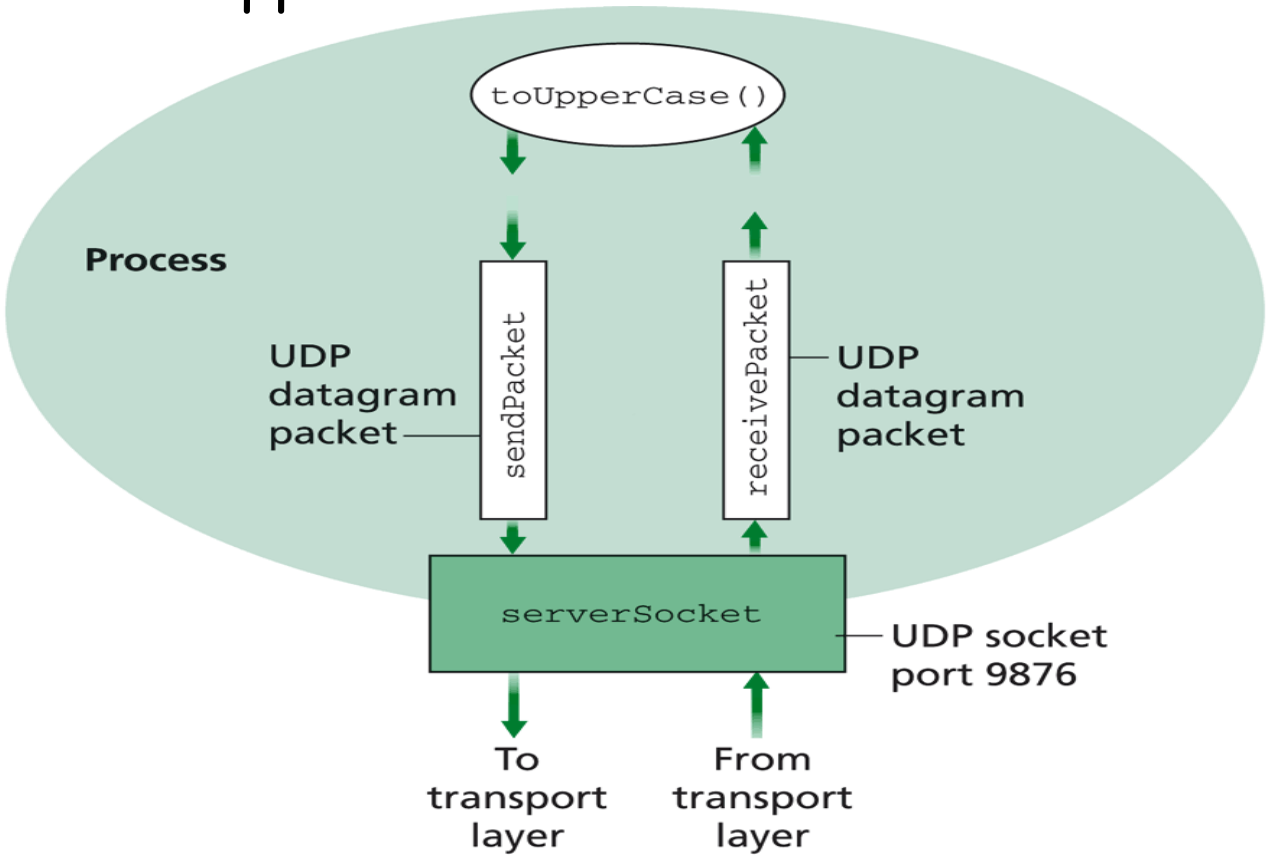
- **close**()
  closes this datagram socket.

Connectionless UDP: Big Picture (Java version)



Example: UDPServer.java

- A simple UDP server which changes any received sentence to upper case.



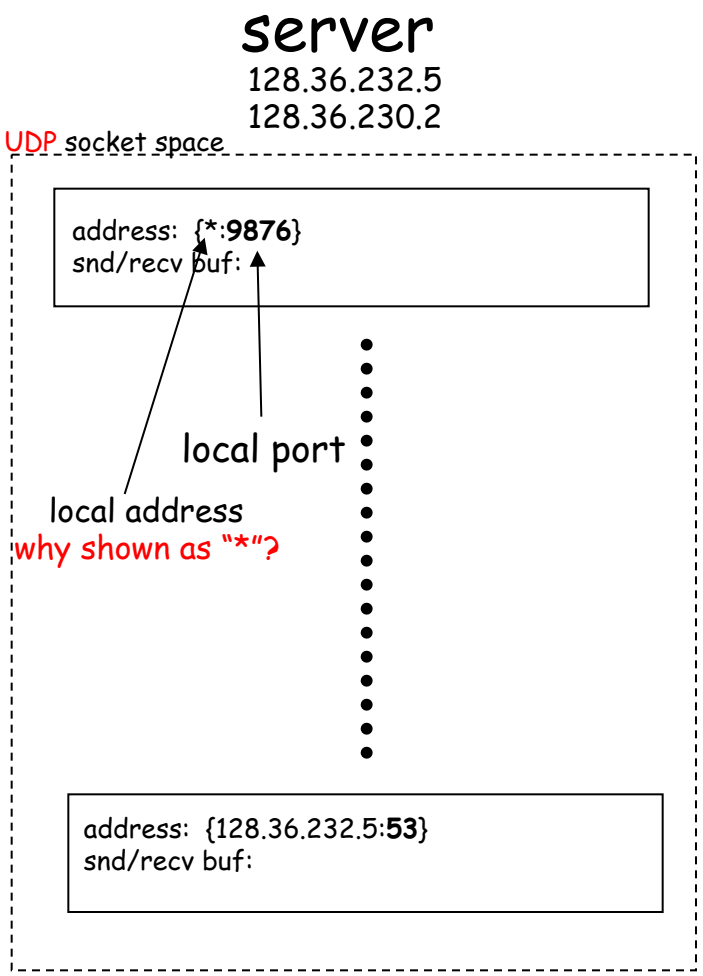
Java Server (UDP): Create Socket

```
import java.io.*;
import java.net.*;

class UDPServer {
  public static void main(String args[]) throws Exception
   {

    DatagramSocket serverSocket = new DatagramSocket(9876);
```

Create datagram socket bind at port 9876

Check socket state:
%netstat –a –p udp –n

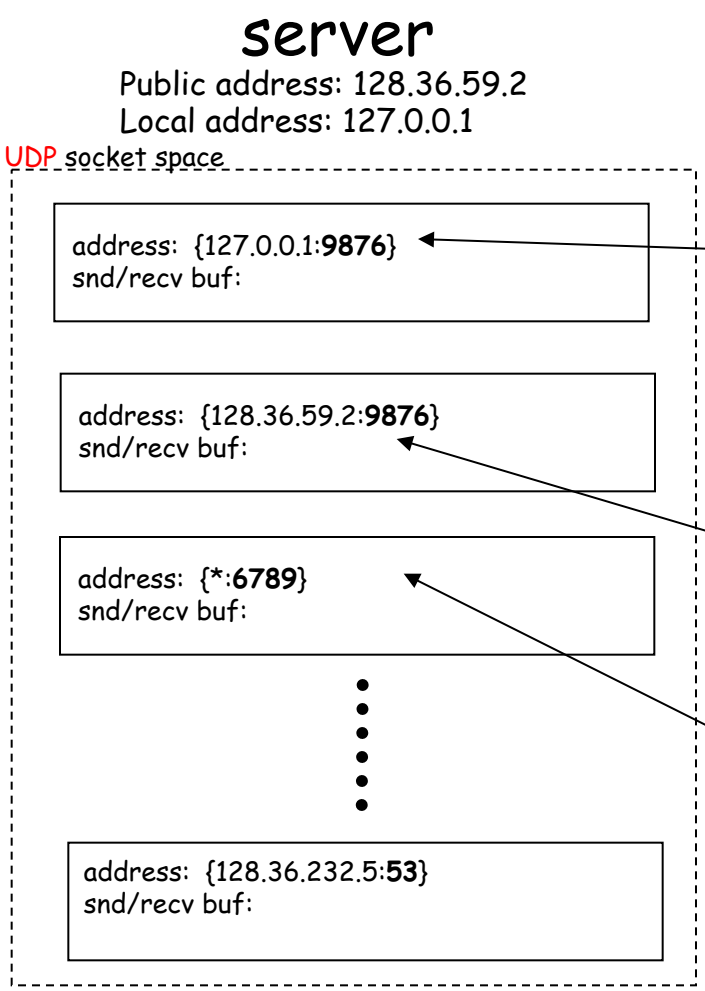
System State after the Call



"*" indicates that the socket binds to all IP addresses of the machine:

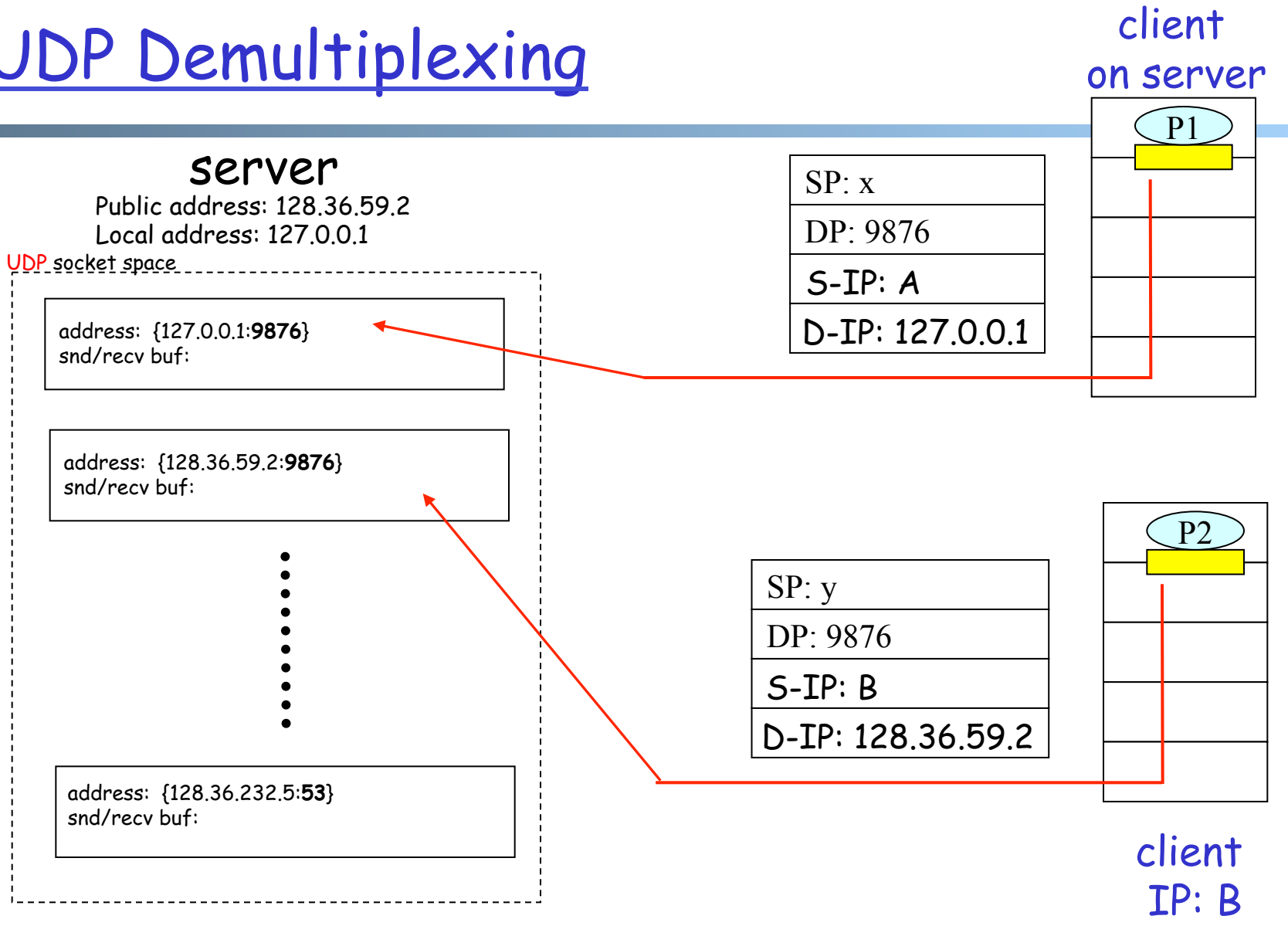
```
% ifconfig -a
```

Binding to Specific IP Addresses



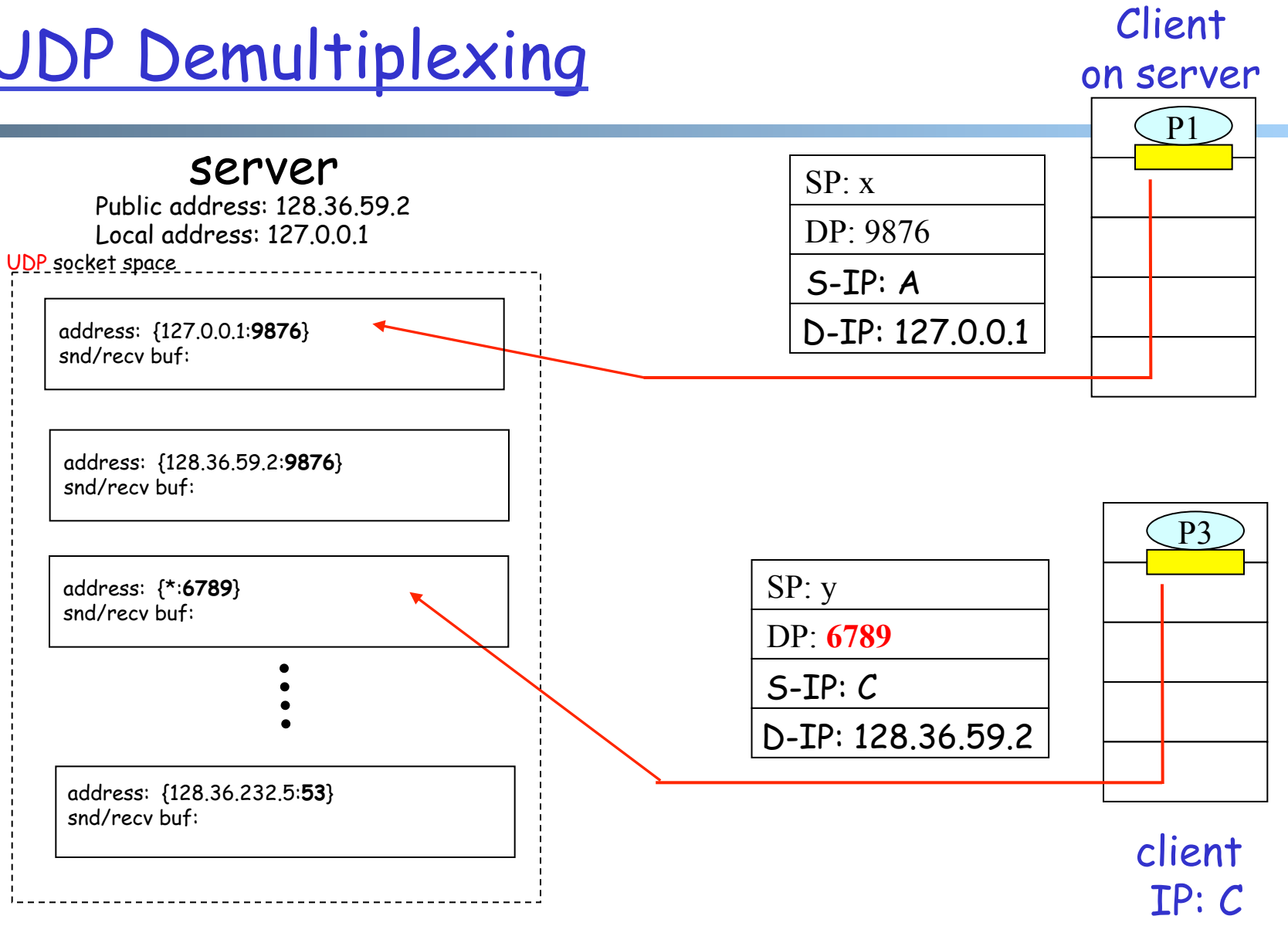

```
InetAddress sIP1 =
   InetAddress.getByName("localhost");
DatagramSocket ssock1 = new
       DatagramSocket(9876, sIP1);

InetAddress sIP2 =
 InetAddress.getByName("128.36.59.2");
DatagramSocket ssock2 = new
       DatagramSocket(9876,sIP2);

DatagramSocket serverSocket = new
DatagramSocket(6789);
```

UDP Demultiplexing



UDP demutiplexing is based on matching (dst address, dst port)

UDP Demultiplexing



UDP demutiplexing is based on matching (dst address, dst port)

Per Socket State

- Each Datagram socket has a set of states:
  - local address
  - send buffer size
  - receive buffer size
  - timeout
  - traffic class

See http://download.java.net/jdk7/archive/b123/docs/api/java/net/DatagramSocket.html

Example: socket state after clients sent msgs to the server

Java Server (UDP): Receiving

```
import java.io.*;
import java.net.*;

class UDPServer {
  public static void main(String args[]) throws Exception
    {

      DatagramSocket serverSocket = new DatagramSocket(9876);

      byte[] receiveData = new byte[1024];
      byte[] sendData = null;

      while(true)
        {

          DatagramPacket receivePacket =
            new DatagramPacket(receiveData, receiveData.length);

          serverSocket.receive(receivePacket);
```

Create space for received datagram

Receive datagram

DatagramPacket

- **Receiving**
  - **DatagramPacket**(byte[] buf, int length)
    constructs a DatagramPacket for receiving packets of length length.
  - **DatagramPacket**(byte[] buf, int offset, int length)
    constructs a DatagramPacket for receiving packets starting at offset, length length.

- **Sending**
  - **DatagramPacket**(byte[] buf, int length, InetAddress address, int port)
    constructs a datagram packet for sending packets of length length to the specified port number on the specified host.
  - **DatagramPacket**(byte[] buf, int offset, int length, InetAddress address, int port)

Java Server (UDP): Processing

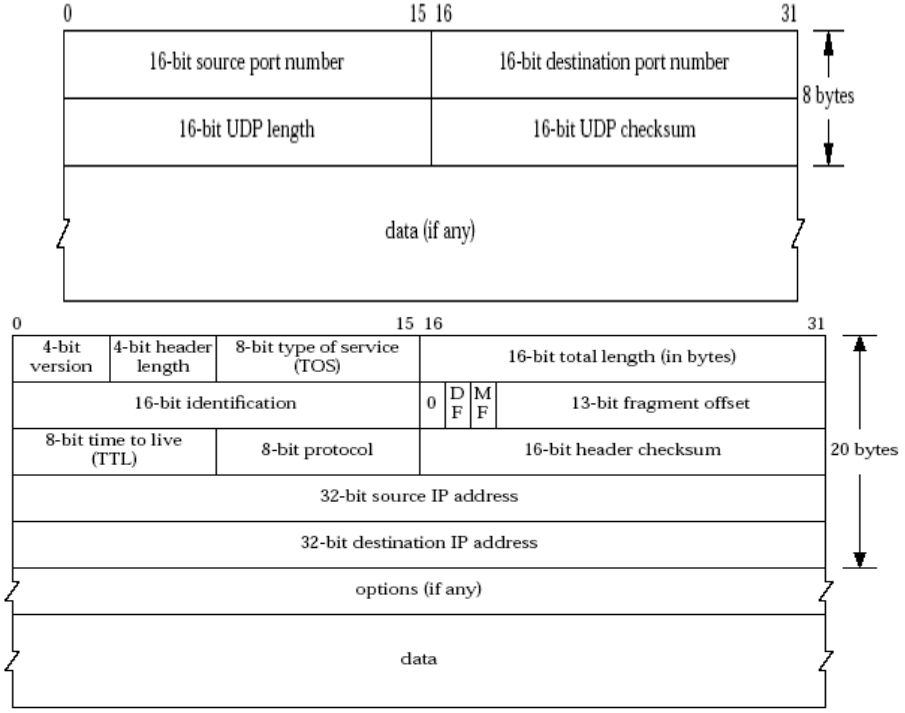
```
import java.io.*;
import java.net.*;

class UDPServer {
  public static void main(String args[]) throws Exception  {

…
// process data
String sentence = new String(receivePacket.getData(),
                             0, receivePacket.getLength());
String capitalizedSentence = sentence.toUpperCase();
sendData = capitalizedSentence.getBytes();
```

getData() returns a pointer to an underlying buffer array; for efficiency, don't assume receive() will reset the rest of the array

getLength() returns how much data is valid.

Java Server (UDP): Response

- Java DatagramPacket:
  - `getAddress()/ getPort()` returns the source address/port



Java server (UDP): Reply

Get IP addr port #, of sender

```
InetAddress IPAddress = receivePacket.getAddress();
int port = receivePacket.getPort();
```

Create datagram to send to client

```
DatagramPacket sendPacket =
  new DatagramPacket(sendData, sendData.length,
                     IPAddress, port);
```

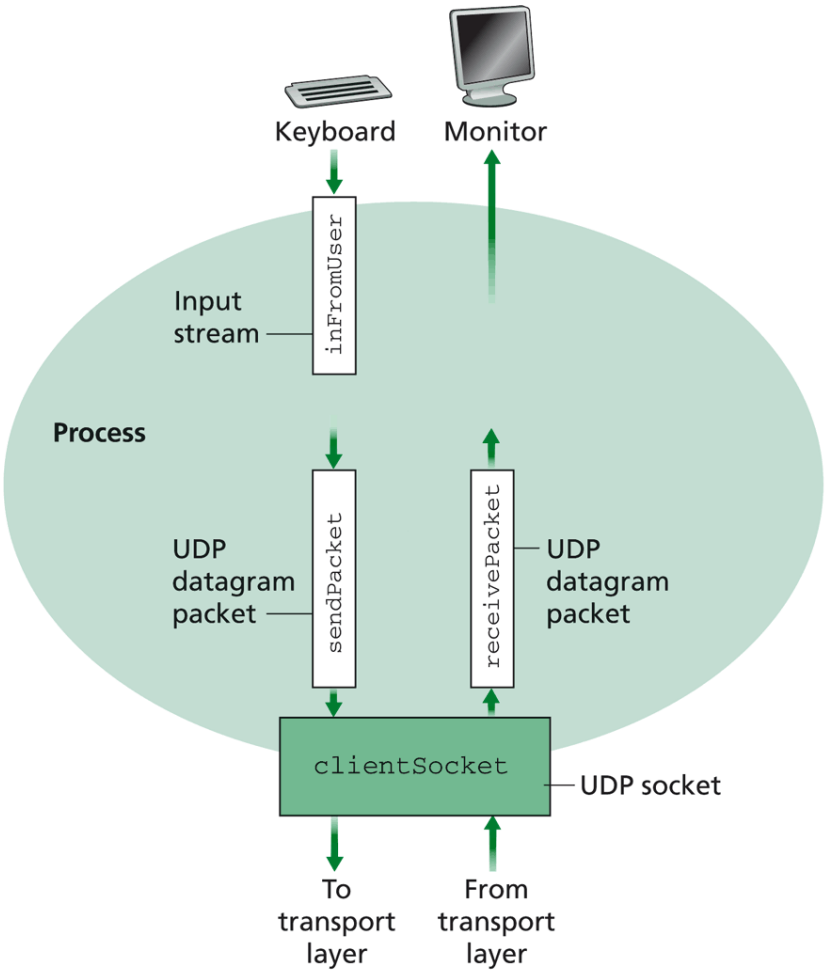
Write out datagram to socket

```
serverSocket.send(sendPacket);
    }
  }
}
```

End of while loop, loop back and wait for another datagram

Example: UDPClient.java

- A simple UDP client which reads input from keyboard, sends the input to server, and reads the reply back from the server.



Example: Java client (UDP)

```
import java.io.*;
import java.net.*;

class UDPClient {
   public static void main(String args[]) throws Exception
   {
     BufferedReader inFromUser =
       new BufferedReader(new InputStreamReader(System.in));
     String sentence = inFromUser.readLine();
     byte[] sendData = sentence.getBytes();

     DatagramSocket clientSocket = new DatagramSocket();

     InetAddress sIPAddress = InetAddress.getByName("servname");
```

Create input stream

Create client socket

Translate hostname to IP address using DNS

Example: Java client (UDP), cont.

Create datagram with data-to-send, length, IP addr, port

Send datagram to server

Read datagram from server

```
DatagramPacket sendPacket =
   new DatagramPacket(sendData, sendData.length, sIPAddress, 9876);

clientSocket.send(sendPacket);

byte[] receiveData = new byte[1024];
DatagramPacket receivePacket =
   new DatagramPacket(receiveData, receiveData.length);

clientSocket.receive(receivePacket);

String modifiedSentence =
    new String(receivePacket.getData());

System.out.println("FROM SERVER:" + modifiedSentence);
clientSocket.close();
}

}
```

Demo

%mac: java UDPServer
% netstat to see buffer

%cicada: java UDPClient <server>

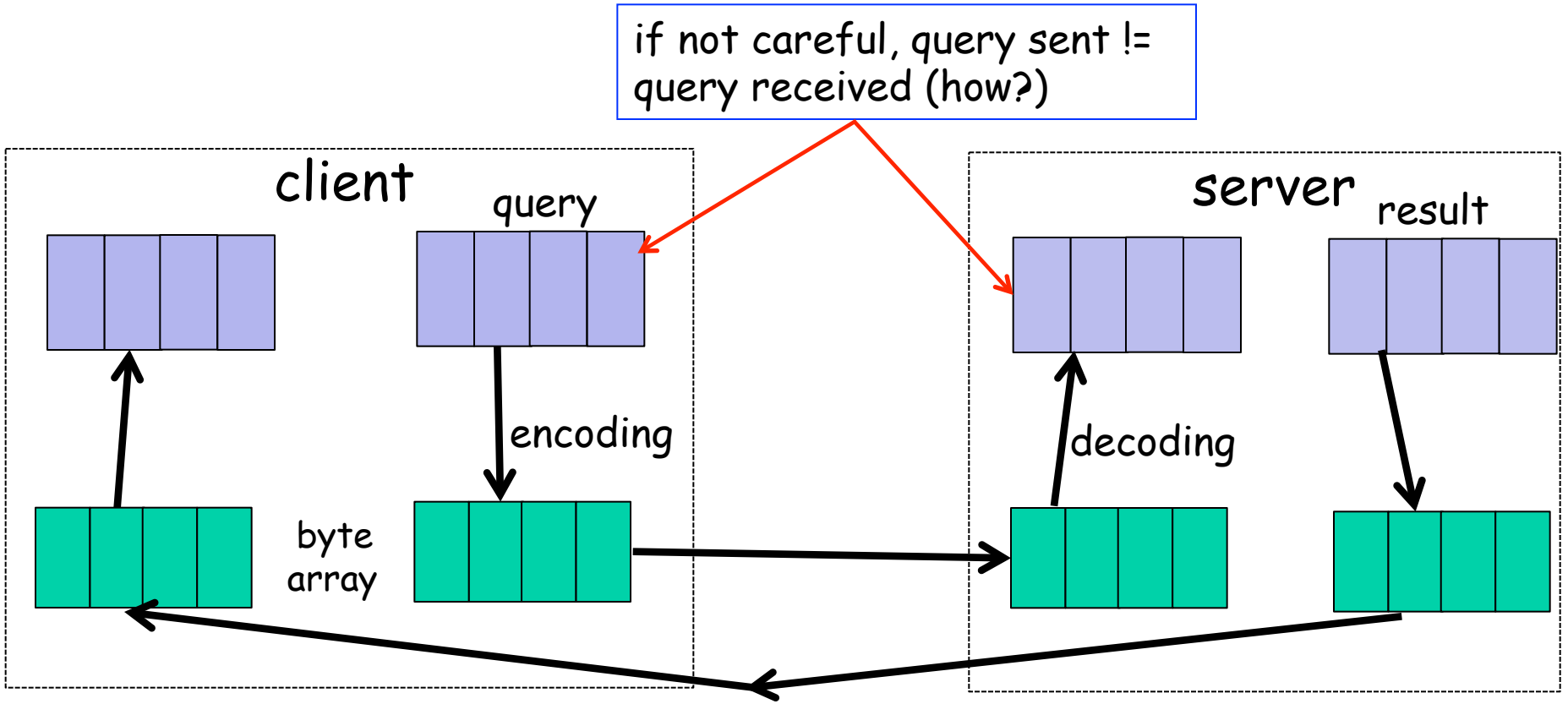
% wireshark to capture traffic

Discussion on Example Code

- A simple upper-case UDP echo service is among the simplest network service.
- Are there any problems with the program?

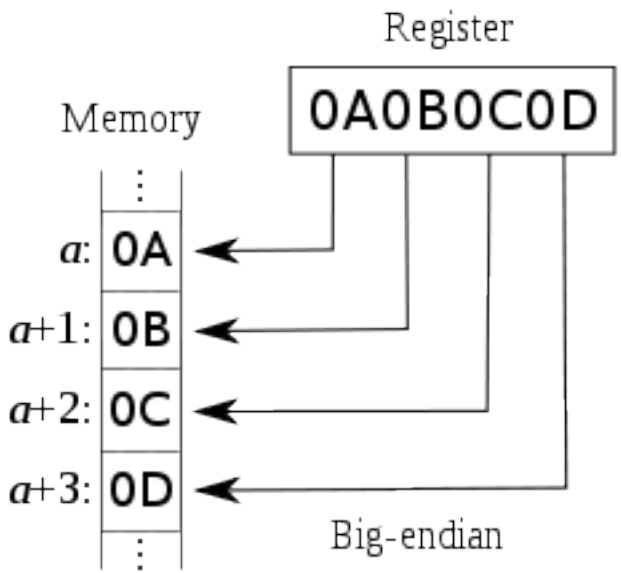
Data Encoding/Decoding

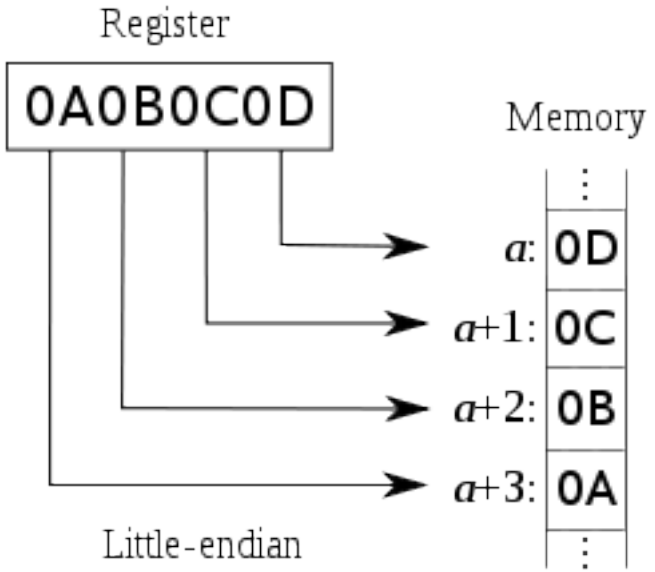
- Pay attention to encoding/decoding of data: transport layer handles only a sequence of bytes



Example: Endianness of Numbers

- int var = 0x0A0B0C0D

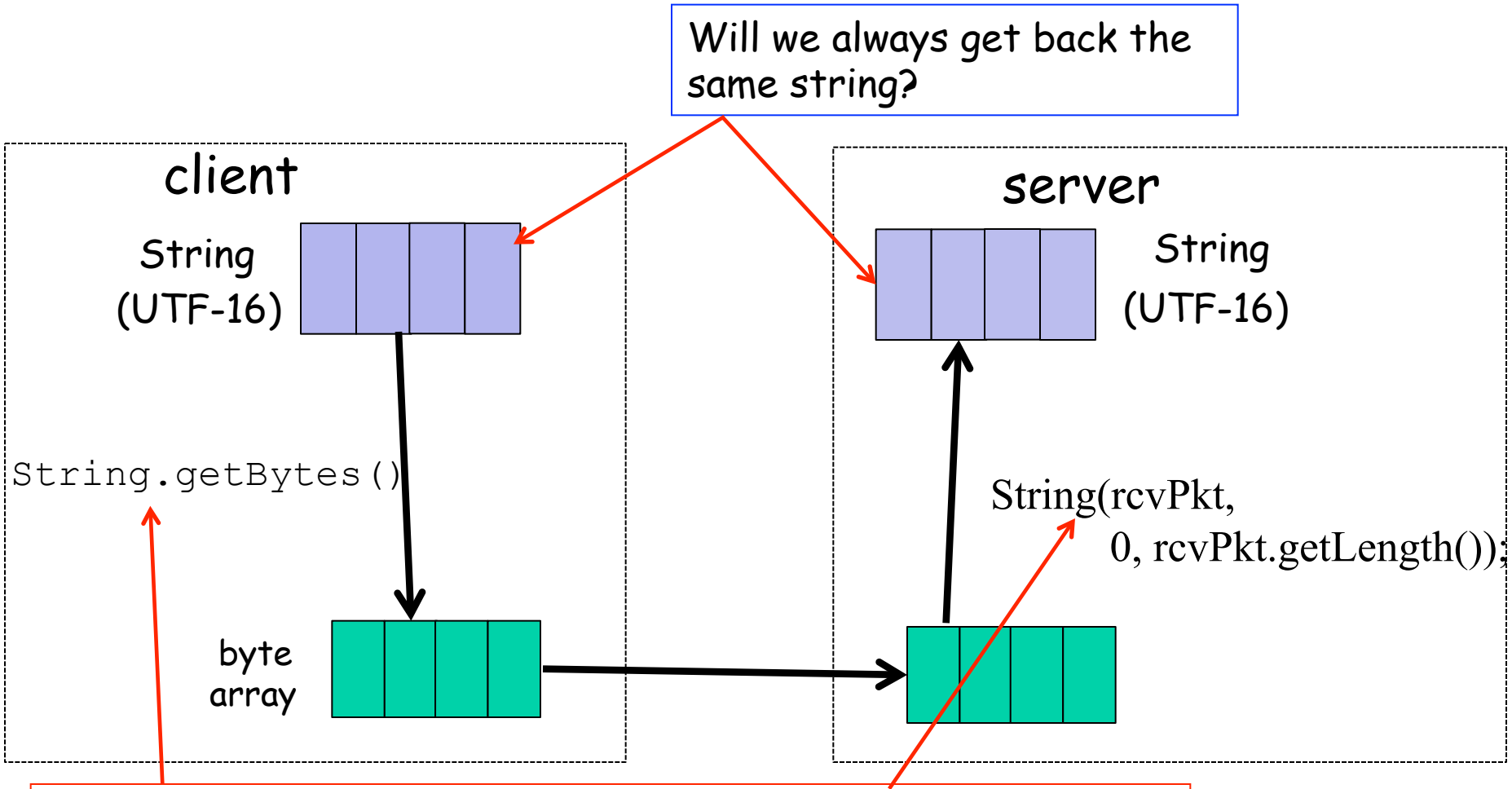




ARM, Power PC, Motorola 68k, IA-64

Intel x86

Example: String and Chars



Depends on default local platform char set (why?) : java.nio.charset.Charset.defaultCharset()

Example: Charset Troubles

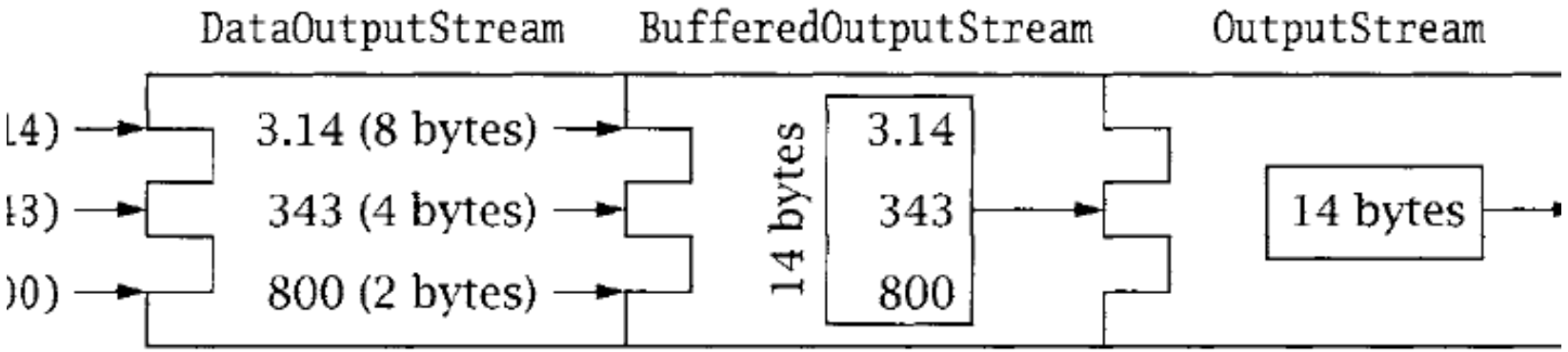
- Try
  - java EncodingDecoding US-ASCII UTF-8

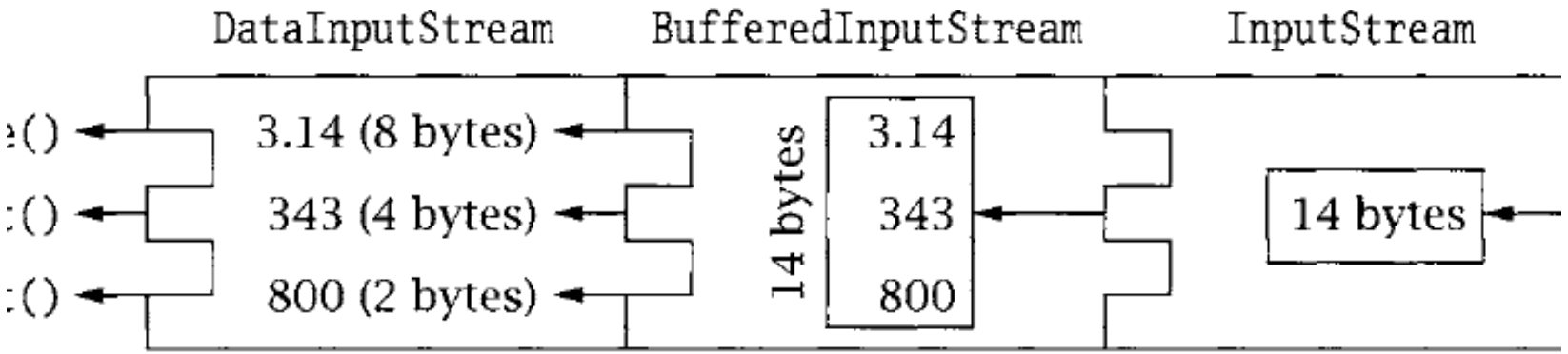
Encoding/Decoding as a Common Source of Errors

- Please read chapter 4 of Java Network Programming for more details

- Common mistake even in many (textbook) examples:
  - http://www.java2s.com/Code/Java/Network-Protocol/UseDatagramSockettosendoutandreceiveDatagramPacket.htm

DataStream


DataOutputStream
BufferedOutputStream
OutputStream
3.14 (8 bytes)
343 (4 bytes)
800 (2 bytes)
14 bytes
3.14
343
800
14 bytes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