C#

Socket Programming in C# − Part II

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This is the second part of Ashish's two part series about handling sockets in the C# language. Read this article to learn how to use sockets with the .Net framework.This is the second part of the previous article about the socket programming. In the earlier article we created a client but that client used to make blocking IO calls (Receive) to read data at regular intervals (via clicking the Rx button). But as I said in my earlier article, that model does not work very well in a real world application. Also since Windows is an events−based system, the application (client) should get notifications of some kind whenever the data is received so that client can read it rather than client continuously polling for data.

Well that is possible with a little effort. If you read the first part of this article, you already know that the Socket class in the Systems.Net.Sockets namespace has several methods like Receive and Send which are blocking calls. Besides there are also functions like BeginReceive , BeginSend etc. These are meant for asynchronous IO . For example , there are at least two problems with the blocking Receive:

1. When you call Receive function the call blocks if no data is present, the call blocks till some data arrives.
2. Even if there is data when you made the receive call , you don't know when to call next time. You need to do polling which is not an efficient way.

Although you can argue that one can overcome these *shortcomings* by multithreading meaning that one can spawn a new thread and let that thread do the polling and notifies the main thread of the data. Well this concept will work well. But even if you create a new thread it would require your main thread to share the CPU time with this new thread. Windows operating system (Windows NT /2000 /XP) provide what is called Completion Port IO model for doing overlapped (asynchronous) IO.

The details of IO Completion port are beyond the scope of the current discussion, but to make it simple you can think of IO Completion Ports as the most efficient mechanism for doing asynchronous IO in Windows that is provided by the Operating system. Completion Port model can be applied to any kind of IO including the file read /write and serial communication.

The .NET asynchronous socket programming helper class's Socket provides the similar model.

BeginReceive

.NET framework's Socket class provides BeginReceive method to receive data asynchronously i.e., in an non−blocking manner The BeginReceive method has following signature:

public **IAsyncResult BeginReceive**(byte[] buffer, int offset, int size, SocketFlags socketFlags, AsyncCallback callback, object state);

The way BeginReceive function works is that you pass the function a buffer , a callback function (delegate) which will be called whenever data arrives.

The last parameter, object, to the BeginReceive can be any class derived from object (even null) .
When the callback function is called it means that the BeginReceive function completed which means that the data has arrived.
The callback function needs to have the following signature:

void AsyncCallback(IAsyncResult ar);

As you can see the callback returns void and is passed in one parameter , **IAsyncResult** interface , which contains the status of the asynchronous receive operation.

The IAsyncResult interface has several properties. The first parameter − AsyncState − is an object which is same as the last parameter that you passed to BeginReceive(). The second property is AsyncWaitHandle which we will discuss in a moment. The third property indicates whether the receive was really asynchronous or it finished synchronously. The important thing to follow here is that it not necessary for an asynchronous function to always finish asynchronously − it can complete immediately if the data is already present. Next parameter is IsComplete which indicates whether the operation has completed or not.

If you look at the signature of the BeginReceive again you will note that the function also returns ***IAsyncResult***. This is interesting. Just now I said that I will talk about the second peoperty of the IAsyncResult in a moment. Now is that moment. The second parameter is called **AsyncWaitHandle.**

The AsyncWaitHandle is of type **WaitHandle**, a class defined in the System.Threading namespace. WaitHandle class encapsulates a Handle (which is a pointer to int or handle) and provides a way to wait for that handle to become signaled. The class has several static methods like WaitOne (which is similar to WaitForSingleObject) WaitAll (similar to WaitForMultipleObjects with waitAll true) , WaitAny etc. Also there are overloads of these functions available with timeouts.

Coming back to our discussion of IAsyncResult interface, the handle in AsyncWaitHandle (WaitHandle) is signalled when the receive operation completes. So if we wait on that handle infinitely we will be able to know when the receive completed. This means if we pass that WaitHandle to a different thread, the different thread can wait on that handle and can notify us of the fact that the data has arrived and so that we can read the data. So you must be wondering if we use this mechanism why would we use callback function. We won't. Thats right. If we choose to use this mechanism of the WaitHandle then the callback function parameter to the BeginReceive can be null as shown here:

```
//m_asynResult is  declared of type IAsyncResult and assumming that m_socClient has made a connection.
m_asynResult = m_socClient.BeginReceive(m_DataBuffer,0,m_DataBuffer.Length,SocketFlags.None,null,null);
if ( m_asynResult.AsyncWaitHandle.WaitOne () )
{
int iRx = 0 ;
iRx = m_socClient.EndReceive (m_asynResult);
char[] chars = new char[iRx + 1];
System.Text.Decoder d = System.Text.Encoding.UTF8.GetDecoder();
int charLen = d.GetChars(m_DataBuffer, 0, iRx, chars, 0);
System.String szData = new System.String(chars);
txtDataRx.Text = txtDataRx.Text + szData;
}
```

Even though this mechanism will work fine using multiple threads, we will for now stick to our callback mechanism where the system notifies us of the completion of asynchronous operation which is Receive in this

case .
Lets say we made the call to BeginReceive and after some time the data arrived and our callback function got called.Now question is where's the data? The data is now available in the buffer that you passed as the first parameter while making call to BeginReceive() method . In the following example the data will be available in m_DataBuffer :

BeginReceive(**m_DataBuffer**,0,m_DataBuffer.Length,SocketFlags.None, pfnCallBack,null);

But before you access the buffer you need to call EndReceive() function on the socket. The EndReceive will return the number of bytes received . Its not legal to access the buffer before calling EndReceive.
To put it all together look at the following simple code:

```
byte[] m_DataBuffer = new byte [10];
IAsyncResult m_asynResult;
public AsyncCallback pfnCallBack ;
public Socket m_socClient;
// create the socket...
public void OnConnect()
{
m_socClient = new Socket (AddressFamily.InterNetwork,SocketType.Stream ,ProtocolType.Tcp );
// get the remote IP address...
IPAddress ip = IPAddress.Parse ("10.10.120.122");
int iPortNo = 8221;
//create the end point
IPEndPoint ipEnd = new IPEndPoint (ip.Address,iPortNo);
//connect to the remote host...
m_socClient.Connect ( ipEnd );
//watch for data ( asynchronously )...
WaitForData();
}
public void WaitForData()
{
if ( pfnCallBack == null )
pfnCallBack = new AsyncCallback (OnDataReceived);
// now start to listen for any data...
m_asynResult =
m_socClient.BeginReceive (m_DataBuffer,0,m_DataBuffer.Length,SocketFlags.None, pfnCallBack,null);
}
public void OnDataReceived(IAsyncResult asyn)
{
//end receive...
int iRx = 0 ;
iRx = m_socClient.EndReceive (asyn);
char[] chars = new char[iRx + 1];
System.Text.Decoder d = System.Text.Encoding.UTF8.GetDecoder();
int charLen = d.GetChars(m_DataBuffer, 0, iRx, chars, 0);
System.String szData = new System.String(chars);
WaitForData();
}
```

The OnConnect function makes a connection to the server and then makes a call to WaitForData. WaitForData creates the callback function and makes a call to BeginReceive passing a global buffer and the callback function. When data arrives the OnDataReceive is called and the m_socClient's EndReceive is called which returns the number of bytes received and then the data is copied over to a string and a new call is made to WaitForData which will call BeginReceive again and so on. This works fine if you have one socket in you application.

MULTIPLE SOCKETS

Now lets say you have two sockets connecting to either two different servers or same server(which is valid) . One way is to create two different delegates and attach a different delegate to different BeginReceive function. What if you have 3 sockets or for that matter n sockets , this approach of creating multiple delegates does not fit well in such cases. So the solution should be to use only one delegate callback. But then the problem is how do we know what socket completed the operation.

Fortunately there is a better solution. If you look at the BeginReceive function again, the last parameter is a state is an object. You can pass anything here . And whatever you pass here will be passed back to you later as the part of parameter to the callback function. Actually this object will be passed to you later as a IAsyncResult.AsyncState. So when your callback gets called, you can use this information to identify the socket that completed the operation. Since you can pass any thing to this last parameter, we can pass a class object that contains as much information as we want. For example we can declare a class as follows:

```
public class CSocketPacket
{
public System.Net.Sockets.Socket thisSocket;
public byte[] dataBuffer = new byte[1024];
}
```

and call BeginReceive as follows:

```
CSocketPacket theSocPkt = new CSocketPacket ();
theSocPkt.thisSocket = m_socClient;
// now start to listen for any data...
m_asynResult = m_socClient.BeginReceive (theSocPkt.dataBuffer ,0,theSocPkt.dataBuffer.Length ,
SocketFlags.None,pfnCallBack,theSocPkt);
```

and in the callback function we can get the data like this:

```
public void OnDataReceived(IAsyncResult asyn)
{
  try
  {
CSocketPacket theSockId = (CSocketPacket)asyn.AsyncState ;
//end receive...
int iRx = 0 ;
iRx = theSockId.thisSocket.EndReceive (asyn);
char[] chars = new char[iRx + 1];
System.Text.Decoder d = System.Text.Encoding.UTF8.GetDecoder();
int charLen = d.GetChars(theSockId.dataBuffer, 0, iRx, chars, 0);
System.String szData = new System.String(chars);
txtDataRx.Text = txtDataRx.Text + szData;
WaitForData();
  }
  catch (ObjectDisposedException )
  {
System.Diagnostics.Debugger.Log(0,"1","\nOnDataReceived: Socket has been closed\n");
  }
  catch(SocketException se)
  {
MessageBox.Show (se.Message );
  }
}
```

To see the whole application download the code and you can see the code.

There is one thing which you may be wondering about. When you call BeginReceive , you have to pass a buffer and the number of bytes to receive. The question here is how big should the buffer be. Well, the answer is it depends. You can have a very small buffer size say, 10 bytes long and if there are 20 bytes ready to be read, then you would require 2 calls to receive the data. On the other hand if you specify the length as 1024 and you know you are always going to receive data in 10−byte chunks you are unnecessarily wasting memory. So the length depends upon your application.

Server Side

If you have understood whatever I have described so far, you will easily understand the Server part of the socket application. So far we have been talking about a client making connection to a server and sending and receiving data.

On the Server end, the application has to send and receive data. But in addition to adding and receiving data, server has to allow the clients to make connections by listening at some port. Server does not need to know client I.P. addresses. It really does not care where the client is because its not the server but client who is responsible for making connection. Server's responsibility is to manage client connections.

On the server side there has to be one socket called the Listener socket that listens at a specific port number for client connections. When the client makes a connection, the server needs to accept the connection and then in order for the server to send and receive data from that connected client it needs to talk to that client through the socket that it got when it accepted the connection . Following code illustrates how server listens to the connections and accepts the connection:

```
public Socket m_socListener;
public void StartListening()
{
 try
 {
//create the listening socket...
m_socListener = new Socket(AddressFamily.InterNetwork,SocketType.Stream,ProtocolType.Tcp);
IPEndPoint ipLocal = new IPEndPoint ( IPAddress.Any ,8221);
//bind to local IP Address...
m_socListener.Bind( ipLocal );
//start listening...
m_socListener.Listen (4);
// create the call back for any client connections...
m_socListener.BeginAccept(new AsyncCallback ( OnClientConnect ),null);
cmdListen.Enabled = false;
 }
 catch(SocketException se)
 {
MessageBox.Show ( se.Message );
 }
}
```

If you look at the above code carefully you will see that its similar to we did in the asynchronous client. First of all the we need to create a listening socket and bind it to a local IP address. Note that we have given Any as the IPAddress . I will explain what it means later. and also we have passed port number as 8221. Next we made a call to Listen function. The 4 is a parameter indicating *backlog* indicating the maximum length of the queue of pending connections.

Next we made a call to BeginAccept passing it a delegate callback. BeginAccept is a non−blocking method that returns immediately and when a client has made requested a connection, the callback routine is called and you can accept the connection by calling EndAccept. The EndAccept returns a socket object which represents the incoming connection. Here is the code for the callback delegate:

```
public void OnClientConnect(IAsyncResult asyn)
{
try
{
  m_socWorker = m_socListener.EndAccept (asyn);
WaitForData(m_socWorker);
}
catch(ObjectDisposedException)
{
        System.Diagnostics.Debugger.Log(0,"1","\n OnClientConnection: Socket has been closed\n");
}
catch(SocketException se)
{
```

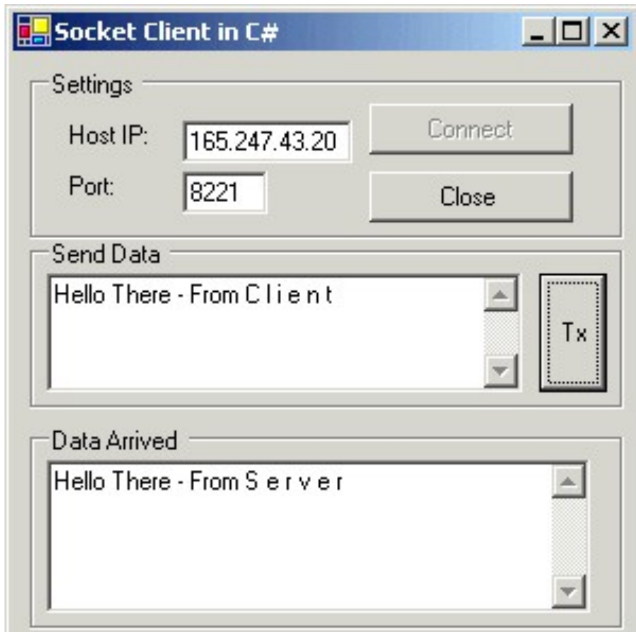
```
MessageBox.Show ( se.Message );
}
}
```

Here we accept the connection and call WaitForData which in turn calls BeginReceive for the m_socWorker.

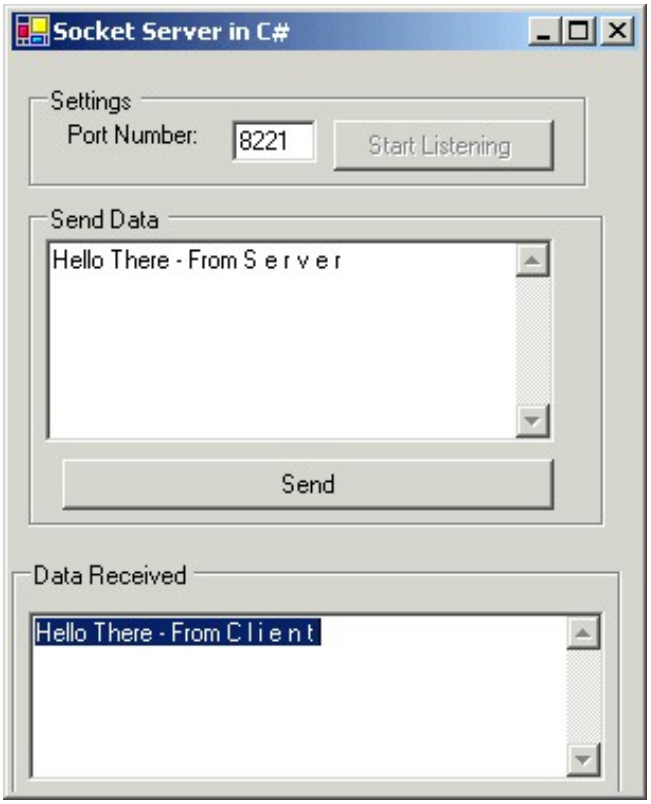
If we want to send data some data to client we use m_socWorker socket for that purpose like this:

```
Object objData = txtDataTx.Text;
byte[] byData = System.Text.Encoding.ASCII.GetBytes(objData.ToString ());
m_socWorker.Send (byData);
```

Here is how our client looks like



Here is how our server looks like



That is all there is to the socket programming.