Win32 Sockets

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CSE 687 – Object Oriented Design
Spring 2015

References

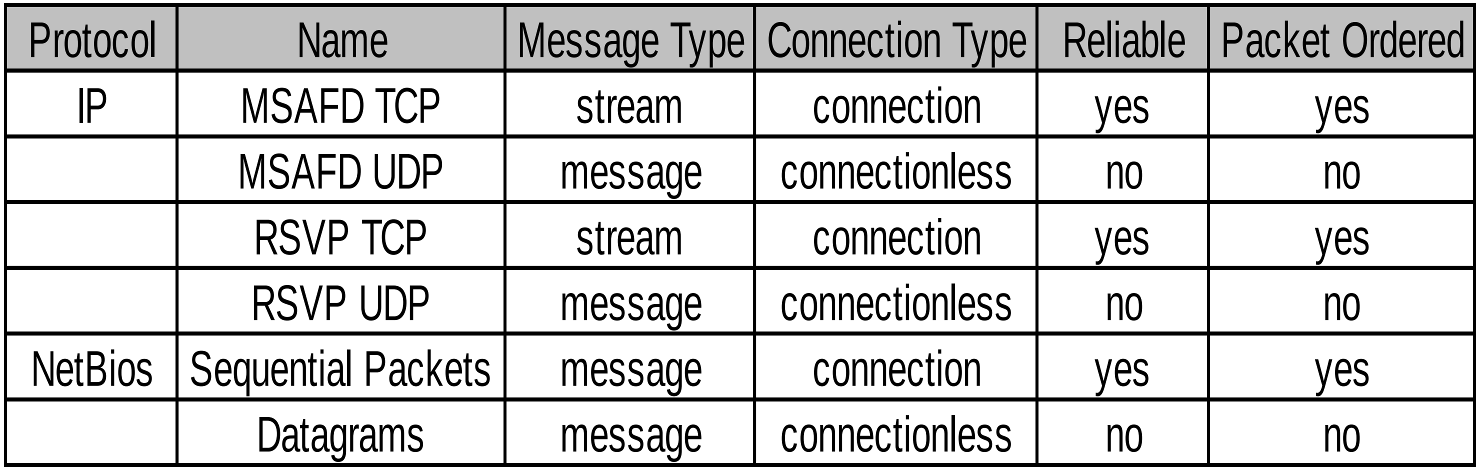
- Socket Routines, MSDN help
- Network Programming for Microsoft Windows, Jones & Ohlund, Microsoft Press, 1999 (a later edition is in print)
- C# Network Programming, Richard Blum, Sybex, 2003
- http://tangentsoft.net/wskfaq

What are Sockets?

- Sockets provide a common interface to the various protocols supported by networks.
- They allow you to establish connections between machines to send and receive data.
- Sockets support the simultaneous connection of multiple clients to a single server machine.

Network Protocols

- Socket applications can adopt communication styles supported by a specific underlying protocol, e.g.:



Protocol	Name	Message Type	Connection Type	Reliable	Packet Ordered
IP	MSAFD TCP	stream	connection	yes	yes
	MSAFD UDP	message	connectionless	no	no
	RSVP TCP	stream	connection	yes	yes
	RSVP UDP	message	connectionless	no	no
NetBios	Sequential Packets	message	connection	yes	yes
	Datagrams	message	connectionless	no	no

- We will focus on sockets using TCP/IP, that is, reliable, packet ordered, connection-oriented communication with streams.

TCP Protocol

- ***TCP/IP stands for "Transmission Control Protocol / Internet Protocol*.** TCP/IP is the most important of several protocols used on the internet. Some others are: HyperText Transport Protocol (HTTP), File Transfer Protocol (FTP), Simple Mail Transfer Protocol (SMTP), and Telnet, a protocol for logging into a remote computer. Sockets provide a standard interface for a variety of network protocols. TCP/IP is, by far, the most commonly used protocol for sockets. Here are the main features of TCP/IP:
  - ***IP is a routable protocol.***
    That means that TCP/IP messages can be passed between networks in a Wide Area Network (WAN) cluster.
  - ***Each device using TCP/IP must have an IP address*.**
    This address is a 32 bit word, organized into four 8-bit fields, called octets. Part of the IP address identifies the network and the rest identifies a specific host on the network.
  - ***IP addresses are organized into three classes*.**
    Each class has a different allocation of octets to these two identifiers. This allows the internet to define many networks, each containing up to 256 devices (mostly computers), and a few networks, each containing many more devices.
  - ***A single machine can run mulitple communictaions sessions using TCP/IP.***
    That is, you can run a web browser while using Telnet and FTP, simultaneously.

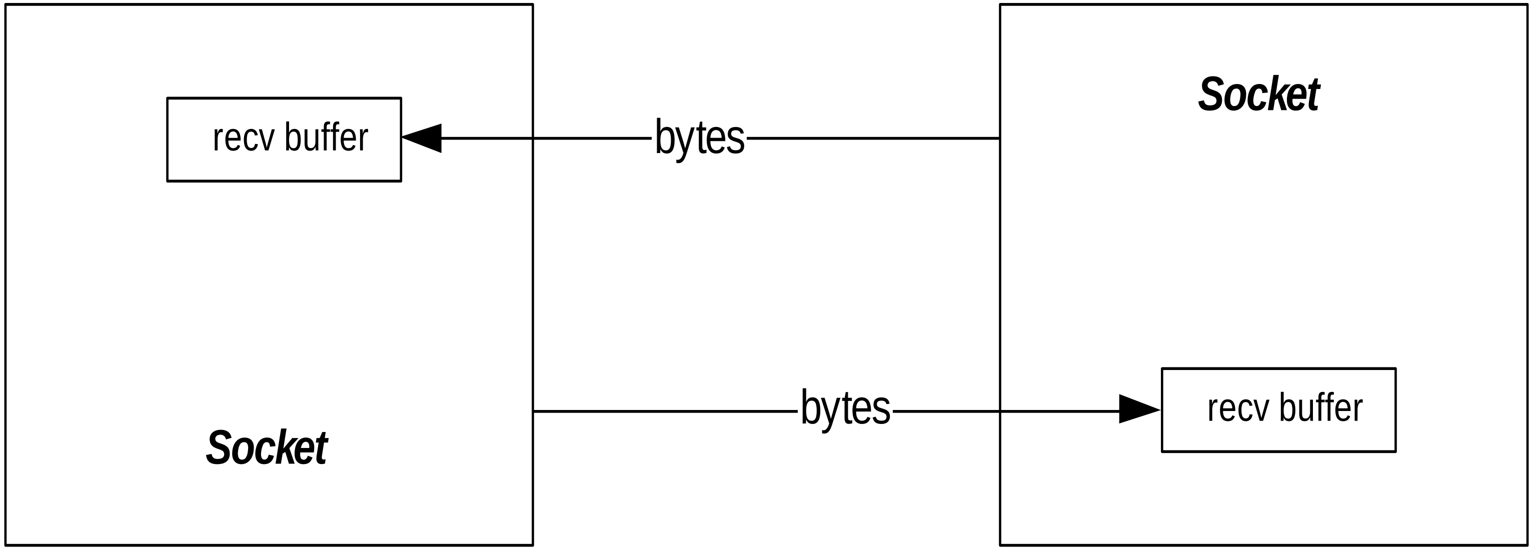
TCP/IP based Sockets

- Connection-oriented means that two communicating machines must first connect.

- All data sent will be received in the same order as sent.
  - Note that IP packets may arrive in a different order than that sent.
  - This occurs because all packets in a communication do not necessarily travel the same route between sender and receiver.

- Streams mean that, as far as sockets are concerned, the only recognized structure is bytes of data.

Socket Logical Structure



Creating Sockets

- Socket connections are based on:
  - Domains – network connection or IPC pipe
    - AF_INET for IPv4 protocol
    - AF_INET6 for IPv6 protocol
  - Type – stream, datagram, raw IP packets, …
    - SOCK_STREAM → TCP packets
    - SOCK_DGRAM → UDP packets
  - Protocol – TCP, UDP, …
    - 0 → default, e.g., TCP for SOCK_STREAM
  - Example:

```
HANDLE sock = socket(AF_INET,SOCK_STREAM,0);
```

Connecting Sockets

- Socket addresses

```
struct SOCKADDR_IN {
    sin_family          // AF_INET
    sin_address.s_addr  // inet_addr(“127.0.0.1”);
    sin_port            // htons(8000);
} addr;
```

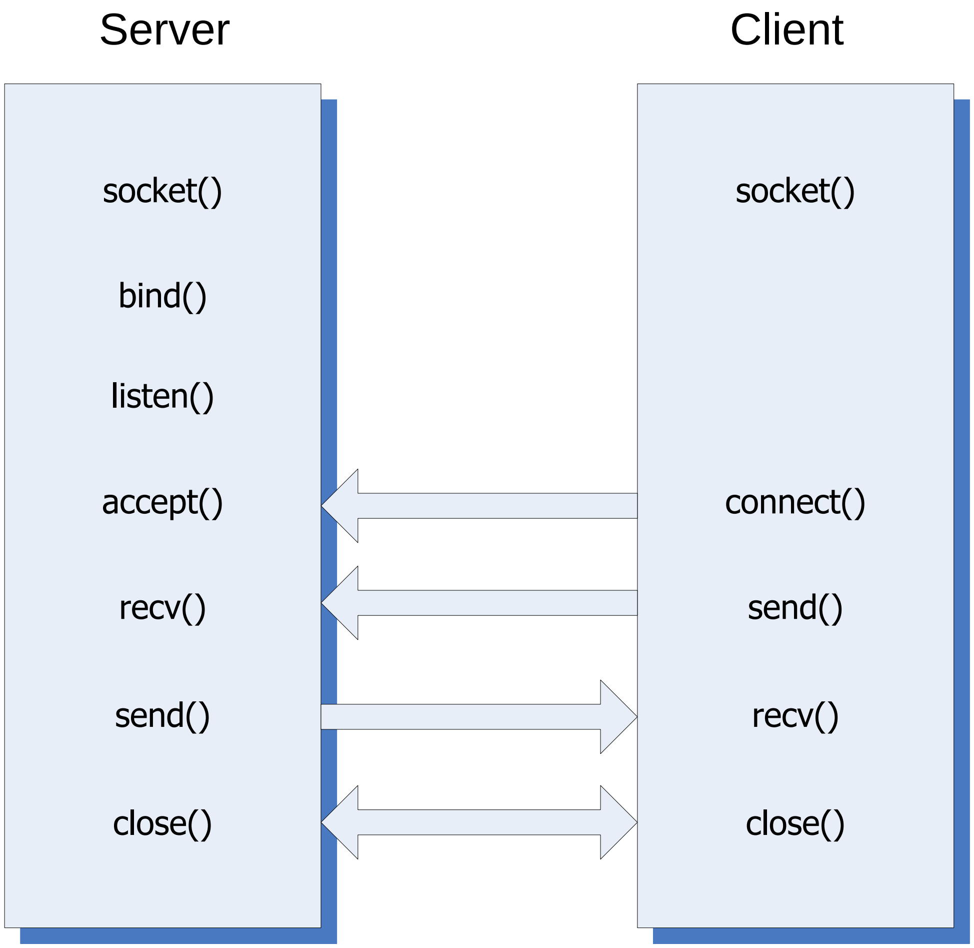
- Bind server listener to port:

```
int err = bind(sock, (SOCKADDR_IN*)&addr,sizeof(addr));
```

- Connect client to server:

```
HANDLE connect(sock, (SOCKADDR_IN*)&addr,sizeof(addr))
```

Client / Server Processing



Accessing Sockets Library

- `#include <winsock2.h>`

- Link with wsock32.lib

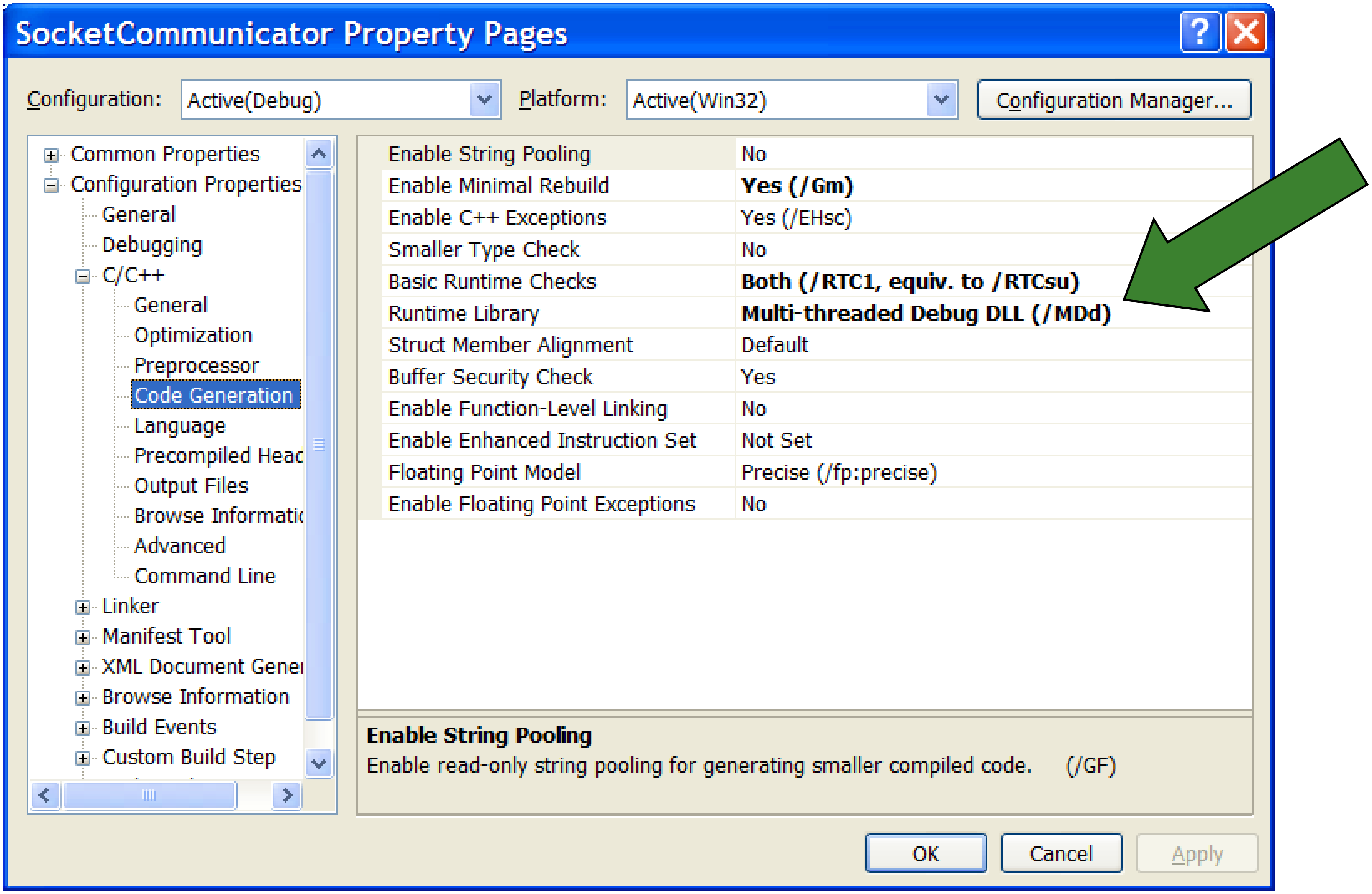
- To build a server for multiple clients you will need to use threads, e.g.:

  ```
  #include <process.h>
  ```

  and use the Project Settings:

  C/C++ language\category=code generation\debug multithreaded

Project Setting #1

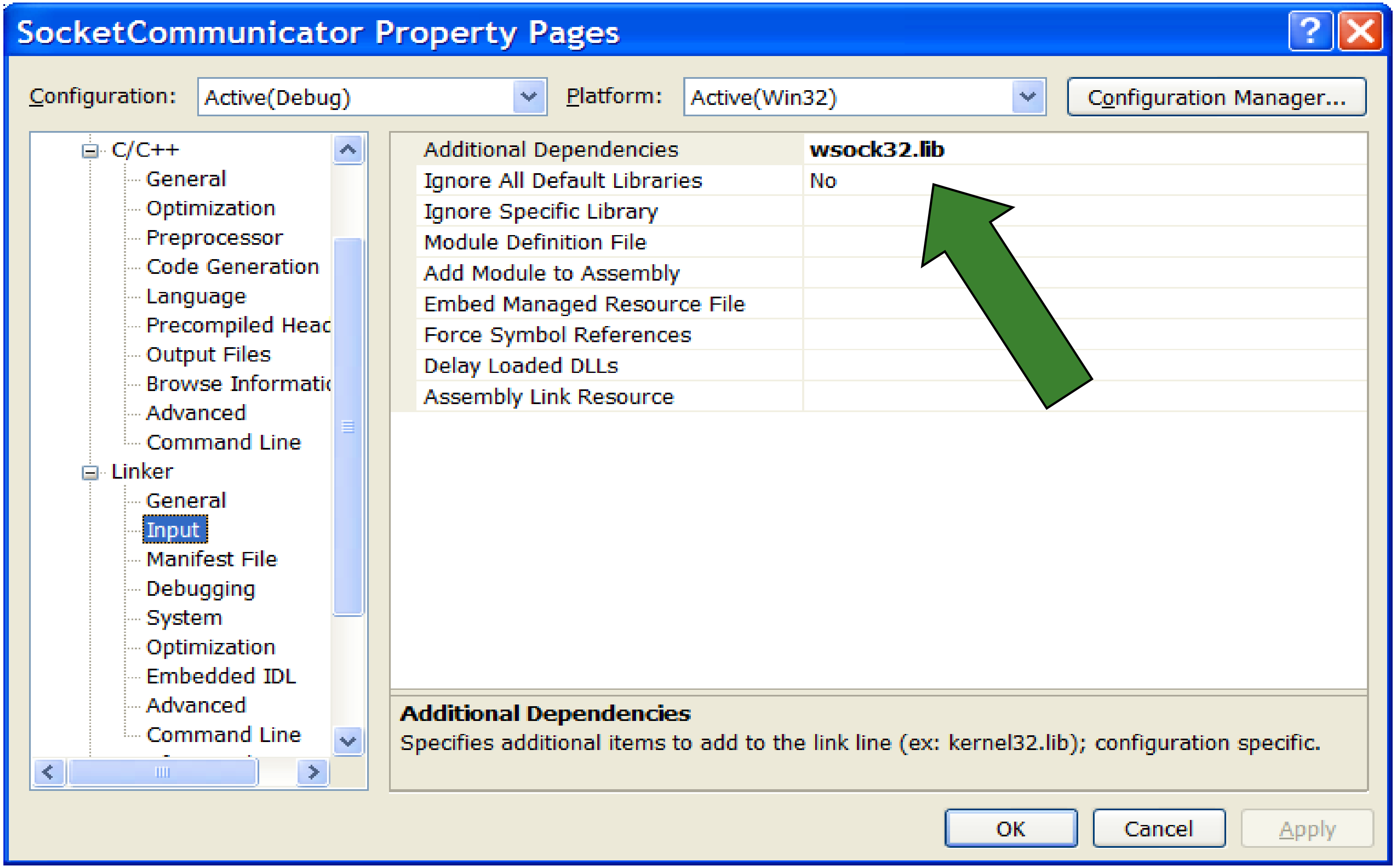


Configuration: Active(Debug) Platform: Active(Win32)

Enable String Pooling	No
Enable Minimal Rebuild	**Yes (/Gm)**
Enable C++ Exceptions	Yes (/EHsc)
Smaller Type Check	No
Basic Runtime Checks	**Both (/RTC1, equiv. to /RTCsu)**
Runtime Library	**Multi-threaded Debug DLL (/MDd)**
Struct Member Alignment	Default
Buffer Security Check	Yes
Enable Function-Level Linking	No
Enable Enhanced Instruction Set	Not Set
Floating Point Model	Precise (/fp:precise)
Enable Floating Point Exceptions	No

Enable String Pooling
Enable read-only string pooling for generating smaller compiled code. (/GF)

Project Setting #2



SocketCommunicator Property Pages

Configuration: Active(Debug)

Platform: Active(Win32)

Additional Dependencies	**wsock32.lib**
Ignore All Default Libraries	No
Ignore Specific Library	
Module Definition File	
Add Module to Assembly	
Embed Managed Resource File	
Force Symbol References	
Delay Loaded DLLs	
Assembly Link Resource	

Additional Dependencies

Specifies additional items to add to the link line (ex: kernel32.lib); configuration specific.

Sockets API

WSAStartup	- loads WS2_32.dll
WSACleanup	- unloads dll
socket	- create socket object
connect	- connect client to server
bind	- bind server socket to address/port
listen	- request server to listen for connection requests
accept	- server accepts a client connection
send	- send data to remote socket
recv	- collect data from remote socket
Shutdown	- close connection
closesocket	- closes socket handle

Sequence of Server Calls

- WSAStartup
- socket (create listener socket)
- bind
- listen
- accept
  - create new socket so listener can continue listening
  - create new thread for socket
  - send and recv
  - closesocket (on new socket)
  - terminate thread
- shutdown
- closesocket (on listener socket)
- WSACleanup

WSAStartup

```
wVersionRequested = MAKEWORD(1,1);
WSAData wData;
lpWSAData = &wData

int WSAStartup(
  WORD wVersionRequested,
  LPWSADATA lpWSAData
)
```

- Loads `WS2_32.dll`

TCP/IP socket

```
af        = AF_INET
type      = SOCK_STREAM
protocol  = IPPROTO_IP

SOCKET socket(int af, int type, int protocol)
```

- Creates a socket object and returns handle to socket.

Bind socket

```
Struct sockaddr_in local;
    … define fields of local …
name = (sockaddr*)&local
namelen = sizeof(local)

int bind(
  SOCKET s,
  const struct sockaddr *name,
  int namelen
)
```

- Bind listener socket to network card and port

Listen for incoming requests

```
int listen(SOCKET s, int backlog)
```

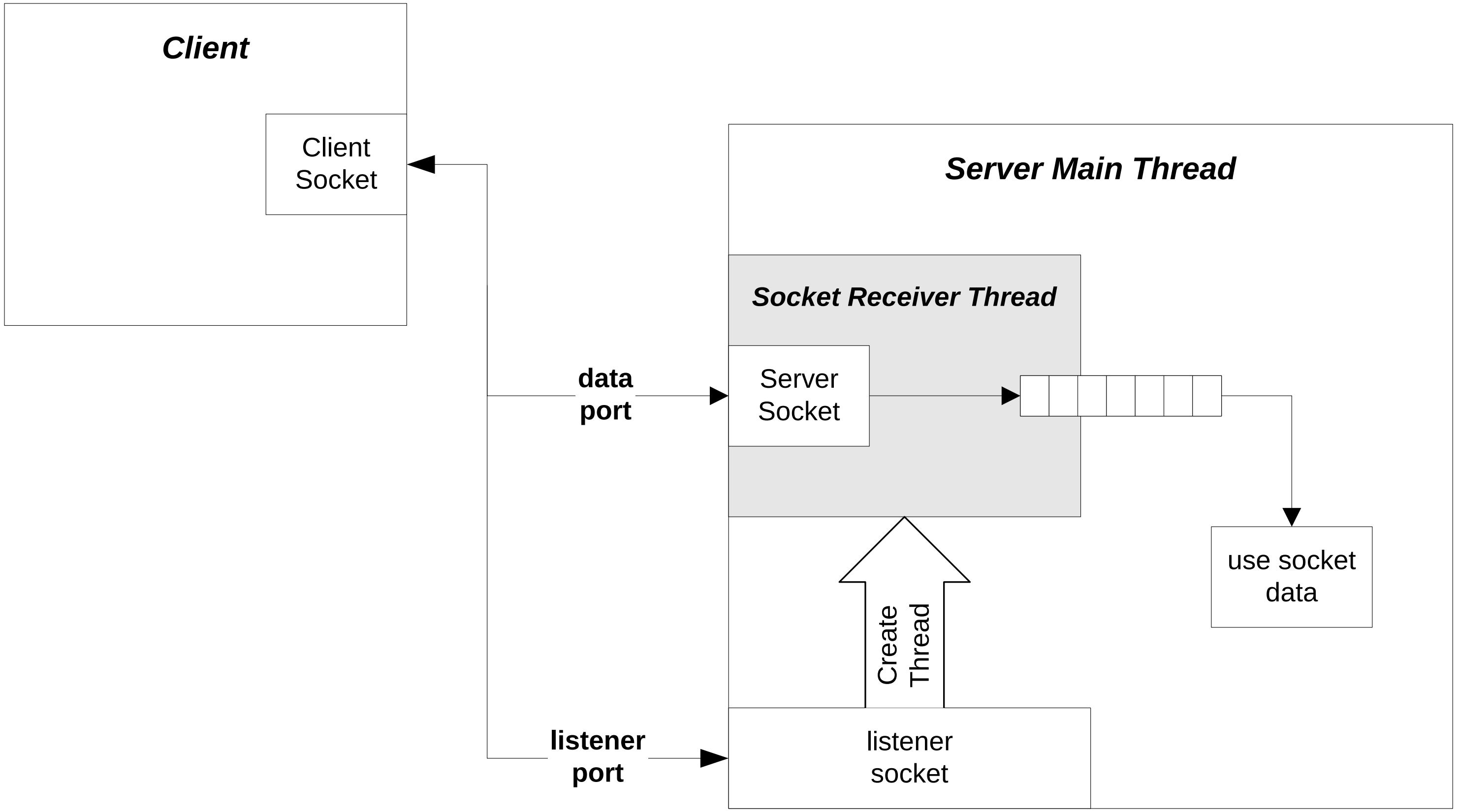
- backlog is the number of incoming connections queued (pending) for acceptance
- Puts socket in listening mode, waiting for requests for service from remote clients.

Accept Incoming Connection

```
SOCKET accept(
  SOCKET s,
  struct sockaddr *addr,
  int *addrLen
)
```

- Accepts a pending request for service and returns a socket bound to a new port for communication with new client.
- Usually server will spawn a new thread to manage the socket returned by accept.

Client/Server Configuration



recv

```
int recv(
   SOCKET s,
   char *buff,
   int len,
   int flags
)
```

- Receive data in buff up to len bytes.
- Returns actual number of bytes read.
- flags variable should normally be zero.

send

```
int send(
    SOCKET s,
    char *buff,
    int len,
    int flags
)
```

- Send data in buff up to len bytes.
- Returns actual number of bytes sent.
- flags variable should normally be zero.

shutdown

```
int shutdown(SOCKET s, int how)
```

- `how = SD_SEND or SD_RECEIVE or SD_BOTH`

- Disables new sends, receives, or both, respectively. Sends a FIN to server causing thread for this client to terminate (server will continue to listen for new clients).

closesocket

```
int closesocket(SOCKET s)
```

- Closes socket handle s, returning heap allocation for that data structure back to system.

WSACleanup

```
int WSACleanup( )
```

- Unloads `W2_32.dll` if no other users. Must call this once for each call to `WSAStartup`.

Sequence of Client Calls

- WSAStartup
- socket
- address resolution - set address and port of intended receiver
- connect - send and recv
- shutdown
- closesocket
- WSACleanup

TCP Addresses

```
struct sockaddr_in{
    short              sin_family;
    unsigned short     sin_port;
    struct in_addr     sin_addr;
    char               sin_zero[8];
} SOCKADDR_IN;
```

TCP/IP Address fields

sin_family	AF_INET
sin_port	at or above 1024
sin_addr	inet_addr(“127.0.0.1”);
sin_zero	padding

- Setting sin_addr.s_addr = INADDR_ANY allows a server application to listen for client activity on every network interface on a host computer.

connect

```
int connect(
   SOCKET s,
   const struct sockaddr *name,
   int namelen
)
```

- Connects client socket to a specific machine and port.

Special Functions

- htons – converts short from host to network byte order
- htonl – converts long from host to network byte order
- ntohs – converts short from network to host byte order
- ntohl – converts long from network to host byte order

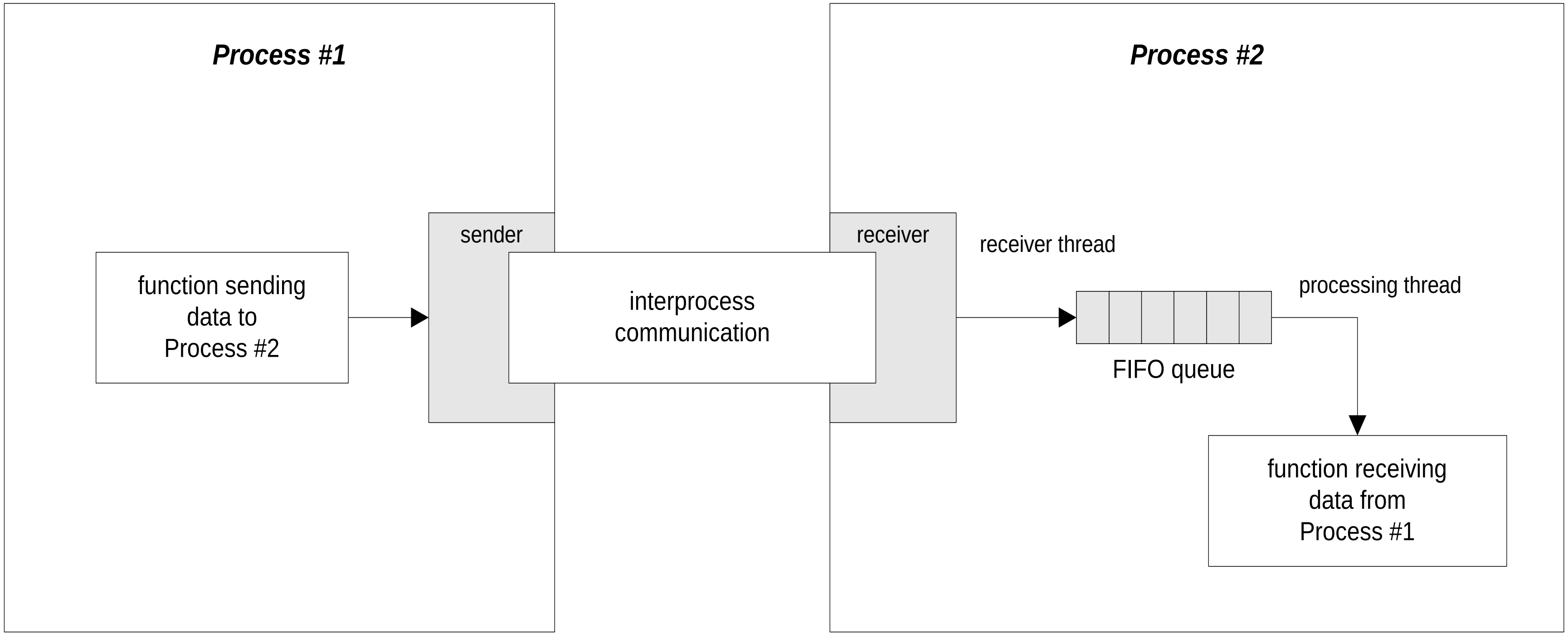
A Word of Caution

- With stream oriented sockets, send does not guarantee transfer of all bytes requested in a single call.

- That’s why send returns an int, the number of bytes actually send.

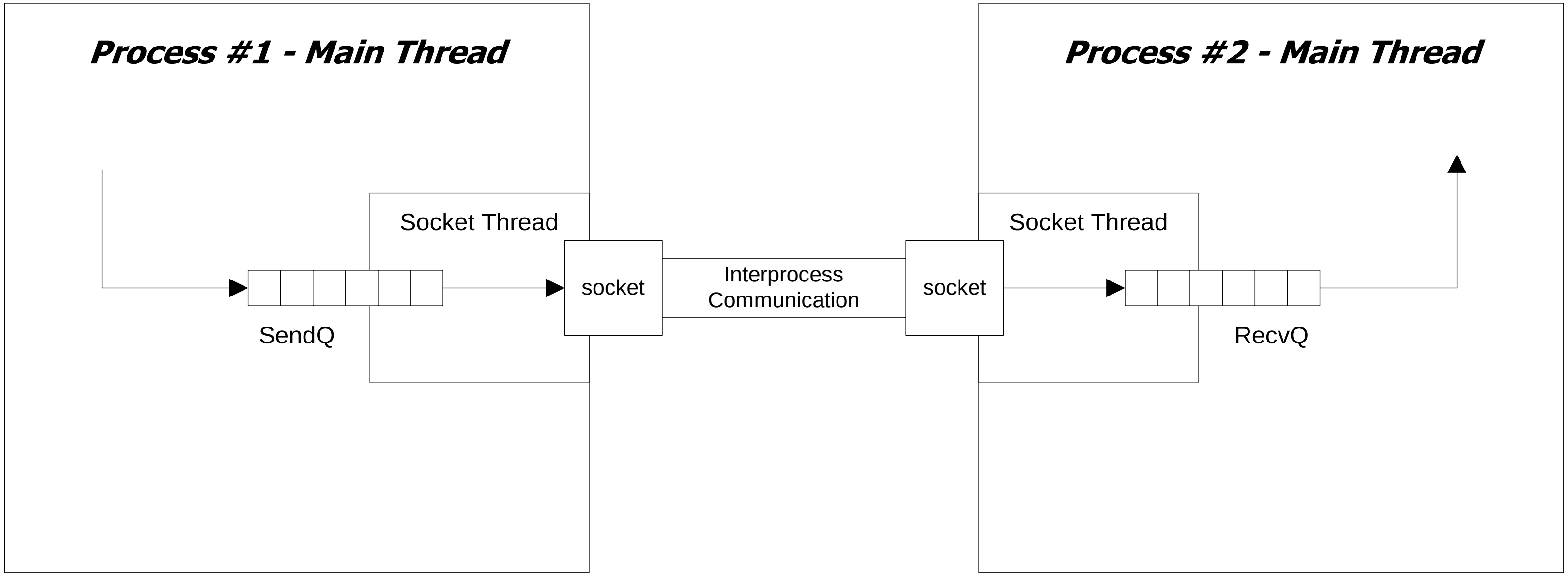
- It’s up to you to ensure that all the bytes are actually sent
  - See my code example – socks.cpp

Non-Blocking Communication



Process #1
Process #2
function sending data to Process #2
sender
interprocess communication
receiver
receiver thread
processing thread
FIFO queue
function receiving data from Process #1

Store and Forward Architecture

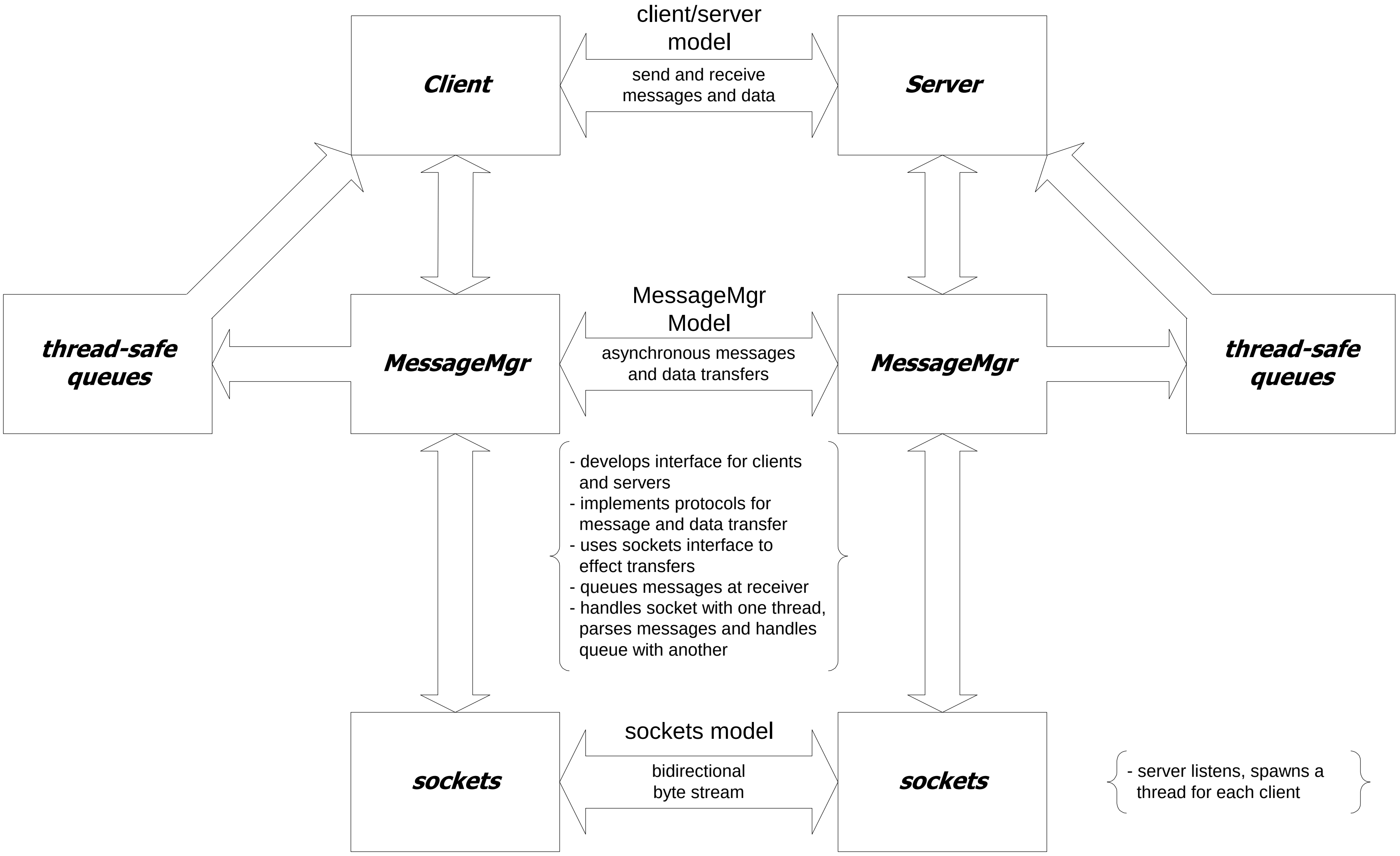


SendQ is used to hold messages in the event that communication with the remote receiver fails.

Messages are held until communication is re-established.

RecvQ is used to quickly remove messages from the socket connection so that the socket buffer never fills (that would block the sender).

Messaging System Architecture



Client

client/server model

send and receive messages and data

Server

thread-safe queues

MessageMgr

MessageMgr Model

asynchronous messages and data transfers

MessageMgr

thread-safe queues

- develops interface for clients and servers
- implements protocols for message and data transfer
- uses sockets interface to effect transfers
- queues messages at receiver
- handles socket with one thread, parses messages and handles queue with another

sockets

sockets model

bidirectional byte stream

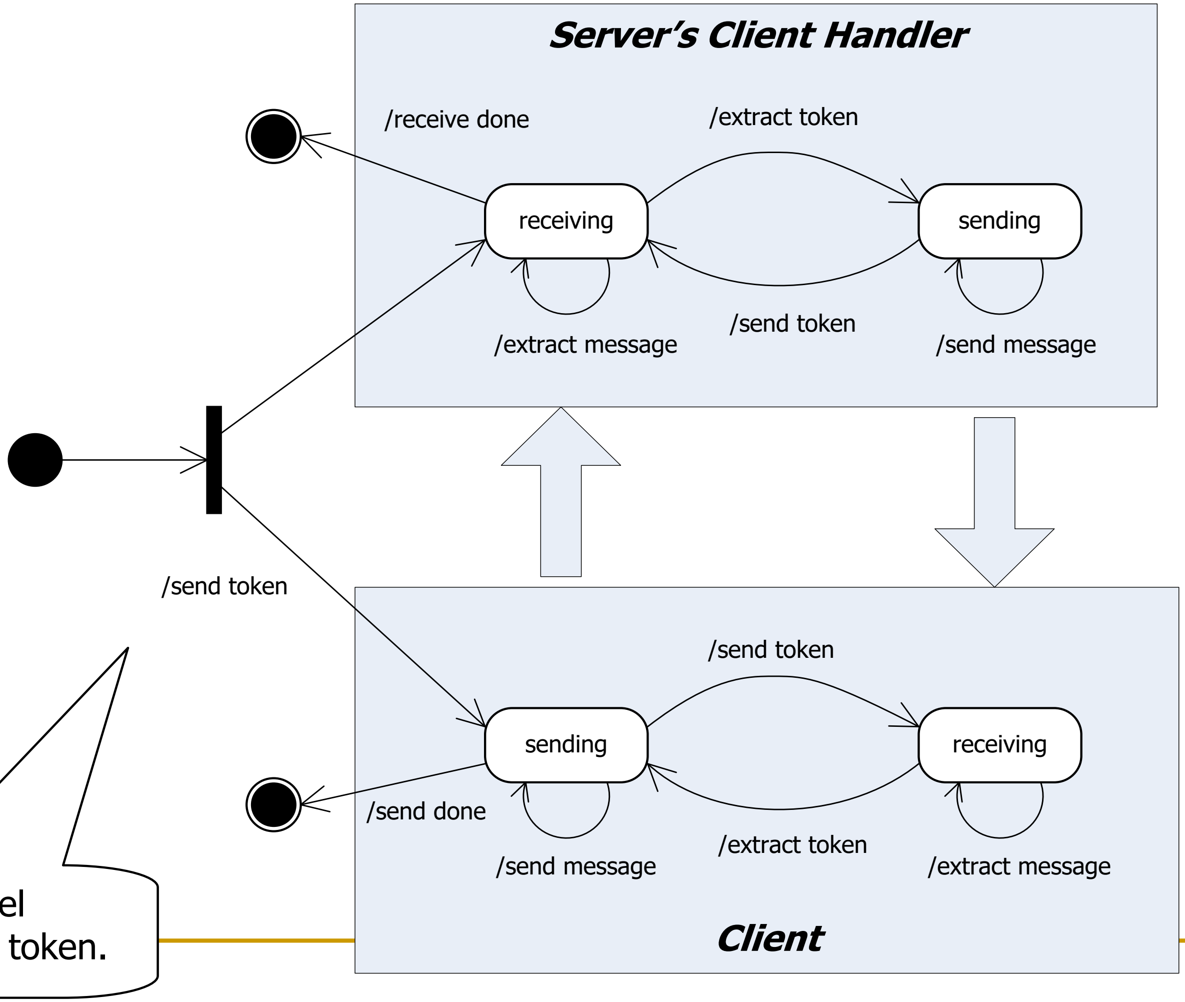
sockets

- server listens, spawns a thread for each client

Talk Protocol

- The hardest part of a client/server socket communication design is to control the active participant
  - If single-threaded client and server both talk at the same time, their socket buffers will fill up and they both will block, e.g., deadlock.
  - If they both listen at the same time, again there is deadlock.
  - Often the best approach is to use separate send and receive threads

State Chart - Socket
Bilateral Communication Protocol



Each connection channel contains one “sending” token.

Message Length

- Another vexing issue is that the receiver may not know how long a sent message is.
  - so the receiver doesn’t know how many bytes to pull from the stream to compose a message.
  - Often, the communication design will arrange to use message delimiters, fixed length messages, or message headers that carry the message length as a parameter.
    - MessageFramingWithThreadsAndQs – only in C# right now
    - SocketBlocks → SocketCommunicator

Message Framing

- Sockets only understand arrays of bytes
  - Don’t know about strings, messages, or objects
- In order to send messages you simply build the message string, probably with XML
  - string msg = “<msg>message text goes here</msg>”
  - Then send(sock,msg,strlen(msg),flags)
- Receiving messages requires more work
  - Read socket one byte at a time and append to message string:
  - recv(sock,&ch,1,flags); msg.append(ch);
  - Search string msg from the back for </
  - Then collect the msg>

They’re Everywhere

- Virtually every network and internet communication method uses sockets, often in a way that is invisible to an application designer.
  - Browser/server
  - ftp
  - SOAP
  - Network applications

What we didn’t talk about

- udp protocol
- socket select(…) function
- non-blocking sockets

Sockets

The End