

COMO(C++ Component Model)原理

RPC (Remote Process Call) 远程过程调用

COMO RPC程序组成

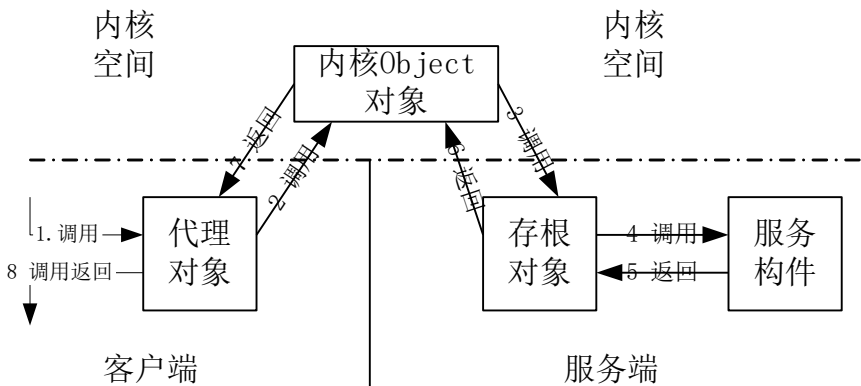
- ❑ 客户端Client ---- Proxy
- ❑ 服务器端Server ---- Stub
- ❑ COMO远程对象服务管理ServiceManager
- ❑ 操作系统内核支持D-Bbus/IBinder

COMO远程接口自动列集\散集技术

当客户端Client和服务器端Server所在地址空间不同时，客户端进程对服务器端构件服务的调用，属于远程构件调用RPC。由于两个不同空间之间不允许彼此直接访问或者具有不同的访问权限，所以需要某种通讯机制来实现不同地址空间之间的数据交互。

COMO构件技术支持远程接口调用，通过数据的自动列集\散集技术进行不同地址空间的数据交互。构件服务和构件服务调用者可以处于操作系统的不同空间，而调用者可以如同在同一地址空间里面使用构件一样透明的进行远程接口调用，也就是说完全向用户屏蔽了底层使用的标准的列集\散集过程。

COMO对象流程调用示意图



以存根\代理机制来实现远程接口自动列集\散集, 主要涉及到三个对象, 处于客户端的代理(Proxy)对象, 处于服务端的存根(stub)对象, 以及处于内核的(Object)对象 (基于D-Bus、IBinder的版本没有内核对象)。

一个客户端进程不一定只调用一个远程构件的服务, 为了方便有效的和各个远程构件交互数据, COMO在客户端为每一个对应的远程服务建立一个代理对象, 记录一些客户进程的信息、远程服务的构件对象的信息以及一些调用的状态等, 负责为客户进程与对应的远程服务联系。

COMO会为每个提供远程服务的构件对象建立一个存根对象, 客户端代理不是直接与远程提供服务的构件对象联系的, 而是与存根对象进行联系, 通过存根对象来调用构件对象。

客户端Client -- Proxy

- 客户端是引用服务的一端。
- 通过这个机制，不只是让C++程序得以使用COMO构件服务，实现多语言的绑定也是很容易的。

客户端Client

❑ 源码: /como/como/test/runtime/rpc/client/main.cpp

```
28 static AutoPtr<IService> SERVICE;
29
30 TEST(RPCTest, TestGetRPCService)
31 {
32     AutoPtr<IInterface> obj;
33     ServiceManager::GetInstance()->GetService("rpcservice", obj);
34     SERVICE = IService::Probe(obj);
35     EXPECT_TRUE(SERVICE != nullptr);
36 }
37
38 TEST(RPCTest, TestCallTestMethod1)
39 {
40     EXPECT_TRUE(SERVICE != nullptr);
41     ECode ec = E_REMOTE_EXCEPTION;
42     Integer result;
43     ec = SERVICE->TestMethod1(9, result);
44     EXPECT_EQ(9, result);
45     EXPECT_EQ(ec, NOERROR);
46 }
```

GetService中的obj哪里来的？

GetService()

❑ 源码: /como/como/servicemanager/lib/linux/ServiceManager.cpp

```
131 ECode ServiceManager::GetService(  
132     /* [in] */ const String& name,  
133     /* [out] */ AutoPtr<IInterface>& object)  
134 {
```

```
209     if (replyData != nullptr) {  
210         AutoPtr<IParcel> parcel;  
211         CoCreateParcel(RPCType::Local, parcel);  
212         parcel->SetData(reinterpret_cast<HANDLE>(replyData), replySize);  
213  
214         AutoPtr<IInterfacePack> ipack;  
215         CoCreateInterfacePack(RPCType::Local, ipack);  
216         IParcelable::Probe(ipack)->ReadFromParcel(parcel);  
217         ec = CoUnmarshalInterface(ipack, RPCType::Local, object);  
218     }
```

GetService中的obj哪里来的?

CoUnmarshalInterface()

❑ 源码: /como/como/como/runtime/rpc/comorpc.cpp

```
105 ECode CoUnmarshalInterface(  
106     /* [in] */ IInterfacePack* data,  
107     /* [in] */ RPCType type,  
108     /* [out] */ AutoPtr<IInterface>& object)  
109 {  
110     if (data == nullptr) {  
111         object = nullptr;  
112         return NOERROR;  
113     }  
114  
115     AutoPtr<IRPCChannelFactory> factory =  
116         type == RPCType::Local ? sLocalFactory : sRemoteFactory;  
117     return factory->UnmarshalInterface(data, object);  
118 }
```


GetService中的obj哪里来的?

UnmarshalInterface()

❑ 源码: /como/como/como/runtime/rpc/dbus/CDBusChannelFactory.cpp

```
113 ECode CDBusChannelFactory::UnmarshalInterface(  
114     /* [in] */ IInterfacePack* ipack,  
115     /* [out] */ AutoPtr<IInterface>& object)
```

```
131 AutoPtr<IObject> iobject;  
132 ECode ec = FindImportObject(mType, ipack, iobject);  
133 if (SUCCEEDED(ec)) {  
134     InterfaceID iid;  
135     ipack->GetInterfaceID(iid);  
136     object = iobject->Probe(iid);  
137     return NOERROR;  
138 }  
139  
140 AutoPtr<IStub> stub;  
141 ec = FindExportObject(mType, ipack, stub);  
142 if (SUCCEEDED(ec)) {  
143     CStub* stubObj = (CStub*)stub.Get();  
144     InterfaceID iid;  
145     ipack->GetInterfaceID(iid);  
146     object = stubObj->GetTarget()->Probe(iid);  
147     return NOERROR;  
148 }  
149  
150 AutoPtr<IProxy> proxy;  
151 ec = CoCreateProxy(ipack, mType, nullptr, proxy);  
152 if (FAILED(ec)) {  
153     Logger::E("CDBusChannel", "Unmarshal the interface in ReadInterface failed.");  
154     object = nullptr;  
155     return ec;  
156 }  
157  
158 RegisterImportObject(mType, ipack, IObject::Probe(proxy));  
159  
160 InterfaceID iid;  
161 ipack->GetInterfaceID(iid);  
162 object = proxy->Probe(iid);  
163 }
```

GetService中的obj哪里来的?

CoCreateProxy ()

❑ 源码: /como/como/runtime/rpc/comorpc.cpp

```
53 ECode CoCreateProxy(  
54     /* [in] */ IInterfacePack* ipack,  
55     /* [in] */ RPCType type,  
56     /* [in] */ IClassLoader* loader,  
57     /* [out] */ AutoPtr<IProxy>& proxy)  
58 {  
59     AutoPtr<IRPCChannelFactory> factory =  
60         type == RPCType::Local ? sLocalFactory : sRemoteFactory;  
61     AutoPtr<IRPCChannel> channel;  
62     ECode ec = factory->CreateChannel(RPCPeer::Proxy, channel);  
63     if (FAILED(ec)) {  
64         proxy = nullptr;  
65         return ec;  
66     }  
67     channel->Apply(ipack);  
68  
69     CoclassID cid;  
70     ipack->GetCoclassID(cid);  
71     return CProxy::CreateObject(cid, channel, loader, proxy);  
72 }
```

- 至此，一个假的C++对象就造出来了，它有虚表：sProxyVtable
- 元数据是通过Loader从本地装进来的

```
1674 ECode CProxy::CreateObject(  
1675     /* [in] */ const CoclassID& cid,  
1676     /* [in] */ IRPCChannel* channel,  
1677     /* [in] */ IClassLoader* loader,  
1678     /* [out] */ AutoPtr<IProxy>& proxy)  
1679 {  
1680     proxy = nullptr;  
1681  
1682     if (loader == nullptr) {  
1683         loader = CBootClassLoader::GetSystemClassLoader();  
1684     }  
1685  
1686     AutoPtr<IMetaCoclass> mc;  
1687     loader->LoadCoclass(cid, mc);
```

Obj给Client端源码的“假象”

InterfaceProxy是所有远程过来的Obj的“替身”

RPCTestUnit.cdl

```
como > test > runtime > rpc > component > Service.cdl
37     version(0.1.0)
38 ]
39 interface IService
40 {
41     TestMethod1(
42         [in] Integer arg1,
43         [out] Integer& result1);
44
45     TestMethod2(
46         [in] Integer arg1,
47         [in] Long arg2,
48         [in] Boolean arg3,
49         [in] Char arg4,
50         [in] Short arg5,
```

RPCTestUnit.h

```
74 INTERFACE_ID(afa187cf-8193-4786-8de7-b576c0bdb162)
75 interface IService
76 : public IInterface
77 {
78     using IInterface::Probe;
79
80     inline static IService* Probe(
81         /* [in] */ IInterface* object)
82     {
83         if (object == nullptr) {
84             return nullptr;
85         }
86         return (IService*)object->Probe(IID_IService);
87     }
88
89     inline static const InterfaceID& GetInterfaceID()
90     {
91         return IID_IService;
92     }
93
94     virtual como::ECode TestMethod1(
95         /* [in] */ Integer arg1,
96         /* [out] */ Integer& result1) = 0;
97
98     virtual como::ECode TestMethod2(
99         /* [in] */ Integer arg1,
100         /* [in] */ Long arg2,
101         /* [in] */ Boolean arg3,
102         /* [in] */ Char arg4,
103         /* [in] */ Short arg5,
104         /* [in] */ Double arg6,
```

- RPCTestUnit.h是COMO编译阶段cdlc生成的代码，“夹壁墙”

CProxy.h

替身

```
45 class InterfaceProxy
46 {
47 private:
48     struct Registers
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
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106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125 HANDLE* mVtable; // m
126 HANDLE mProxyEntry; // m
127 Integer mIndex;
128 InterfaceID mIid;
129 IMetaInterface* mTargetMe
130 CProxy* mOwner;
131 };
```

关于替身

Cproxy.cpp

CProxy.h

```
45  class InterfaceProxy
46  {
47  private:
48      struct Registers
```

```
225      HANDLE* mVtable;    // must be the first member
226      HANDLE mProxyEntry;  // must be the second member
227      Integer mIndex;
228      InterfaceID mIid;
229      IMetaInterface* mTargetMetadata;
230      CProxy* mOwner;
231  };
```

```
186  EXTERN_C void __entry();
187
188  __asm(
189      ".text;"
190      ".align 8;"
191      ".global __entry;"
192      "__entry:"
193      "pushq %rbp;"
194      "pushq %rdi;"
195      "subq $8, %rsp;"
196      "movl $0xff, (%rsp);"
197      "movq %rdi, %rax;"
198      "movq %rsp, %rdi;"
199      "call *8(%rax);"
200      "addq $8, %rsp;"
201      "popq %rdi;"
202      "popq %rbp;"
203      "ret;"
204  );
```

- 所有虚函数的入口是 __entry，然后 __entry 再执行 mProxyEntry 函数指针变量中的函数
- Init_Proxy_Entry() 构造了假的虚表

服务器端Server -- Stub

服务器端是真正实施COMO构件运行时服务的，也就是程序的逻辑功能是在这里执行的。

Server端注册服务对象

□ /como/como/test/runtime/rpc/service/main.cpp

```
17 #include "RPCTestUnit.h"
18 #include <comoapi.h>
19 #include <comosp.h>
20 #include <ServiceManager.h>
21 #include <cstdio>
22 #include <unistd.h>
23
24 using como::test::rpc::CService;
25 using como::test::rpc::IService;
26 using como::test::rpc::IID_IService;
27 using jing::ServiceManager;
28
29 int main(int argv, char** argc)
30 {
31     AutoPtr<IService> srv;
32     CService::New(IID_IService, (IInterface**)&srv);
33
34     ServiceManager::GetInstance()->AddService(String("rpcservice"), srv);
35
36     printf("==== rpc service wait for calling ====\n");
37     while (true) {
38         sleep(5);
39     }
40
41     return 0;
42 }
43
```

- COMO机制New出对象

□ RPCTestUnit.cpp

COMO的New与C++的new是不同的

```
44 // CService
45 ECode CService::New(
46     /* [in] */ const InterfaceID& iid,
47     /* [out] */ como::IInterface** object)
48 {
49     return CoCreateObjectInstance(CID_CService, iid, nullptr, object);
50 }
```

Server端注册服务对象

ServiceManager::AddService

□ /como/como/servicemanager/lib/linux/ServiceManager.cpp

```
30 ECode ServiceManager::AddService(  
31     /* [in] */ const String& name,  
32     /* [in] */ IInterface* object)  
33 {  
34     if (name.IsEmpty() || object == nullptr) {  
35         return E_ILLEGAL_ARGUMENT_EXCEPTION;  
36     }  
37  
38     AutoPtr<IInterfacePack> ipack;  
39     ECode ec = CoMarshalInterface(object, RPCType::Local, ipack);
```

- CDBusChannelFactory::MarshalInterface() 里, 创建了IStub,
- CoCreateStub() → CStub::CreateObject()

□ /como/como/como/runtime/rpc/dbus/CDBusChannelFactory.cpp

```
59 ECode CDBusChannelFactory::MarshalInterface(  
60     /* [in] */ IInterface* object,  
61     /* [out] */ AutoPtr<IInterfacePack>& ipack)
```

```
80 AutoPtr<IStub> stub;  
81 ECode ec = FindExportObject(mType, IObject::Probe(object), stub);  
82 if (SUCCEEDED(ec)) {  
83     CDBusChannel* channel = CDBusChannel::GetStubChannel(stub);  
84     pack->SetDBusName(channel->mName);  
85     pack->SetCoclassID(((CStub*)stub.Get())->GetTargetCoclassID());  
86 }  
87 else {  
88     IProxy* proxy = IProxy::Probe(object);  
89     if (proxy != nullptr) {  
90         CDBusChannel* channel = CDBusChannel::GetProxyChannel(proxy);  
91         pack->SetDBusName(channel->mName);  
92         pack->SetCoclassID(((CProxy*)proxy)->GetTargetCoclassID());  
93     }  
94     else {  
95         ec = CoCreateStub(object, mType, stub);  
96         if (FAILED(ec)) {  
97             Logger::E("CDBusChannel", "Marshal interface failed.");  
98             ipack = nullptr;  
99             return ec;  
100         }  
101         CDBusChannel* channel = CDBusChannel::GetStubChannel(stub);  
102         pack->SetDBusName(channel->mName);  
103         pack->SetCoclassID(((CStub*)stub.Get())->GetTargetCoclassID());  
104         RegisterExportObject(mType, IObject::Probe(object), stub);  
105     }  
106 }
```

Server端服务线程

CDBusChannel/CBinderChannel

□ /como/como/runtime/rpc/dbus/CDBusChannel.cpp

```
627 ECode CDBusChannel::StartListening(  
628     /* [in] */ IStub* stub)  
629 {  
630     ECode ec = NOERROR;  
631     if (mPeer == RPCPeer::Stub) {  
632         AutoPtr<ThreadPoolExecutor::Runnable> r = new ServiceRunnable(this, stub);  
633         ec = ThreadPoolExecutor::GetInstance()->RunTask(r);  
634     }  
635  
636     {  
637         Mutex::AutoLock lock(mLock);  
638         while (!mStarted) {  
639             mCond.Wait();  
640         }  
641     }  
642     return ec;  
643 }
```

- CDBusChannel::ServiceRunnable::HandleMessage负责执行具体的方法
- IStub *mTarget

```
178     ECode ec = thisObj->mTarget->Invoke(argParcel, resParcel);
```

- 服务提供者实现IRPCChannel接口
- CDBusChannel::ServiceRunnable::Run()
()除非资源耗尽，否则一直不退出，

```
33 ECode CDBusChannel::ServiceRunnable::Run()  
...  
80 }  
82 }  
84 }  
85 }  
86 }  
87 }  
88 }  
89 }  
90 }  
91 }  
92 }  
93 }  
94 }  
95 }  
96 }  
97 }  
98 }  
99 }  
100 }
```


Server端服务线程

CDBusChannel

□ /como/como/runtime/rpc/dbus/CDBusChannel.cpp

```
73 ECode ThreadPoolExecutor::RunTask(  
74     /* [in] */ Runnable* task)  
75 {  
76     AutoPtr<Worker> w = new Worker(task, this);  
77     {  
78         Mutex::AutoLock lock(w->mLock);  
79  
80         pthread_attr_t threadAttr;  
81         pthread_attr_init(&threadAttr);  
82         pthread_attr_setdetachstate(&threadAttr, PTHREAD_CREATE_DETACHED);  
83  
84         pthread_t thread;  
85         int ret = pthread_create(&thread, &threadAttr, ThreadPoolExecutor::ThreadEntry, (void*)w);  
86         if (ret != 0) {  
87             return E_RUNTIME_EXCEPTION;  
88         }
```

- ThreadPoolExecutor::GetInstance()->RunTask(r)在线程中，把任务w起来CDBusChannel::ServiceRunnable::Run()
- 直到线程中对mStarted赋值为真，CDBusChannel::StartListening才返回。

```
117 void* ThreadPoolExecutor::ThreadEntry(void* arg)  
118 {  
119     AutoPtr<Worker> w = (Worker*)arg;  
120     {  
121         Mutex::AutoLock lock(w->mLock);  
122         assert(w->mThread != 0);  
123     }  
124  
125     ECode ec = w->Run();
```

服务管理ServiceManager

服务管理是对所有远程COMO服务对象进行管理的进程。

服务管理ServiceManager

□ /como/como/servicemanager/exe/linux/main.cpp

```
17 #include "ServiceManager.h"
18 #include <comolog.h>
19 #include <dbus/dbus.h>
20 #include <cstdio>
21
22 using como::Logger;
23 using jing::ServiceManager;
24
25 int main(int argv, char** argc)
26 {
27     DBusError err;
28
29     dbus_error_init(&err);
30
31     DBusConnection* conn = dbus_bus_get_private(DBUS_BUS_SESSION, &err);
32     if (dbus_error_is_set(&err)) {
33         Logger::E("servicemanager", "Connect to bus daemon failed, error is \"%s\\\".",
34             err.message);
35         dbus_error_free(&err);
36         return -1;
37     }
38
39     dbus_bus_request_name(conn, ServiceManager::DBUS_NAME,
40         DBUS_NAME_FLAG_REPLACE_EXISTING, &err);
```

- AddService
- GetService
- RemoveService

D-Bus/IBinder RPC机制简介

D-Bus是一个进程间通信及远程过程调用机制，可以让多个不同的计算机程序在同一台电脑上同时进行通信。**D-Bus**作为**freedesktop.org**项目的一部分，其设计目的是使**Linux**桌面环境提供的服务标准化。

OpenBinder是用于进程间通信的系统。它由**Be Inc.**和**Palm, Inc.**开发，是**Google**开发的**Android**操作系统中现在使用的**Binder**框架的基础。

OpenBinder允许进程显示可由其他线程调用的接口。每个进程都维护一个线程池，该线程池可用于服务此类请求。