
Network Applications: Network Programming: UDP, TCP

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<https://qiaoxiang.me/courses/cnns-xmuf22/index.shtml>

09/29/2022

Outline

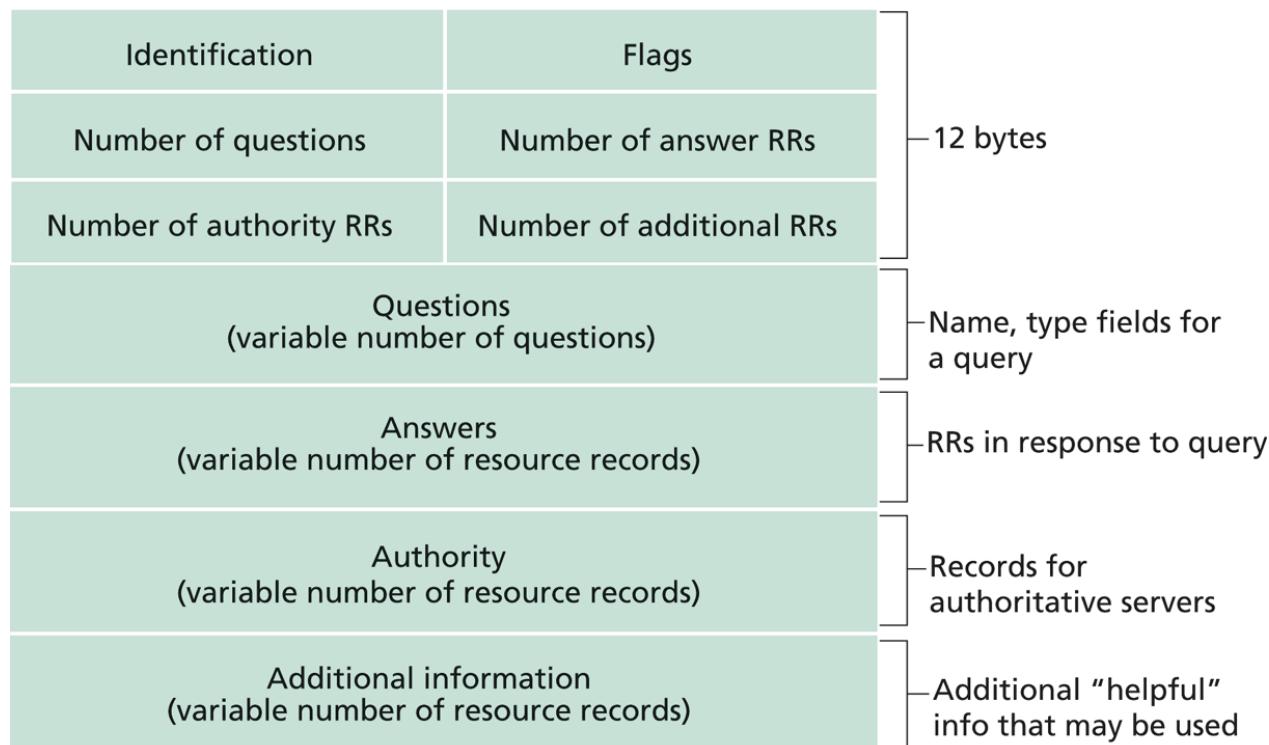
- Admin. and recap
- Basic network applications
 - Email
 - DNS
- Java in a Nutshell
- Network application programming

Admin

- Assignment One due today
- Assignment Two linked on the schedule page
 - Oct. 13, in class or by email to the instructor
- A list of potential project topics linked on the schedule page
 - 2~4 persons per team
 - Talk to the instructor for more details
 - More topics to post soon

Recap: DNS Protocol, Messages

Many features: typically over **UDP** (can use **TCP**); **query** and **reply** messages with the **same message format**; **length/content encoding of names**; **simple compression**; **additional info as server push**



Name Encoding

▼ Queries

▼ xmuxmu.edu.cn: type A, class IN

Name: xmuxmu.edu.cn

[Name Length: 10]

[Label Count: 3]

Type: A (Host Address) (1)

Class: IN (0x0001)

[\[Response In: 3\]](#)

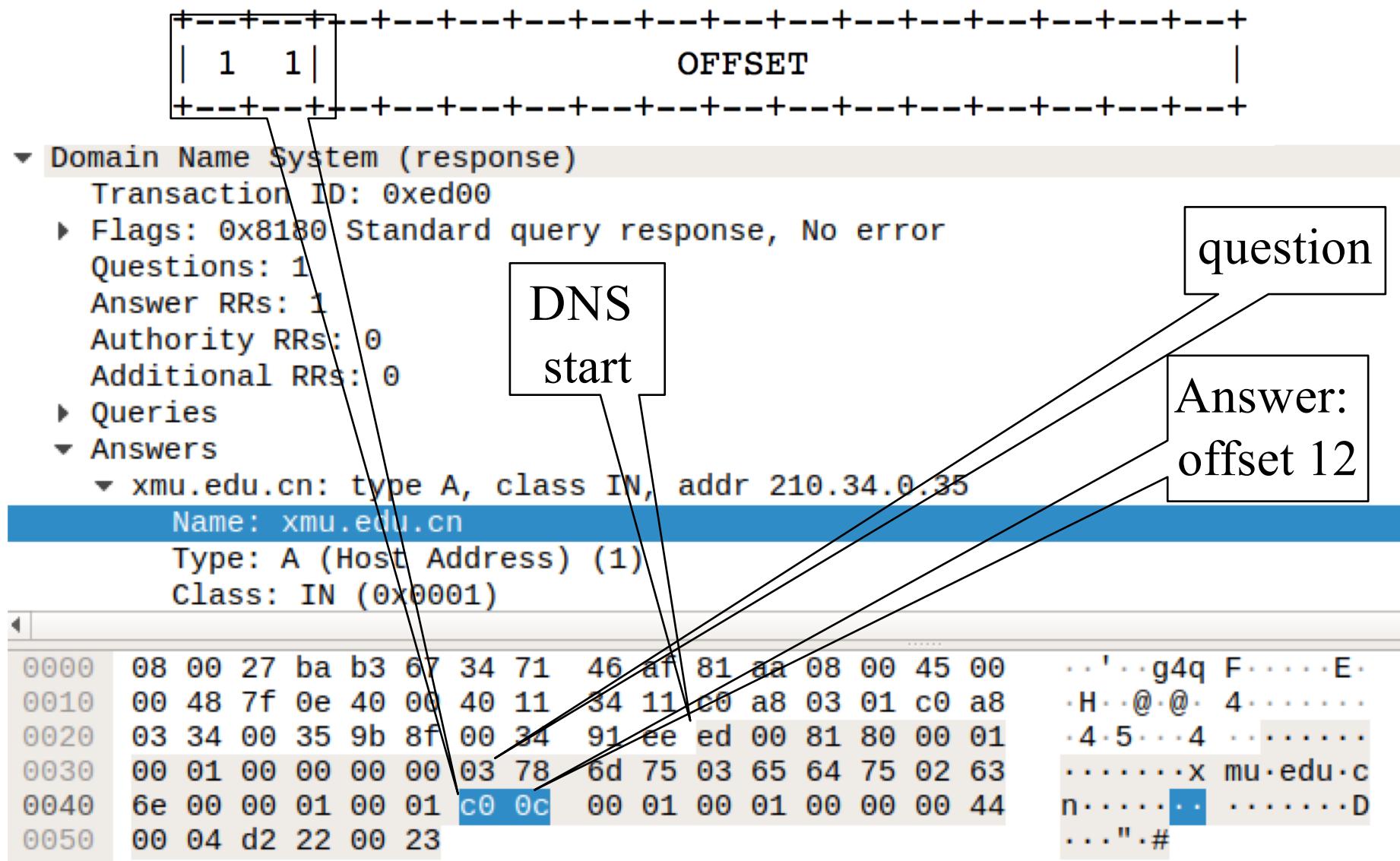
	Raw Hex Data															Decoded ASCII																
0000	34	71	46	af	81	aa	08	00	27	ba	b3	67	08	00	45	00	4qF	'	g	..	E	.	8	@	@	.	[....	4	..	
0010	00	38	02	d4	40	00	40	11	b0	5b	c0	a8	03	34	c0	a8	5	\$
0020	03	01	9b	8f	00	35	00	24	87	bb	ed	00	01	00	00	01	
0030	00	00	00	00	00	00	00	03	78	6d	75	03	65	64	75	02	63	x	mu	.edu	.	c	n			
0040	6e	00	00	01	00	01	00	01	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	

Diagram illustrating the name encoding:

- The label "cn" is at offset 0040, length 1.
- The label "xmu" is at offset 0030, length 3.
- The label "edu" is at offset 0020, length 2.
- The label "length" is at offset 0040, length 4.

Message Compression

(Label Pointer)



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
- Proactive answers reduce # queries on server and latency on client

Problems of DNS

- Simple query model, relatively static resource values and types make it harder to implement generic service discovery
 - e.g., service discovery of all printers
 - 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
- Each local domain needs servers, but an ad hoc domain may not have a DNS server

Outline

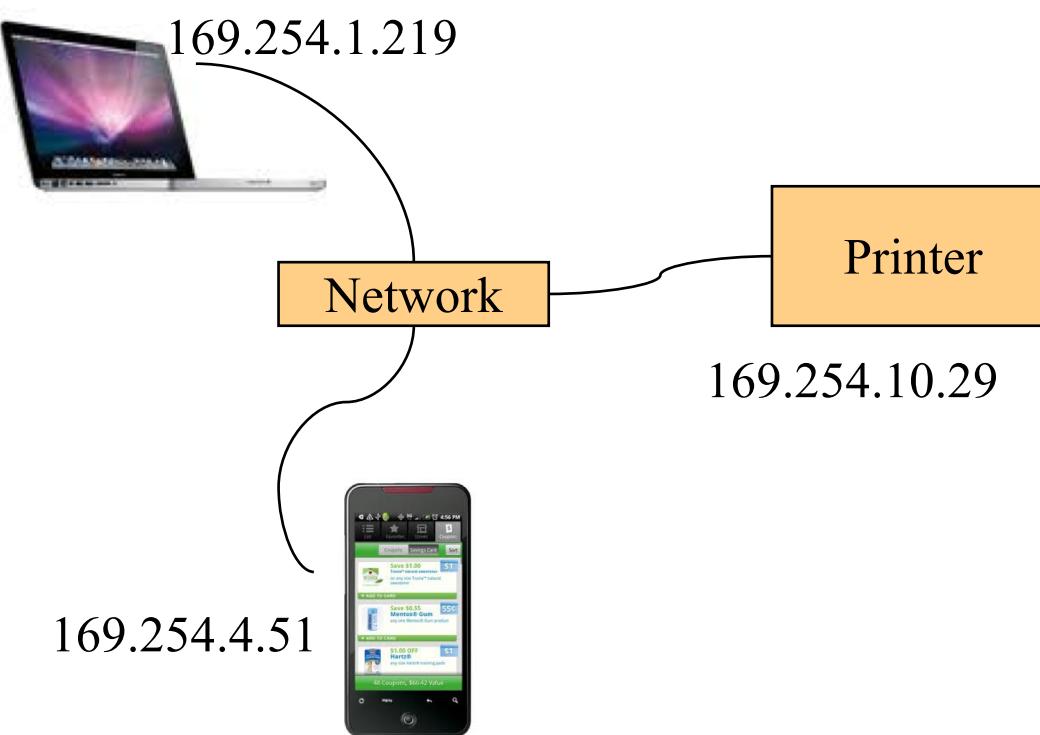
- Admin. and recap
- DNS
 - High-level design
 - Details
 - *Extensions/alternatives*

Discussions

- What extension(s) to standard DNS operations do we need to allow service discovery, say to implement Bonjour (discover all local printers)?
 - each printer needs to provide the following info: host, port, printer info (e.g., support postscript)

DNS-Service Discovery

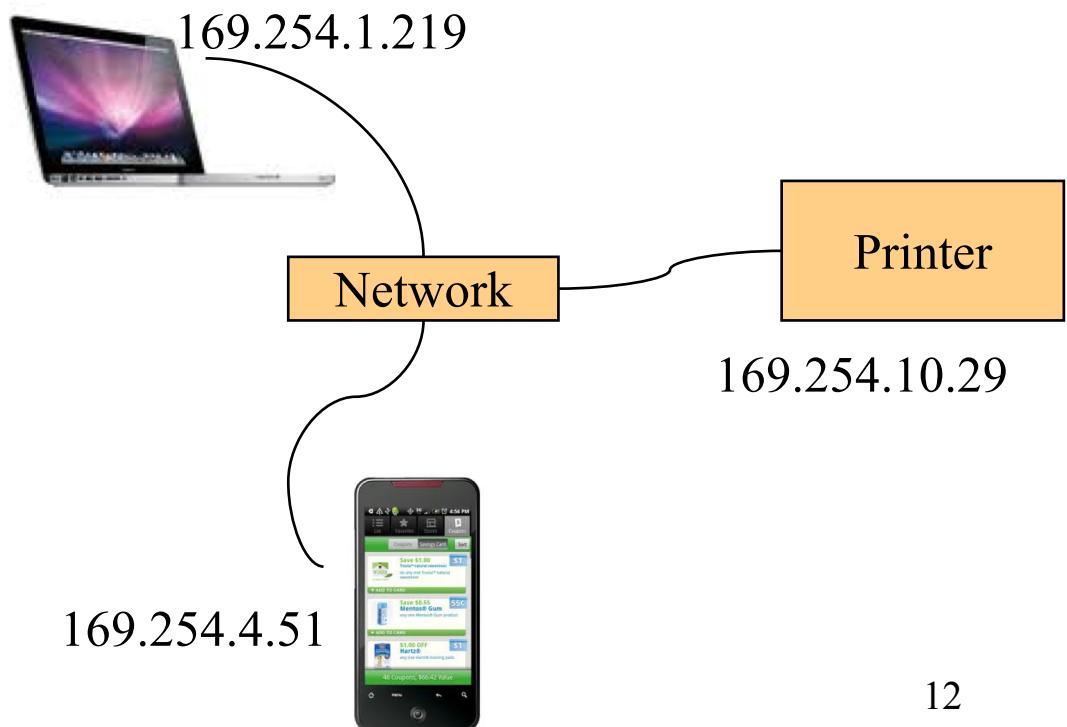
- Leverage DNS message format, but each node can announce its own services



Realizing DNS-SD without Central DNS Server: mDNS

□ Multicast in a small world

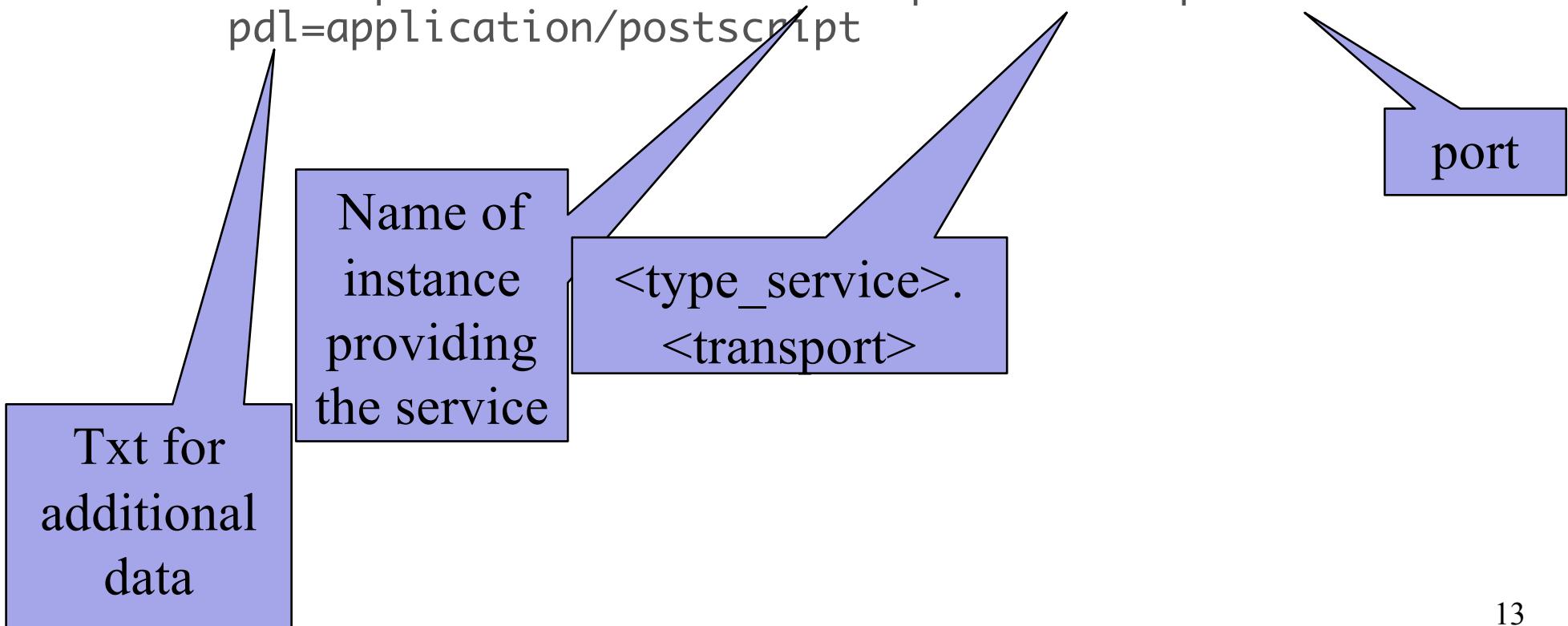
- no central address server
 - each node is a responder
- link-local addressing
 - send to **multicast address: 224.0.0.251**



Example

- Use the avahi-publish-service command on Ubuntu as example
 - Advertise (register) an LPR printer on port 515

```
avahi-publish-service test _printer._tcp . 515  
pdl=application/postscript
```



Example

- Use the dns-sd command on Mac as example
 - Advertise (register) an LPR printer on port 515

```
dns-sd -R "test" _printer._tcp . 515  
pdl=application/postscript
```

Name of instance providing the service

<type_service>
<transport>

domain (. means default, which is local)

port

Txt for additional data

→	1	0.000...	fe80::5052:5af:92fa...	ff02::fb	MDNS	179 Standard query 0x0000 ANY test._printer._tcp.local, "QM" question SRV 0 0 515 qiao-VirtualBox.l...
2	0.000...	192.168.3.52	224.0.0.251	MDNS	159 Standard query 0x0000 ANY test._printer._tcp.local, "QM" question SRV 0 0 515 qiao-VirtualBox.l...	
3	0.255...	fe80::5052:5af:92fa...	ff02::fb	MDNS	179 Standard query 0x0000 ANY test._printer._tcp.local, "QM" question SRV 0 0 515 qiao-VirtualBox.l...	
4	0.255...	192.168.3.52	224.0.0.251	MDNS	159 Standard query 0x0000 ANY test._printer._tcp.local, "QM" question SRV 0 0 515 qiao-VirtualBox.l...	
5	0.501...	fe80::5052:5af:92fa...	ff02::fb	MDNS	179 Standard query 0x0000 ANY test._printer._tcp.local, "QM" question SRV 0 0 515 qiao-VirtualBox.l...	
6	0.501...	192.168.3.52	224.0.0.251	MDNS	159 Standard query 0x0000 ANY test._printer._tcp.local, "QM" question SRV 0 0 515 qiao-VirtualBox.l...	
7	0.701...	192.168.3.52	224.0.0.251	MDNS	248 Standard query response 0x0000 TXT, cache flush PTR test._printer._tcp.local SRV, cache flush 0...	
8	0.701...	fe80::5052:5af:92fa...	ff02::fb	MDNS	252 Standard query response 0x0000 TXT, cache flush PTR test._printer._tcp.local SRV, cache flush 0...	
9	1.919...	192.168.3.52	224.0.0.251	MDNS	248 Standard query response 0x0000 TXT, cache flush PTR test._printer._tcp.local SRV, cache flush 0...	
10	1.919...	fe80::5052:5af:92fa...	ff02::fb	MDNS	252 Standard query response 0x0000 TXT, cache flush PTR test._printer._tcp.local SRV, cache flush 0...	
11	4.127...	192.168.3.52	224.0.0.251	MDNS	248 Standard query response 0x0000 TXT, cache flush PTR test._printer._tcp.local SRV, cache flush 0...	
12	4.127...	fe80::5052:5af:92fa...	ff02::fb	MDNS	252 Standard query response 0x0000 TXT, cache flush PTR test._printer._tcp.local SRV, cache flush 0...	
13	11.73...	fe80::5052:5af:92fa...	ff02::fb	MDNS	183 Standard query 0x0000 PTR _services._dns-sd._udp.local, "QM" question PTR _companion-link._tcp...	
14	11.73...	192.168.3.52	224.0.0.251	MDNS	305 Standard query 0x0000 PTR _services._dns-sd._udp.local, "QM" question TXT Qiao\342\200\231s Mac...	
15	11.83...	192.168.3.38	224.0.0.251	MDNS	230 Standard query response 0x0000 PTR _companion-link._tcp.local SRV, cache flush 0 0 54580 Qiaos...	
16	12.71...	fe80::5052:5af:92fa...	ff02::fb	MDNS	183 Standard query 0x0000 PTR _services._dns-sd._udp.local, "QM" question PTR _companion-link._tcp...	
17	12.71...	192.168.3.52	224.0.0.251	MDNS	212 Standard query 0x0000 PTR _services._dns-sd._udp.local, "QM" question PTR _companion-link._tcp...	
18	14.72...	fe80::5052:5af:92fa...	ff02::fb	MDNS	183 Standard query 0x0000 PTR _services._dns-sd._udp.local, "QM" question PTR _companion-link._tcp...	
19	14.72...	192.168.3.52	224.0.0.251	MDNS	212 Standard query 0x0000 PTR _services._dns-sd._udp.local, "QM" question PTR _companion-link._tcp...	

Offline Exercise

- Use the dns-sd / avahi-publish-service command as example
 - Advertise (register) a web page on local machine

```
dns-sd -R "My Test" _http._tcp . 80  
path=/path-to-page.html
```

Issue: How to Query

- Query needs a back pointer, PTR records
- Exercise: Use the dns-sd / avahi-service-publish command as example
 - Browse web pages on local machines

```
dns-sd -B _http._tcp  
avahi-browse -rt _http._tcp
```

Network Service Discovery in Android

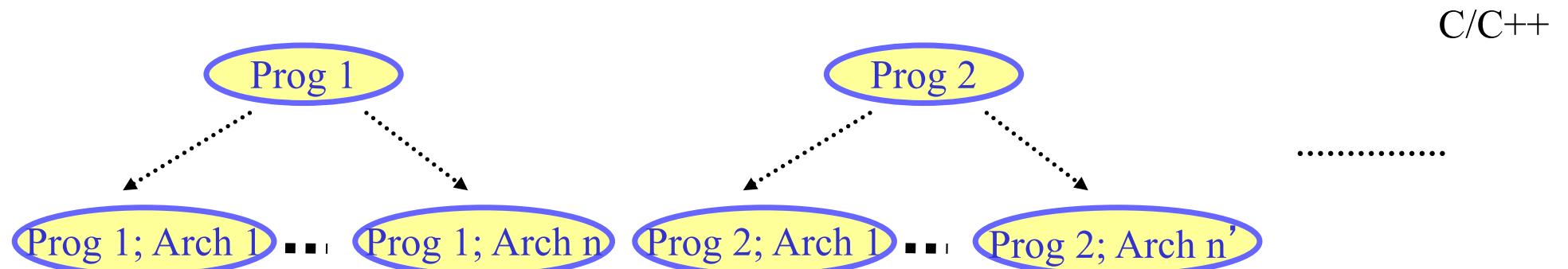
- Based on DNS-SD/mDNS
- Foundation for peer-to-peer/Wi-Fi Direct in Android

- See <https://developer.android.com/training/connect-devices-wirelessly/nsd.html> for programming using nsd

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- *Java in a Nutshell*

High-level Picture



C/C++

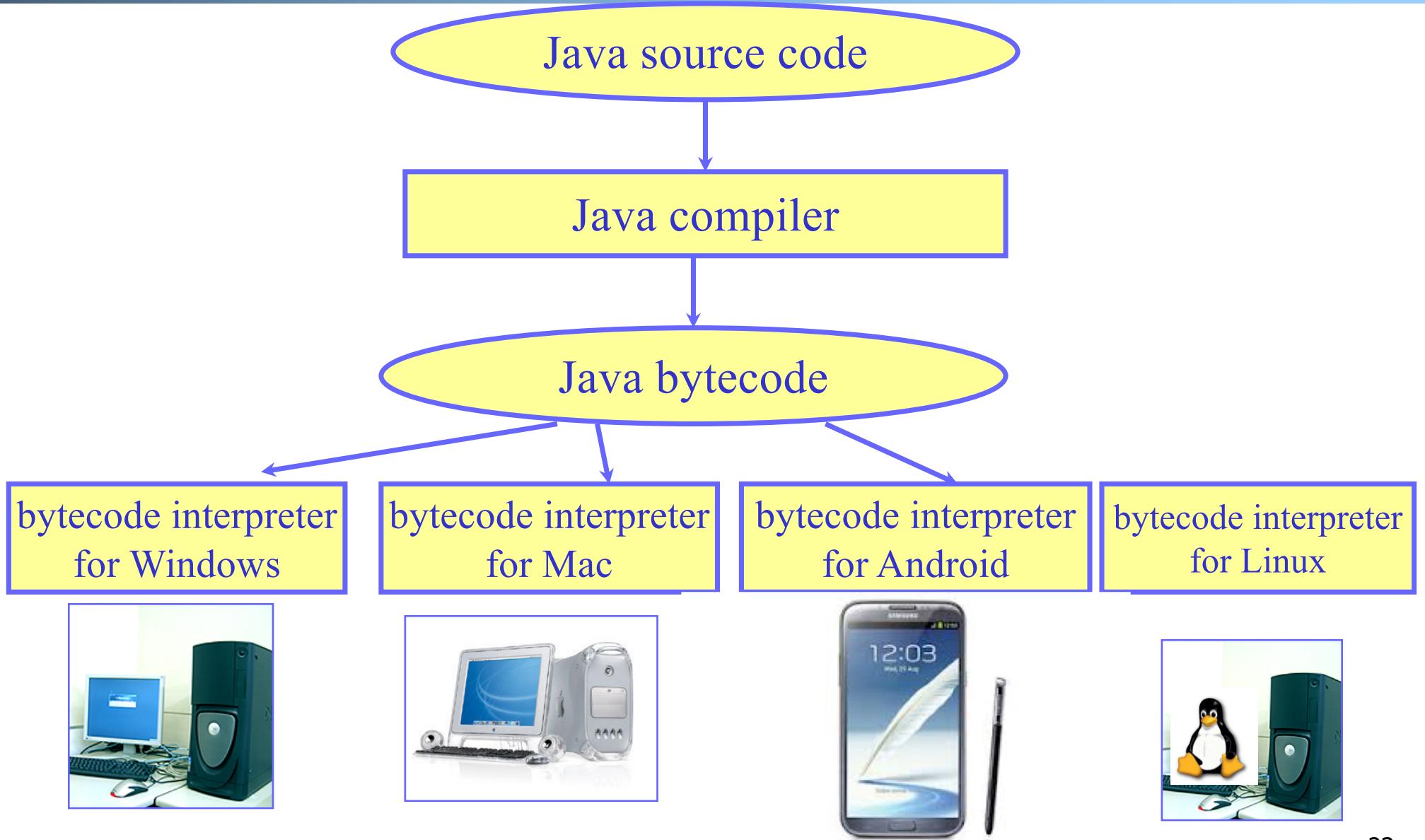
Java Virtual Machine

- To be platform independent, Java designers introduced Java Virtual Machine (JVM), a machine different from any physical platform, but a *virtual machine*
 - The language of the virtual machine is referred to as *bytecode*
 - Thus Java actually has two programming languages
- A Java compiler translates Java source code (.java files) into *bytecode* (in .class files)
 - Each Java software program needs to be compiled only once: from the Java source code to bytecode
- Other languages (e.g., Jruby, Jython, Scala) may also compile to bytecode

Java Execution

- To execute a Java program, another piece of software called an *interpreter*, translates between bytecode and the actual machine
 - an interpreter is specific to a specific platform
 - the interpreter understands java bytecode, and then issues instructions in the specific platform for which it is written
 - we also say that an interpreter provides a java virtual machine (JVM)

Java Translation and Execution



Comparing Traditional (e.g., C/C++) and Java Software Development

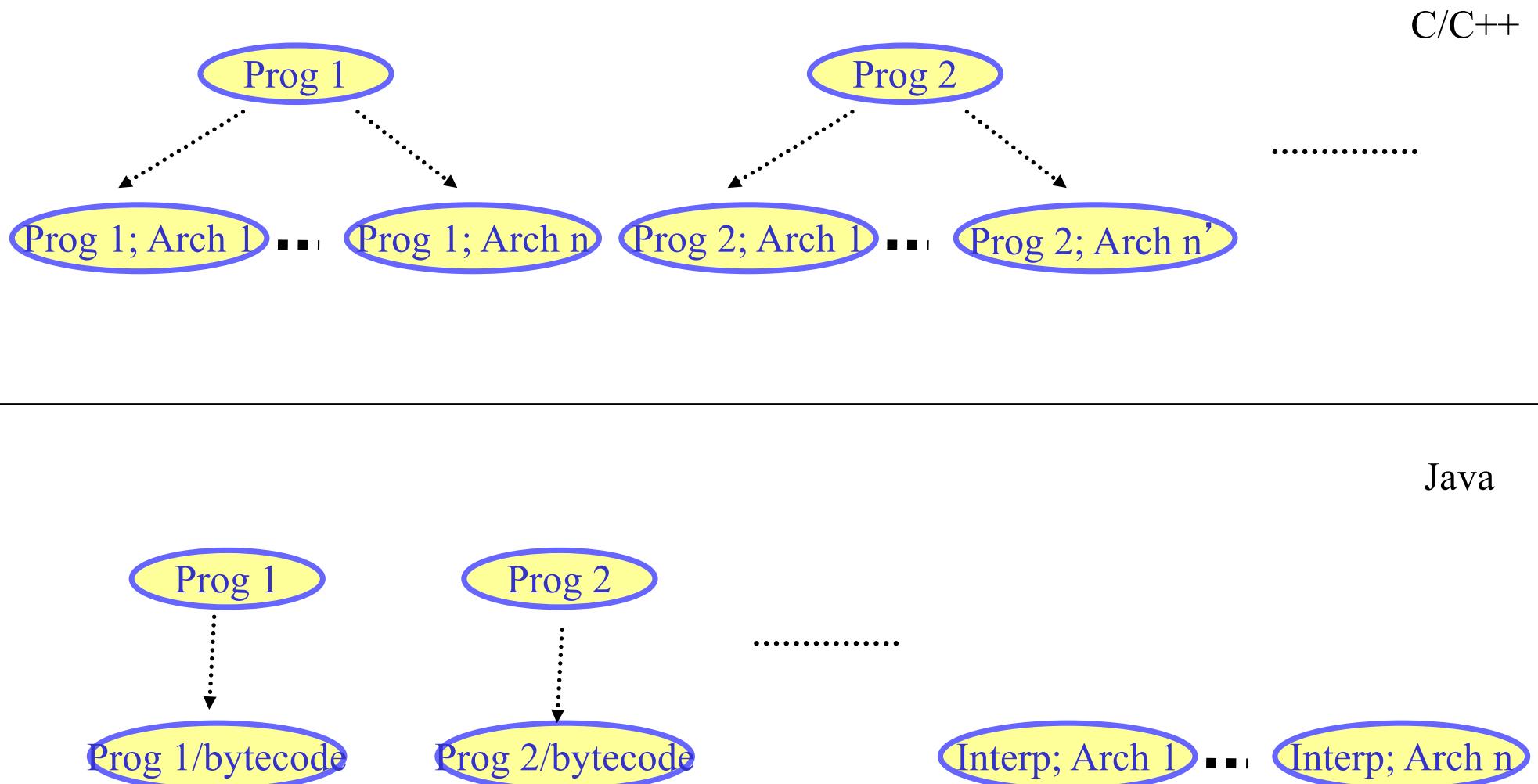
Traditional, e.g., C/C++

- ❑ A developer writes a program in C/C++
- ❑ The C/C++ source code is generally considered proprietary, and not released
- ❑ The developer compiles the C/C++ program for each platform it intends to support, and distributes one version for each platform
 - thus each program has **multiple compiled versions**
 - each compiled version can run by itself
- ❑ **Platform dependency handled by each software developer**

Java

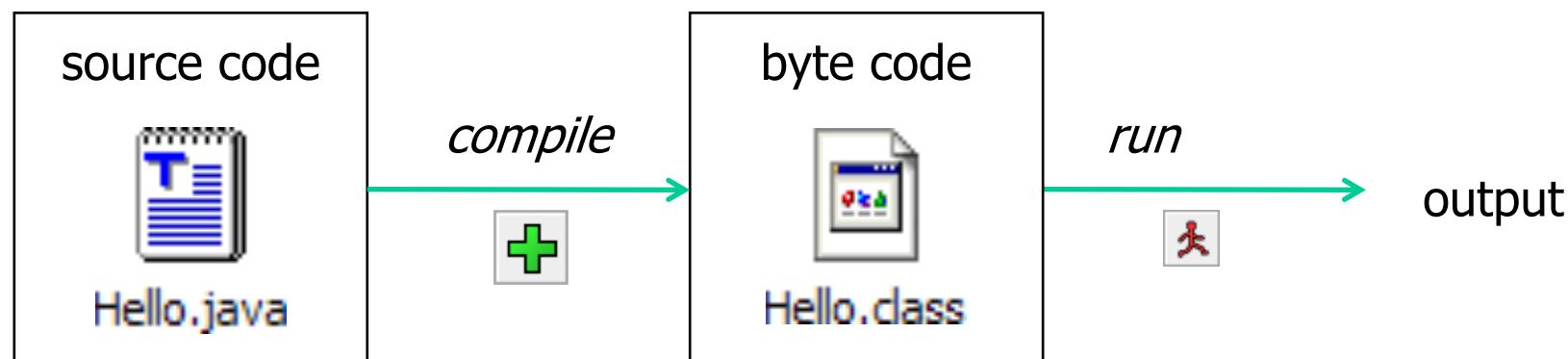
- ❑ A developer writes a program in Java
- ❑ The Java source code is generally considered proprietary, and not released
- ❑ The developer compiles the Java program to bytecode, and distributes the bytecode version
 - thus each program has only **one compiled version**
 - the compiled bytecode needs an interpreter for each platform
- ❑ **Platform dependency handled by platform vendor**

High-level Picture



Recall: Java Programming Steps

- Programming in Java consists of 3 simple steps
 - Create and edit "Java source code" (.java files)
 - Compile into "Java bytecode" (.class files)
 - Execute bytecode with a "Java interpreter"



Programming in Java (Step 1): Create/Edit

- The basic way is to use a text editor
 - Example editors: vim, sublime, Notepad,TextEdit (Format/Make Plain Text) etc.
 - Note: MS Word is NOT a text editor
 - The key is that your .java file *cannot* include any markup or stylistic formatting; just text.
 - You enter your Java code following Java Language syntax (more soon).

Programming in Java (Step 2): Compile

- Compile a Java program
 \$ javac HelloWorld.java

- Take a look to see that HelloWorld.class is generated
 \$ ls
 HelloWorld.java HelloWorld.class

Programming in Java (Step 3): Execute

- Run Java interpreter

```
$ java HelloWorld
```

First Java Program

```
*****  
 * Prints "Hello World"  
 * Everyone's first Java program.  
***** /  
  
public class Hello {  
    public static void main(String[] args) {  
        System.out.println("Hello, world!");  
    }  
}
```

Another Java Program

```
public class Hello2 {  
    public static void main(String[] args) {  
        System.out.println("Hello, world!");  
        System.out.println();  
        System.out.println("This program produces");  
        System.out.println("four lines of output");  
    }  
}
```

Programming in Java: Method 2

- Another way is to use an Integrated Development Environment (IDE)
 - Example IDEs: Eclipse, IDEA, DrJava, etc.
 - An IDE usually presents the user with a space for text (like an editor) but layers *additional features* on top of the text for the user's benefit.
 - Note: The underlying file contains pure text, just like a text editor.
 - These features can be very useful and save time.
 - Example features are GUI compile, GUI execution, code completion, and syntax highlighting.
 - IDEs take more time to get started than a simple text editor, e.g.,
 - set up where to find the "java" and "javac" programs
 - find out where does the IDE save my file

Java Syntax Structure: A Top-Down View

A class:

- has a name, defined in a **file with same name**
Convention we follow: capitalize each English word
- starts with {, and ends with }
- includes a group of methods

```
public class <class name> {
    public static void main(String[] args) {
        <statement>;
        <statement>;
        ...
        <statement>;
    }
}
```

A method:

- has a name

Convention we follow: lowercase first word, capital following

- starts with {, and ends with }
- includes a group of statements

statement:

- a command to be executed
 - end with ;

The System.out.println statement

- A statement that prints a line of output on the console.
 - pronounced "print-linn"

- Two ways to use System.out.println :
 - System.out.println(<string>) ;
Prints the given message <string> as output.

 - System.out.println() ;
Prints a blank line of output.

Java program structure

- A top-down view
- A bottom-up view

Java Syntax: A Bottom-Up View

```
// Comment 1: A Java program
/* Comment 2: a long comment
 *****/
public class Hello {
    public static void main(String[] args) {
        System.out.println("Hello, world!");
        System.out.println();
        System.out.println("This program produces");
        System.out.println("four lines of output");
    }
}
```

Java Syntax: A Bottom-Up View

```
// Comment 1: A Java program
/* Comment 2: a long comment
 *****/
public class Hello {
    public static void main(String[] args) {
        System.out.println("Hello, world!");
        System.out.println();
        System.out.println("This program produces");
        System.out.println("four lines of output");
    }
}
```

- Basic Java syntax units
 - white space and comments
 - identifiers (words)
 - symbols: { } " () < > [] ; = ...
 - strings
 - numbers

Syntax: White Space

- ❑ White space
 - includes spaces, new line characters, tabs
 - white space is used to separate other entities
 - extra white space is ignored

- ❑ White space allows a Java program to be formatted in many ways, and should be formatted to enhance readability
 - the usage of white space forms part of **programming style**

Syntax: Comments

- **comment:** A note written in source code by the programmer to describe or clarify the code.
 - Comments are ignored by the compiler
 - Useful for other people (and yourself!) to understand your code

- Two types of comments in Java
 - single-line comments use `//...`
`// this comment runs to the end of the line`
 - multi-lines comments use `/* ... */`
`/* this is a very long
multi-line comment */`

Syntax: Identifier

- **Identifier:** A name given to an item in a program.

- **Syntax requirement on identifier:**
 - must start with a letter or _ or \$
 - subsequent characters can be any of those or a number
 - Important: Java is case sensitive:
 - Hello and hello are different identifiers

Three Types of Identifiers

1. Identifiers chosen by ourselves when writing a program (such as `HelloWorld`)
2. Identifiers chosen by another programmer, so we use the identifiers that they chose (e.g., `System`, `out`, `println`, `main`)

```
public class HelloWorld
{
    public static void main(String[] args)
    {
        System.out.println("Hello World!");
    }
}
```

Three Types of Identifiers

3. Special identifiers called *keywords* or *reserved words*:
A keyword has a special meaning in Java.

abstract	default	if	private	this
boolean	do	implements	protected	throw
break	double	import	public	throws
byte	else	instanceof	return	transient
case	extends	int	short	try
catch	final	interface	static	void
char	finally	long	strictfp	volatile
class	float	native	super	while
const	for	new	switch	
continue	goto	package	synchronized	

Java reserved words: they are all **lowercase!**

Syntax: Strings

- **string:** A sequence of characters that starts and ends with a " (quotation mark character).
 - The quotes do not appear in the output.

- Examples:

"hello"

"This is a string. It is very long!"

- **Restrictions:**
 - May not span multiple lines

"This is not
a legal String."

Examples

□ Which of the following are legal strings in Java?

- "This is a string. It's very long!"
- "This cool string spans
two lines. "
- "It is a great thing when children cry, "I
want my mommy"! "

Escape Sequences

- **escape sequence:** A special sequence of characters used to represent certain special characters in a string.

\b	backspace
\t	tab character
\n	new line character
\"	quotation mark character
\\\	backslash character

- **Example:**

```
System.out.println("\\hello\\nhow\\tare \"you\"?\\\\\\");
```

- **Output:**

```
\hello  
how      are "you"?\\
```

Comment on syntax errors

- A **syntax/compile error**: A problem in the structure of a program that causes the compiler to fail, e.g.,
 - Missing semicolon
 - Too many or too few { } braces
 - Class and file names do not match
 - ...
- Compilers can't (DO not) read minds.
- Compilers don't make mistakes.
- If the program is not doing what you want, do NOT blame the computer---it's **YOU** who made a mistake.

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Socket Programming

Socket API

- ❑ introduced in
BSD4.1 UNIX, 1981

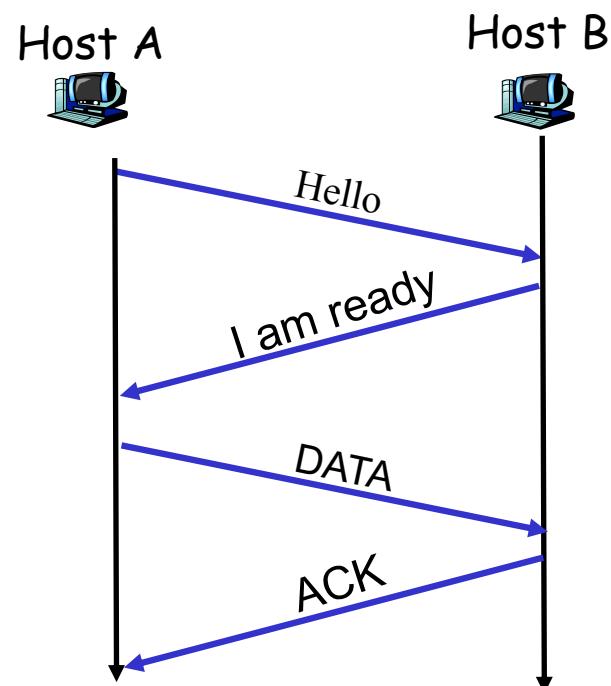
- ❑ Two types of
sockets
 - connectionless (UDP)
 - connection-oriented
(TCP)

socket

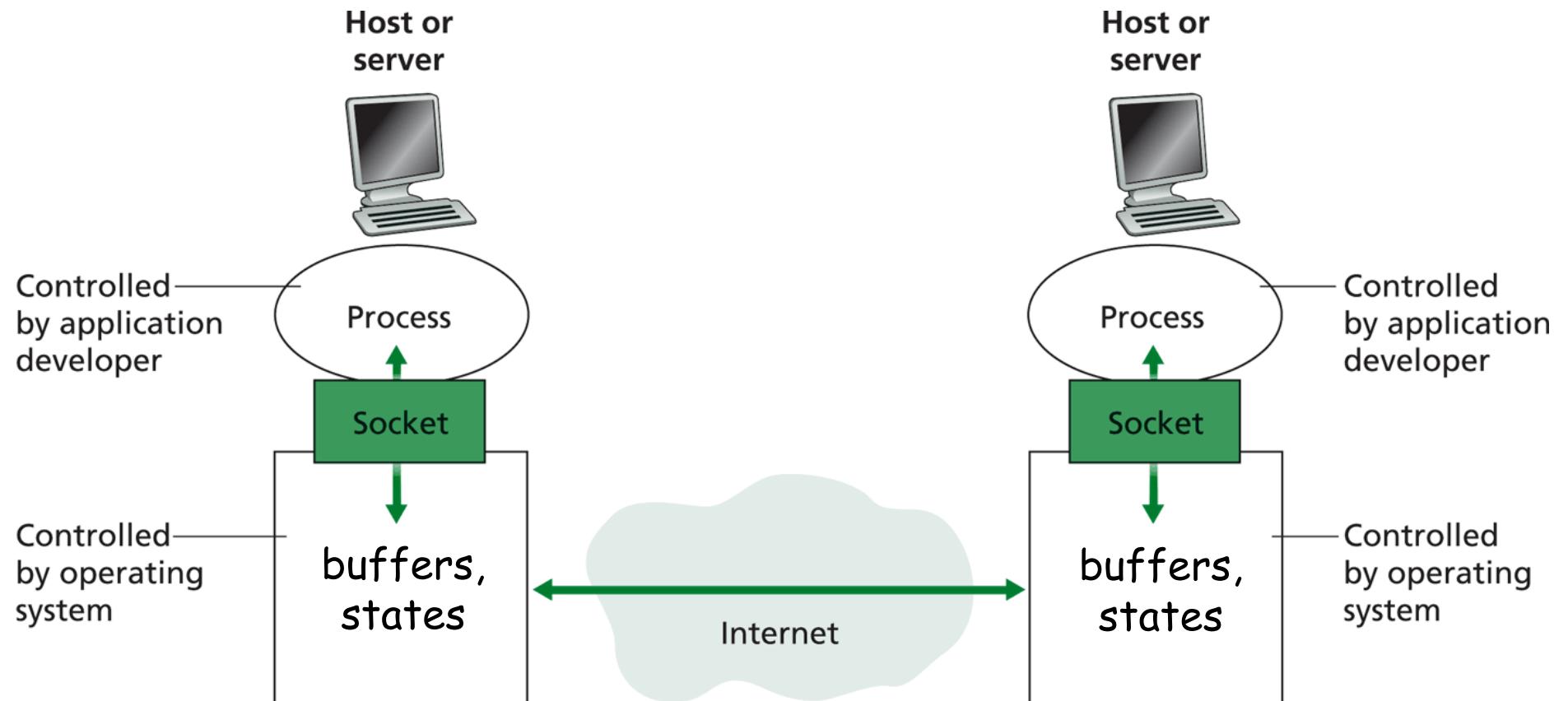
an interface (a “door”) into which one application process can both send and receive messages to/from another (remote or local) application process

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

- Admin. and 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.

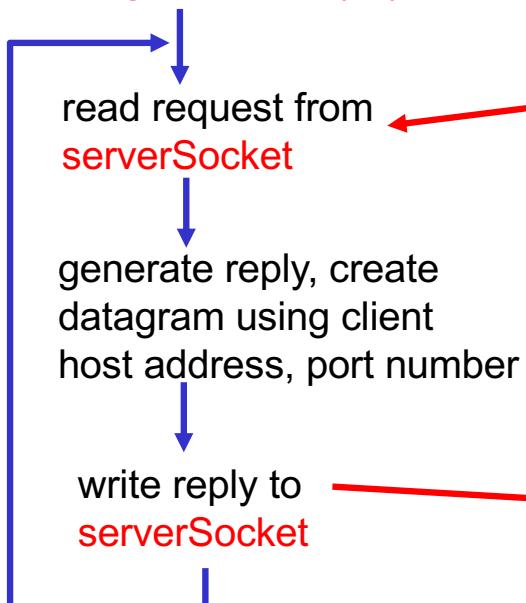
- **receive(DatagramPacket p)**
receives a datagram packet from this socket.
- **send(DatagramPacket p)**
sends a datagram packet from this socket.

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

Connectionless UDP: Big Picture (Java version)

Server (running on serv)

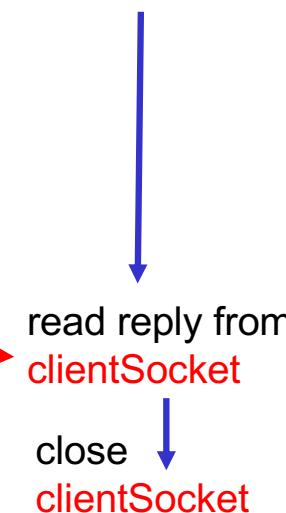
```
create socket,  
port=x, for  
incoming request:  
serverSocket =  
DatagramSocket( x )
```



Client

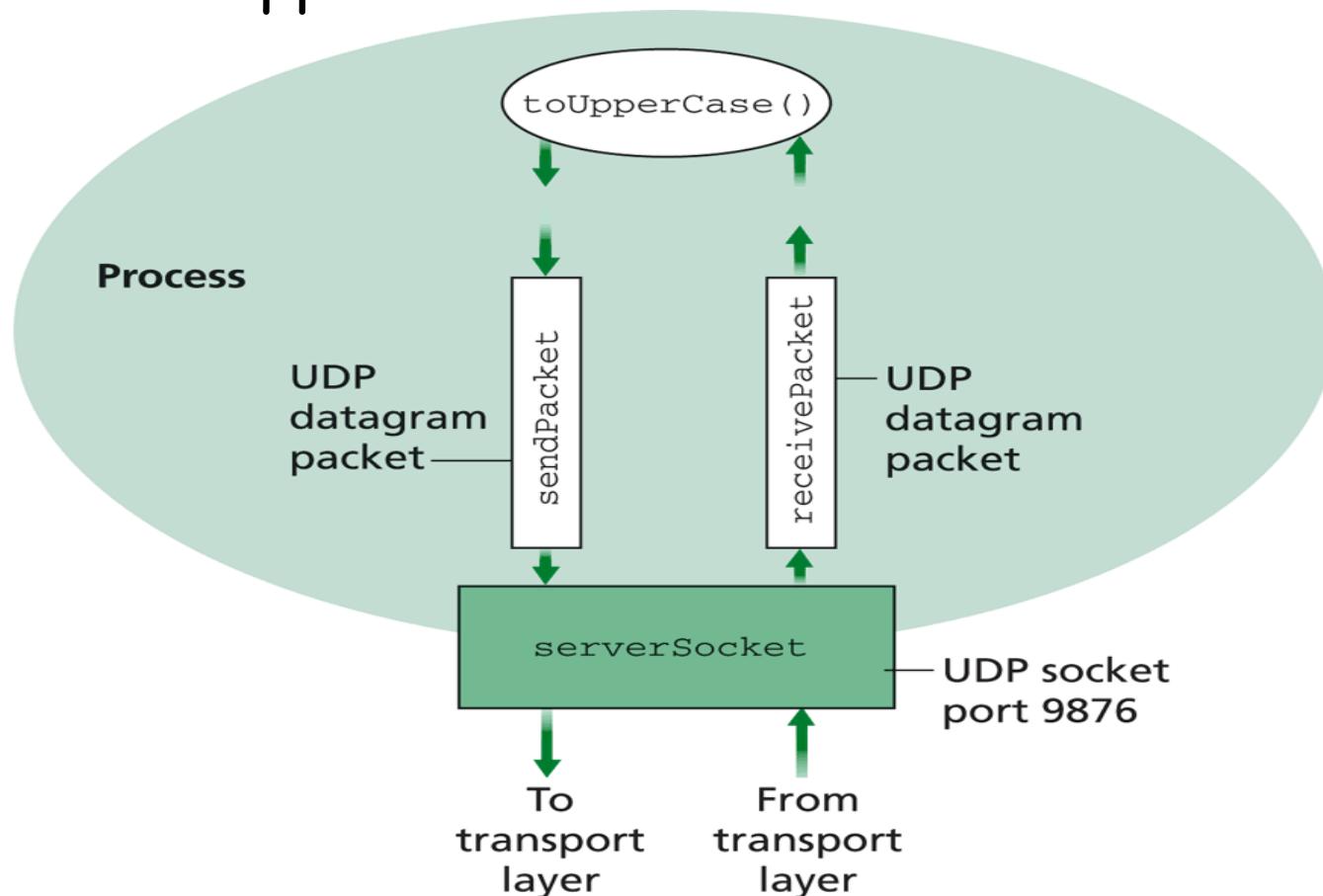
```
create socket,  
clientSocket =  
DatagramSocket()
```

```
Create datagram using (serv,  
x) as (dest addr. port),  
send request using clientSocket
```



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);
    }
}
```

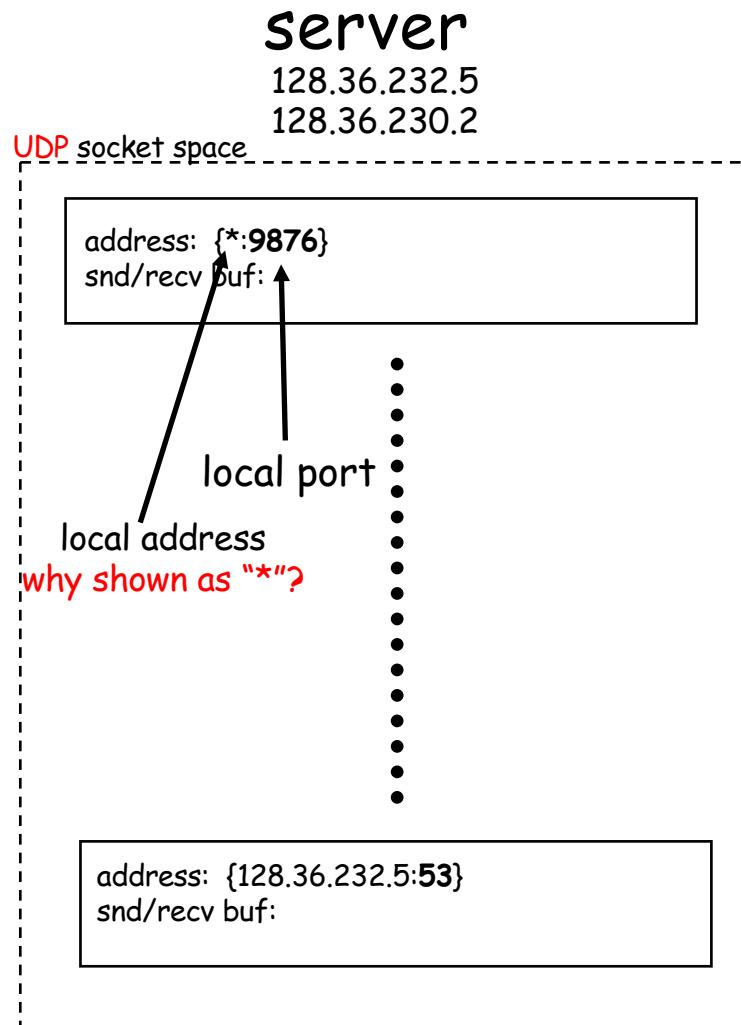
*Create
datagram socket
bind at port 9876*



Check socket state:

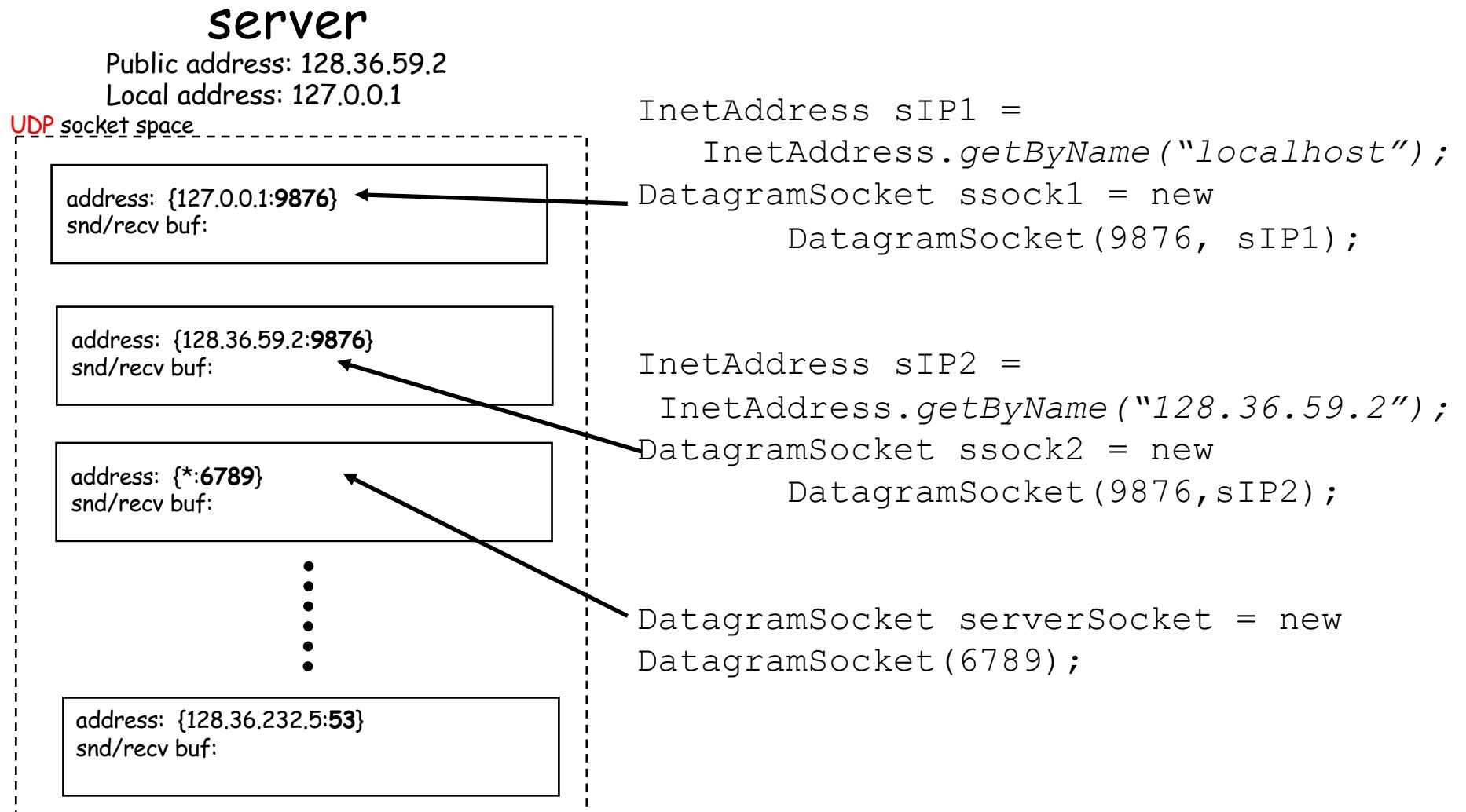
%netstat -a -u -n

System State after the Call

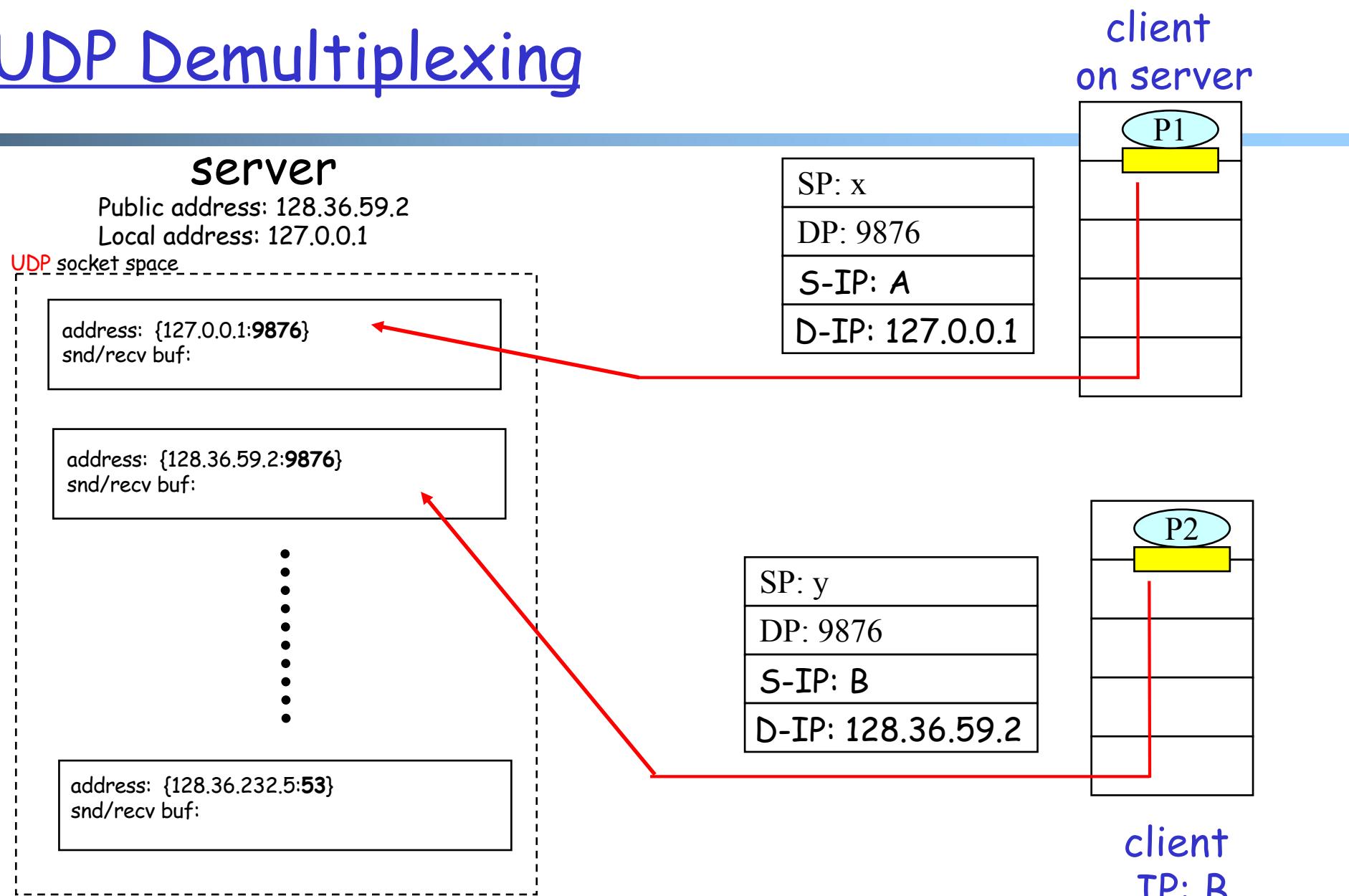


"*" indicates that the socket binds to **all** IP addresses of the machine:
% ifconfig -a

Binding to Specific IP Addresses

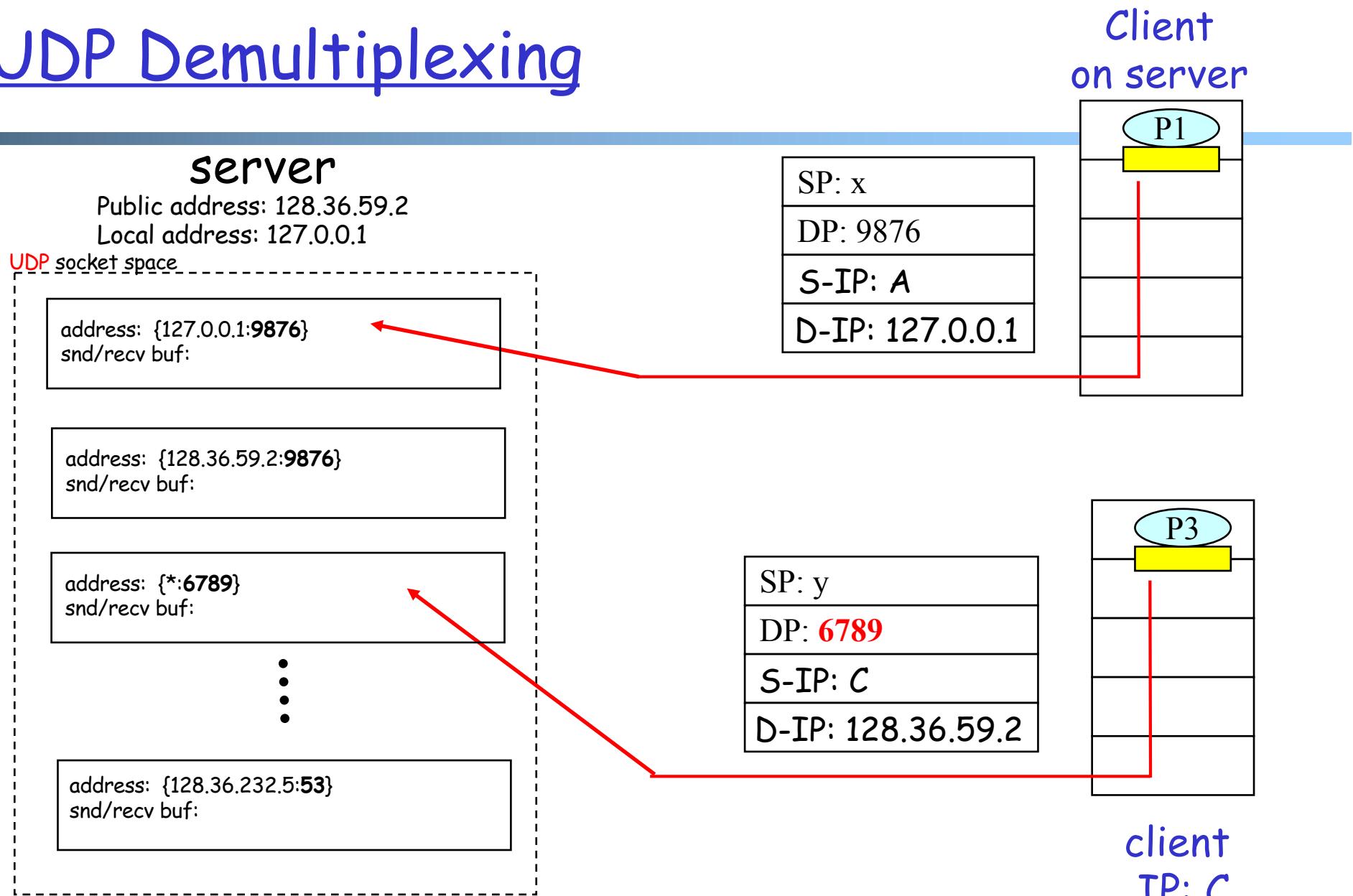


UDP Demultiplexing



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

UDP Demultiplexing



UDP demultiplexing 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 → `DatagramPacket receivePacket =
new DatagramPacket(receiveData, receiveData.length);`

Receive datagram → `serverSocket.receive(receivePacket);`

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.*;

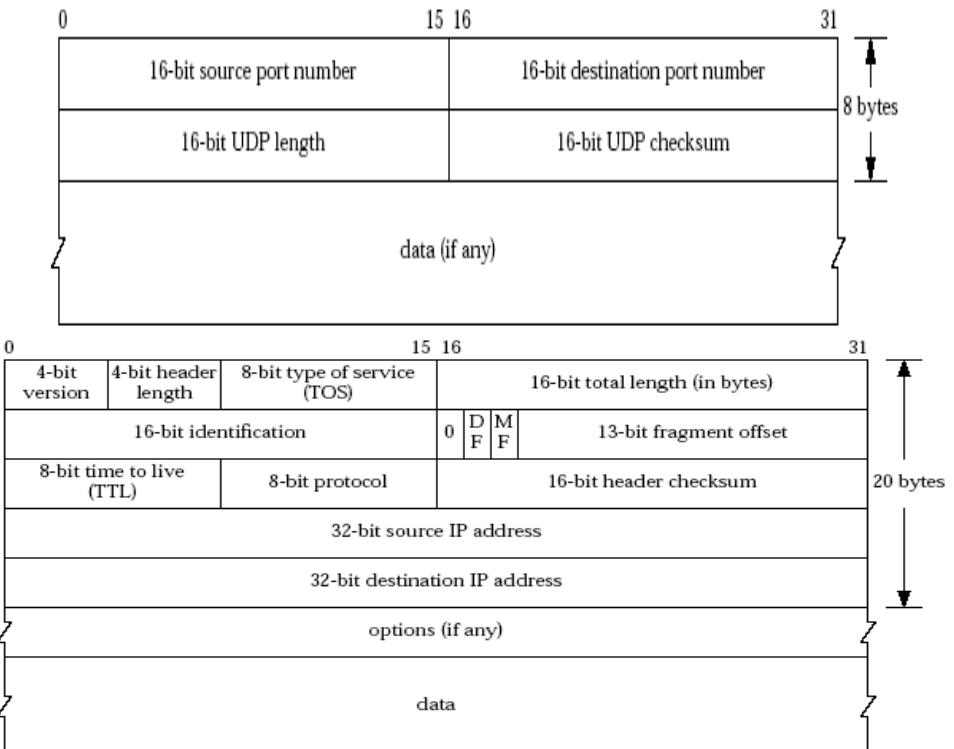
class UDPServer {
    public static void main(String args[]) throws Exception {
        ...
        // process data
        String sentence = new String(receivePacket.getData(),
                                      0, receivePacket.getLength());
        String capitalizedSentence = sentence.toUpperCase();
        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

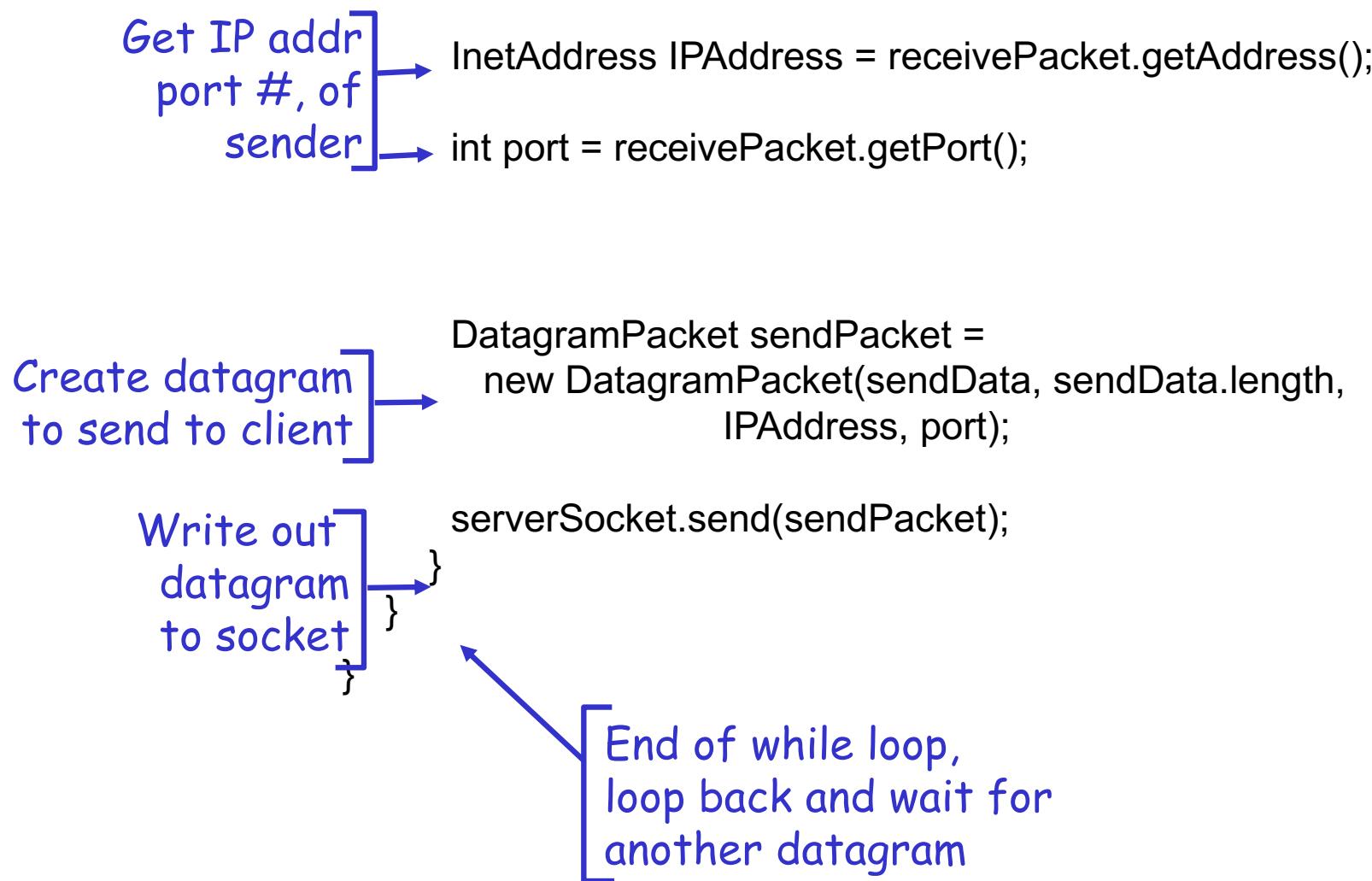
getLength() returns how much data is valid.

Java Server (UDP): Response

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

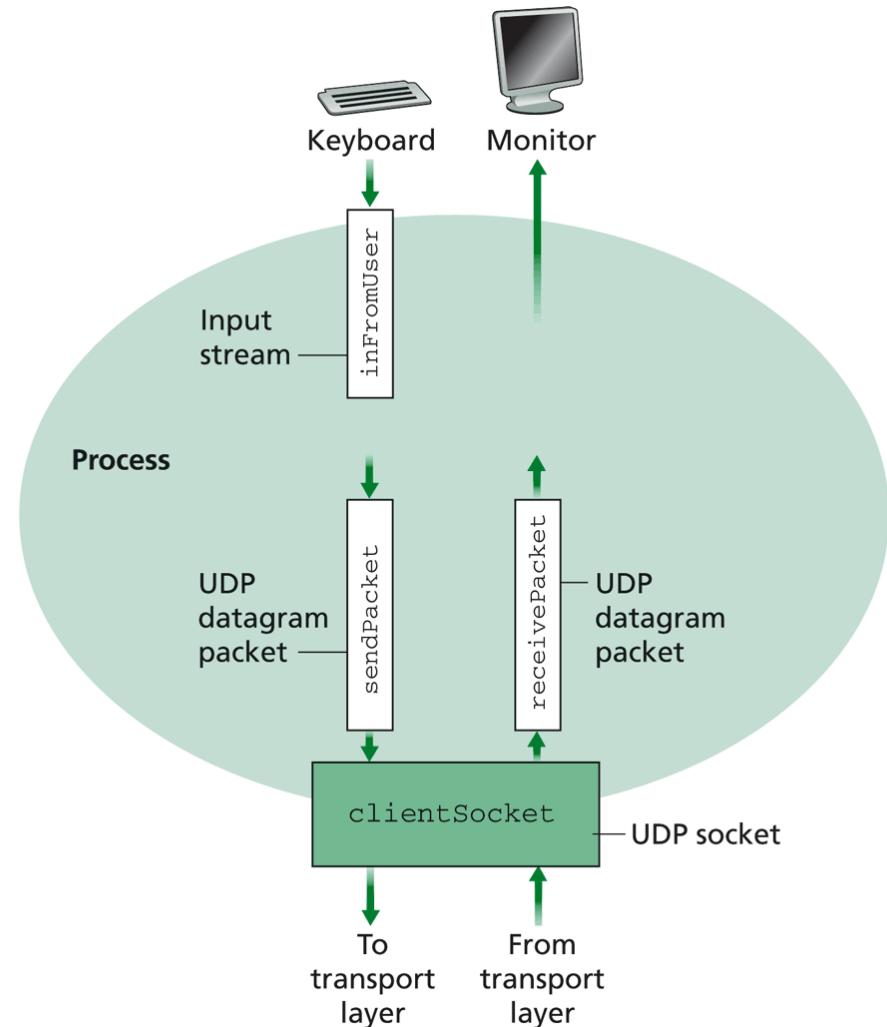


Java server (UDP): Reply



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 → `BufferedReader inFromUser =`

Create client socket → `DatagramSocket clientSocket = new DatagramSocket();`

Translate hostname to IP address using DNS → `InetAddress sIPAddress = InetAddress.getByName("servname");`

Example: Java client (UDP), cont.

```
>Create datagram  
with data-to-send,  
length, IP addr, port] DatagramPacket sendPacket =  
new DatagramPacket(sendData, sendData.length, sIPAddress, 9876);  
  
Send datagram  
to server] clientSocket.send(sendPacket);  
  
byte[] receiveData = new byte[1024];  
DatagramPacket receivePacket =  
new DatagramPacket(receiveData, receiveData.length);  
  
Read datagram  
from server] clientSocket.receive(receivePacket);  
  
String modifiedSentence =  
new String(receivePacket.getData());  
  
System.out.println("FROM SERVER:" + modifiedSentence);  
clientSocket.close();  
}  
}
```

Demo

%ubuntu: java UDPServer

%netstat to see buffer

%ubuntu: java UDPClient <server>

%wireshark to capture traffic

Discussion on Example Code

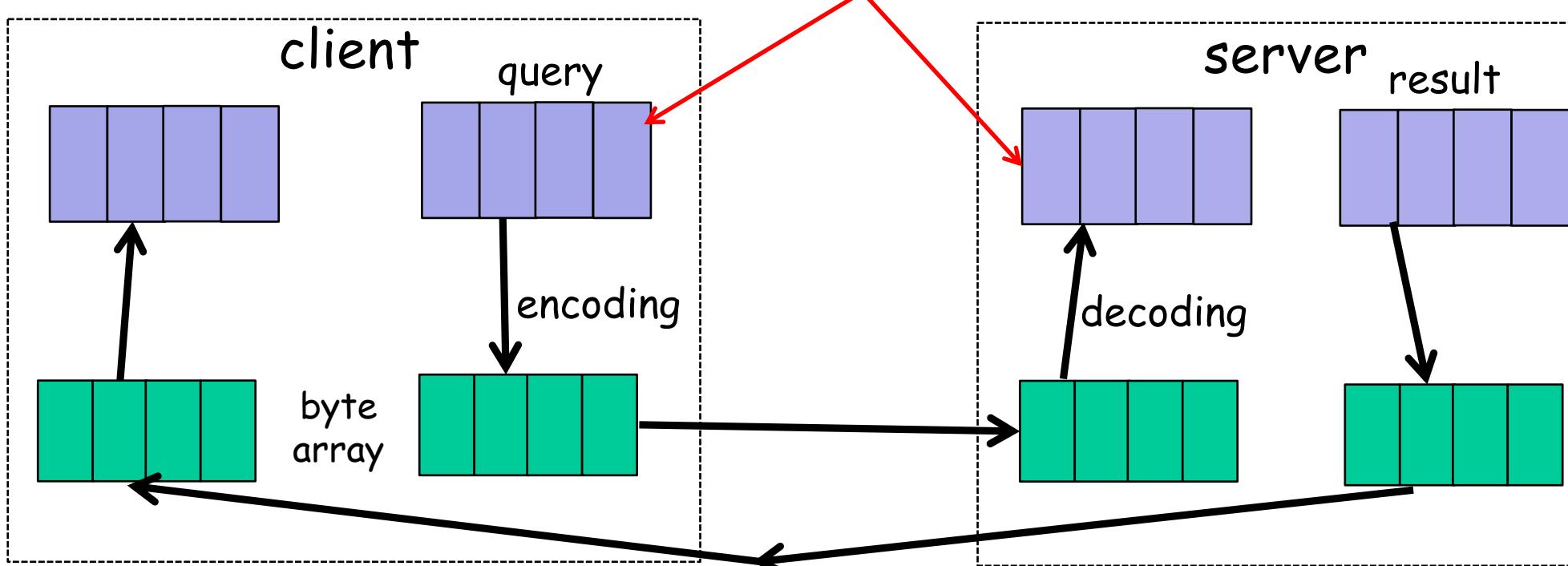
- A simple upper-case UDP echo service is among the simplest network service.

- Are there any problems with the program?

Data Encoding/Decoding

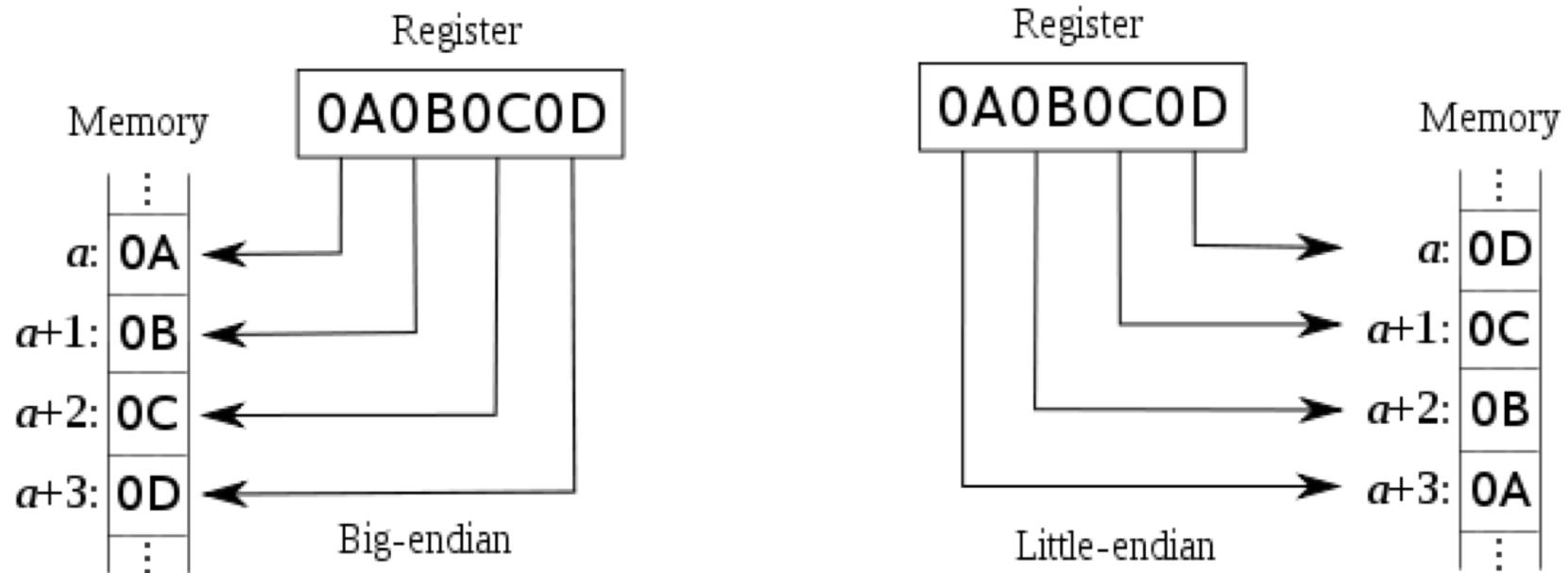
- Rule: **ALWAYS** pay attention to encoding/decoding of data

if not careful, query sent != query received (how?)



Example: Endianness of Numbers

- $\text{int var} = 0xA0B0C0D$

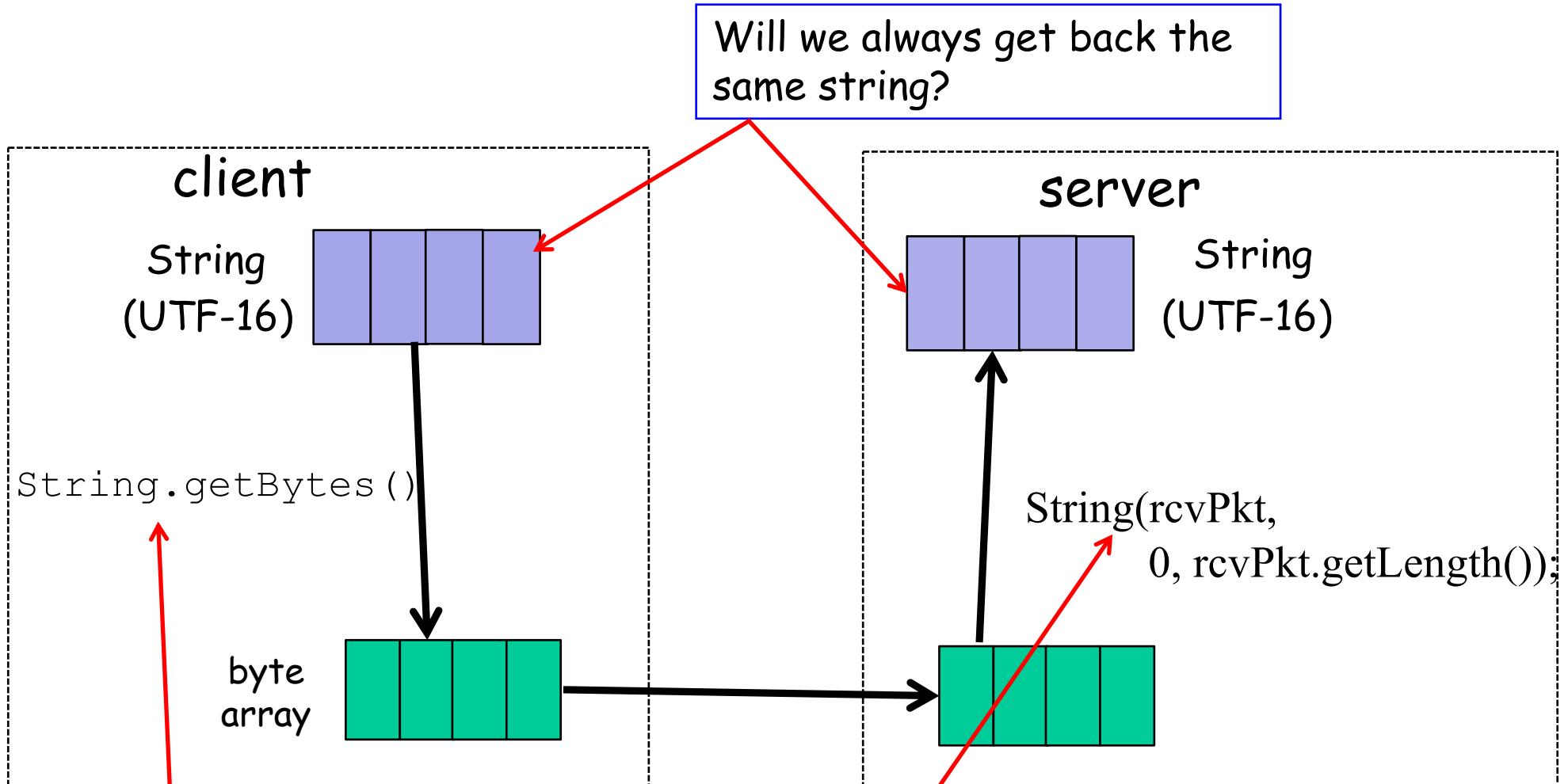


ARM, Power PC, Motorola 68k, IA-64

Intel x86

- **sent != received:** take an int on a big-endian machine and send a little-endian machine

Example: String and Chars



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

Example: Charset Troubles

- Try
 - java EncodingDecoding UTF-8 UTF-16

Encoding/Decoding as a Common Source of Errors

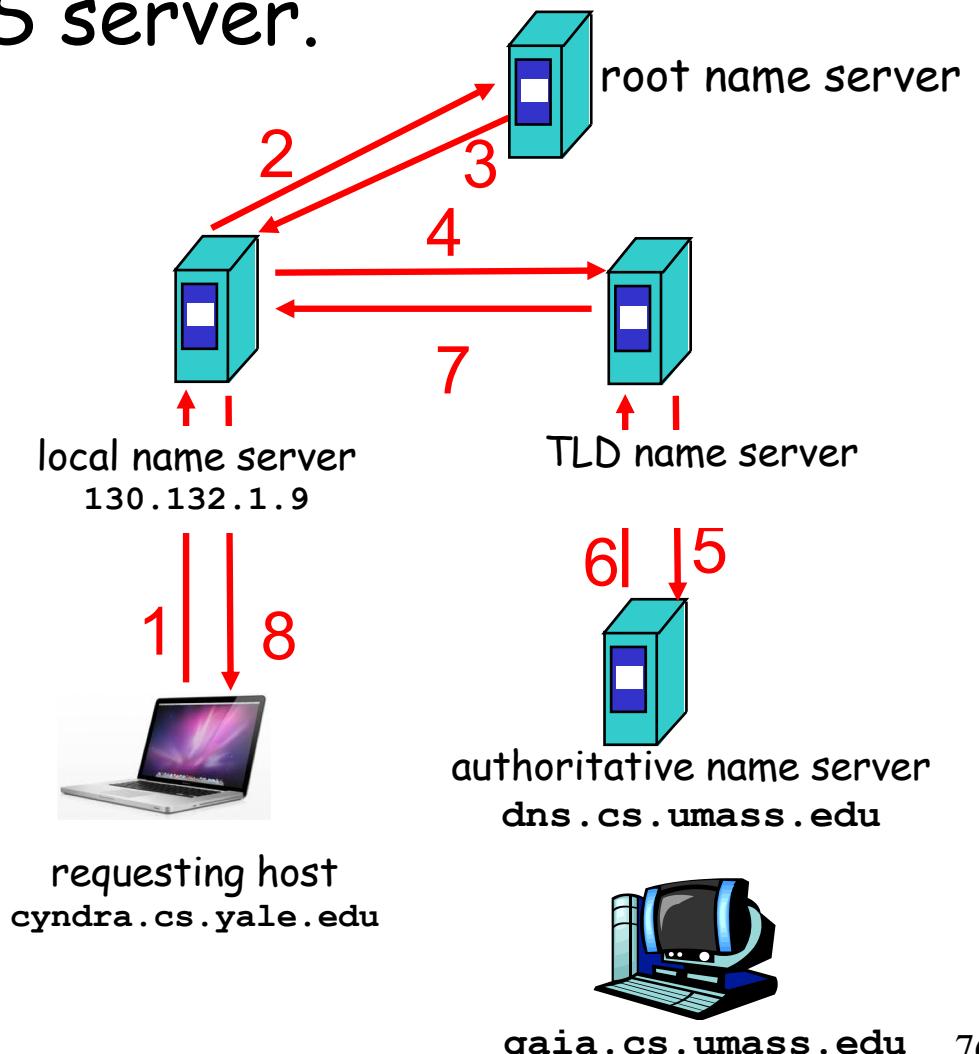
- Please read chapter 2 (Streams) of Java Network Programming for more details
 - Java stream, reader/writer can always be confusing, but it is good to finally understand

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

Exercise: UDP/DNS Server Pseudocode

- Modify the example UDP server code to implement a local DNS server.

Identification	Flags	12 bytes
Number of questions	Number of answer RRs	
Number of authority RRs	Number of additional RRs	
Questions (variable number of questions)	Name, type fields for a query	
Answers (variable number of resource records)	RRs in response to query	
Authority (variable number of resource records)	Records for authoritative servers	
Additional information (variable number of resource records)	Additional "helpful" info that may be used	



UDP/DNS Implementation

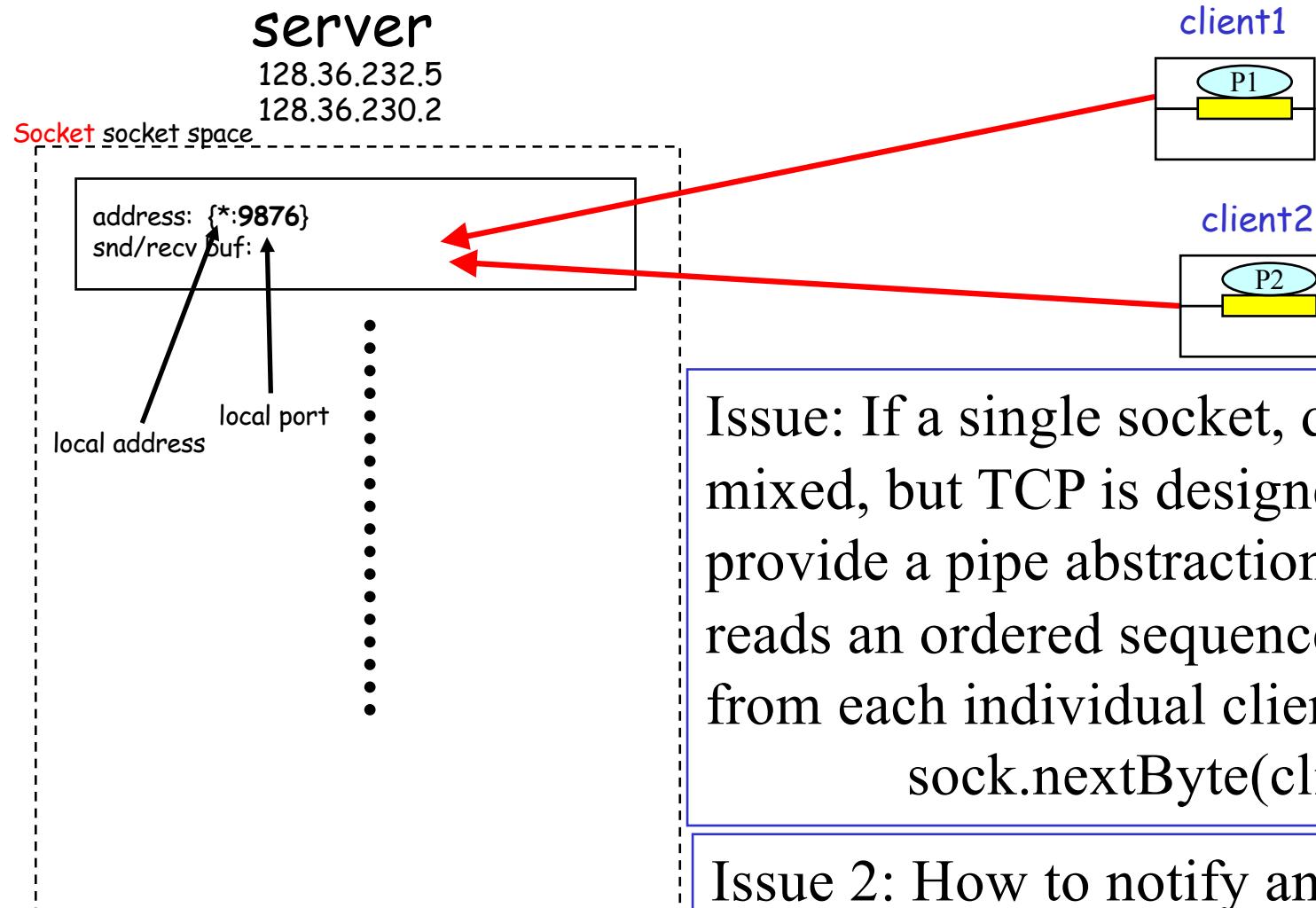
- ❑ Standard UDP demultiplexing (find out return address by `src.addr/src.port` of UDP packet) does not always work
- ❑ DNS solution: identification: remember the mapping

Identification	Flags	12 bytes
Number of questions	Number of answer RRs	
Number of authority RRs	Number of additional RRs	
Questions (variable number of questions)		Name, type fields for a query
Answers (variable number of resource records)		RRs in response to query
Authority (variable number of resource records)		Records for authoritative servers
Additional information (variable number of resource records)		Additional “helpful” info that may be used

Outline

- Admin. and recap
- Network application programming
 - Overview
 - UDP
 - *Basic TCP*

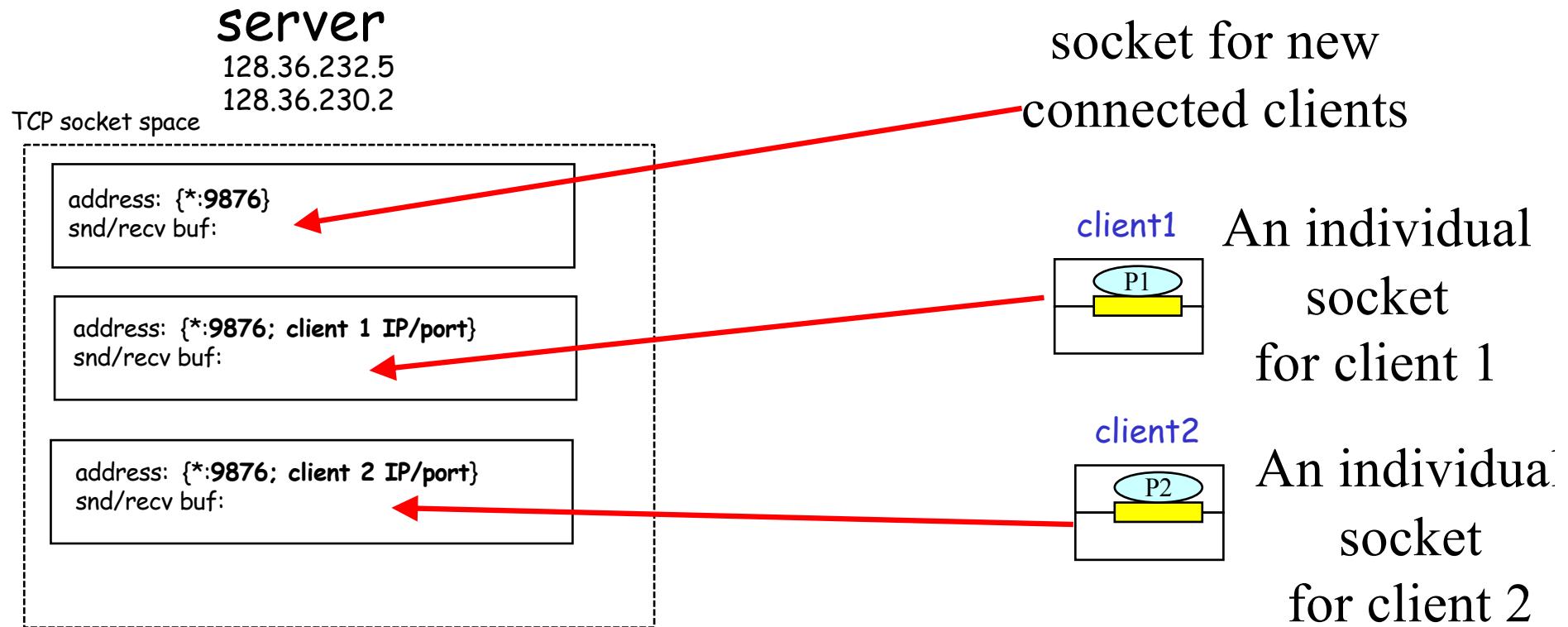
TCP Socket Design: Starting w/ UDP



Issue: If a single socket, data can be mixed, but TCP is designed to provide a pipe abstraction: server reads an ordered sequence of bytes from each individual client.
`sock.nextByte(client1)?`

Issue 2: How to notify an app that a new client is connected?
`newClient = sock.getNewClient()`

BSD TCP Socket API Design



Q: How to decide where to put a new TCP packet?

A: Packet demultiplexing is based on **four tuples**:
(dst addr, dst port, src addr, src port)

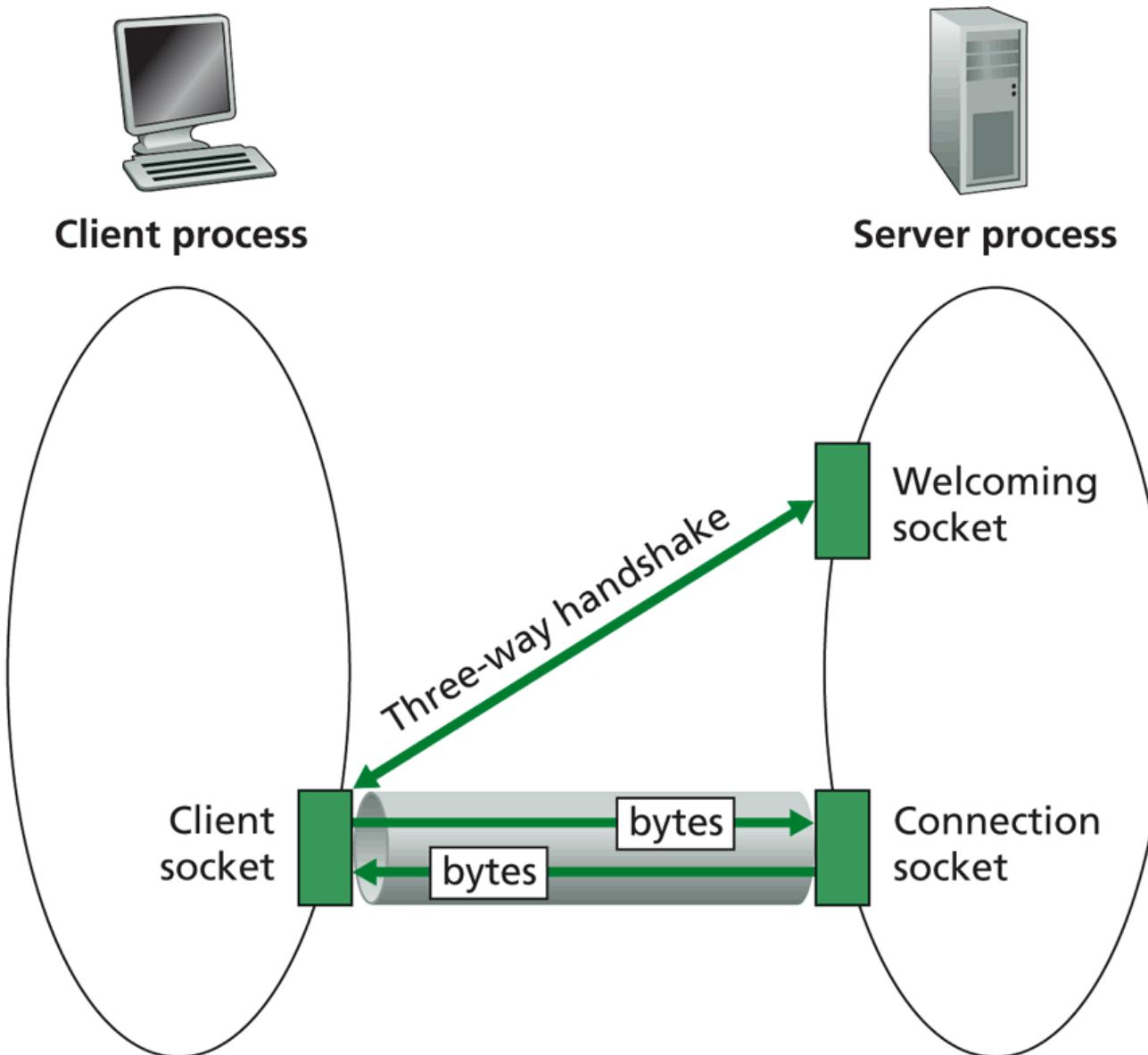
TCP Connection-Oriented Demux

- TCP socket identified by 4-tuple:
 - source IP address
 - source port number
 - dest IP address
 - dest port number

- recv host uses all four values to direct segment to appropriate socket
 - different connections/sessions are automatically separated into different sockets

-Welcome socket: the waiting room
-connSocket: the operation room

TCP Socket Big Picture



Client/server Socket Workflow: TCP

Server (running on hostid)

```
create socket,  
port=x, for  
incoming request:  
welcomeSocket =  
ServerSocket(x)
```

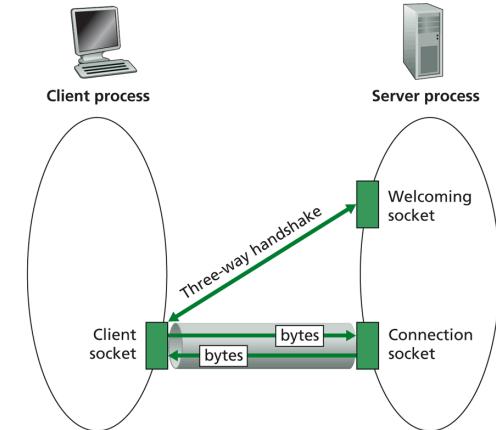
```
wait for incoming  
connection request  
connectionSocket =  
welcomeSocket.accept()
```

```
read request from  
connectionSocket  
write reply to  
connectionSocket  
close  
connectionSocket
```

Client

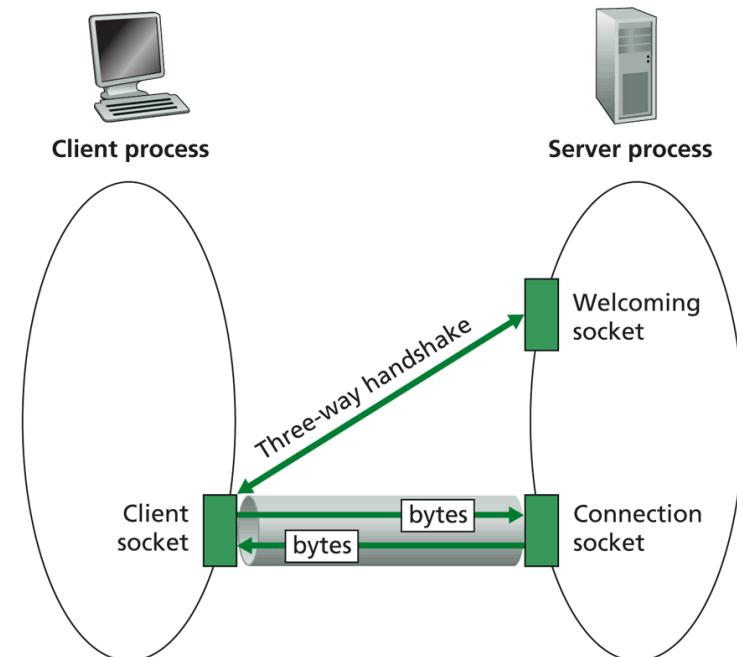
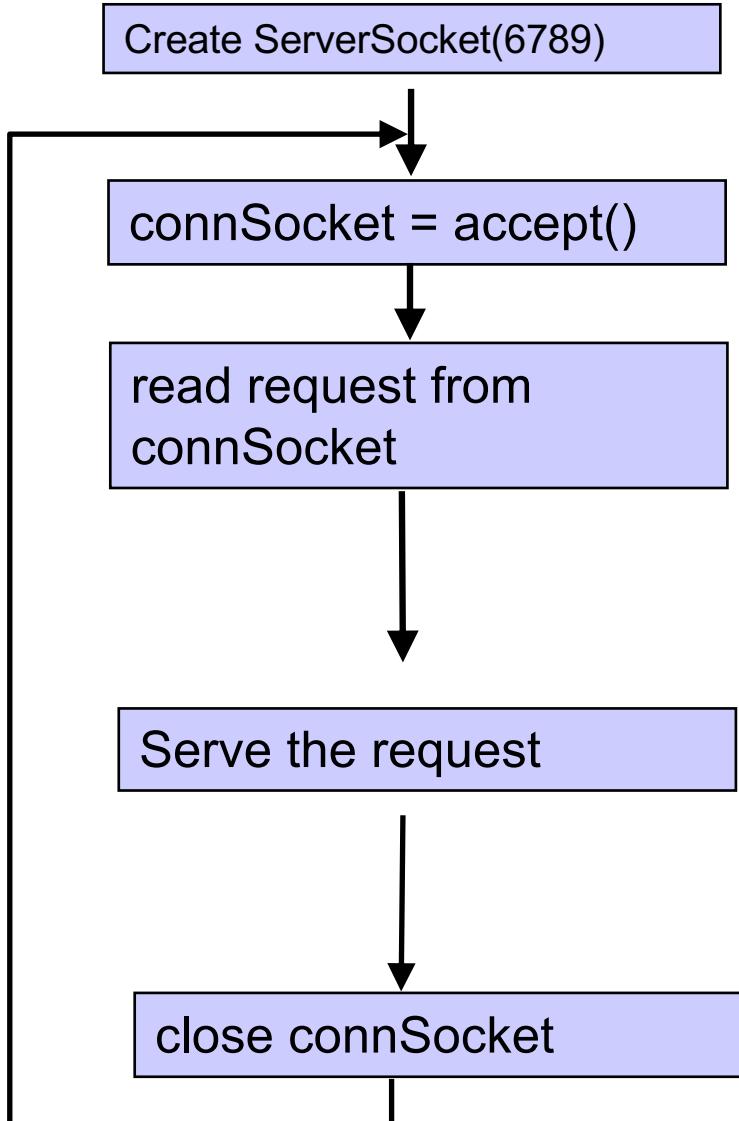
```
create socket,  
connect to hostid, port=x  
clientSocket =  
Socket()
```

```
send request using  
clientSocket  
read reply from  
clientSocket  
close  
clientSocket
```



TCP
connection setup

Server Flow



-Welcome socket: the waiting room
-connSocket: the operation room

Backup Slides
(General Service/Naming
Discovery)

General Service/Naming

Discovery Paradigm: Linda

- “Distributed workspace” by David Gelernter in the 80’s at Yale
- Very influential in naming and resource discovery
- Key issues
 - How to name services/resources
 - How to resolve names

The Linda Paradigm

- Naming scheme:
 - arbitrary tuples (heterogeneous-type vectors)

- Name resolution:
 - Nodes write into shared memory
 - Nodes read matching tuples from shared memory
 - exact matching is required for extraction

Linda: Core API

- `out()`: writes tuples to shared space
 - example: `out("abc", 1.5, 12)`.
 - result: insert ("abc", 1.5, 12) into space
- `read()`: retrieves tuple copy matching arg list (blocking)
 - example: `read("abc", ? A, ? B)`
 - result: finds ("abc", 1.5, 12) and sets local variables
 $A = 1.5, B = 12$. Tuple ("abc", 1.5, 12) is still resident in space.
- `in()`: retrieves and deletes matching tuple from space (blocking)
 - example: same as above except ("abc", 1.5, 12) is deleted
- `eval(expression)`: similar to `out` except that the tuple argument to `eval` is evaluated
 - example: `eval("ab",-6,abs(-6))` creates tuple ("ab", -6, 6)

Linda Extension: JavaSpaces

- Industry took Linda principles and made modifications
 - add transactions, leases, events
 - store Java objects instead of tuples
 - a very comprehensive service discovery system

- Definitive book, “JavaSpaces Principles, Patterns, and Practice”