Sockets

Thomas Schwarz, SJ

Networking

- Networking is organized in layers:
 - Application: Access to network resources
 - Transport: Provides message and error delivery
 - Internet: Moves packets from source to destination through networks owned by different entities
 - Network Interface: How to move data between two machines / switches / routers

Networking

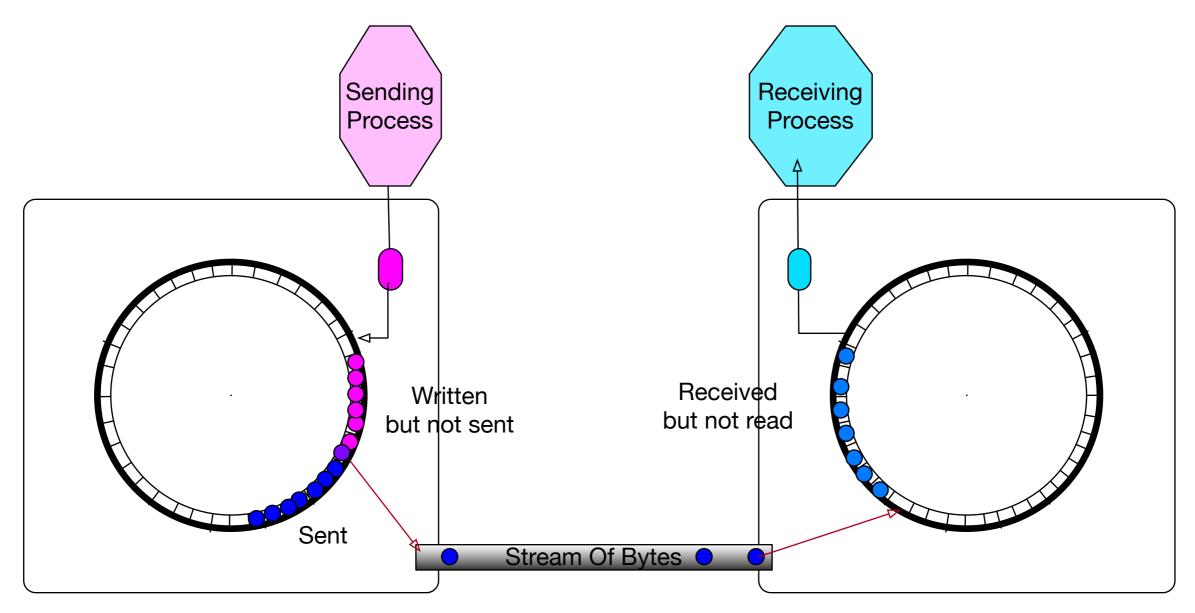
- Transport layer provides:
 - UDP: connectionless, unreliable, fast, datagrams
 - TCP: established connection with error resilience

Transmission Control Protocol: TCP

- Process-to-process communication
- Stream-oriented protocol
- Full duplex communication
- Connection oriented
- Reliable Service

Transmission Control Protocol: TCP

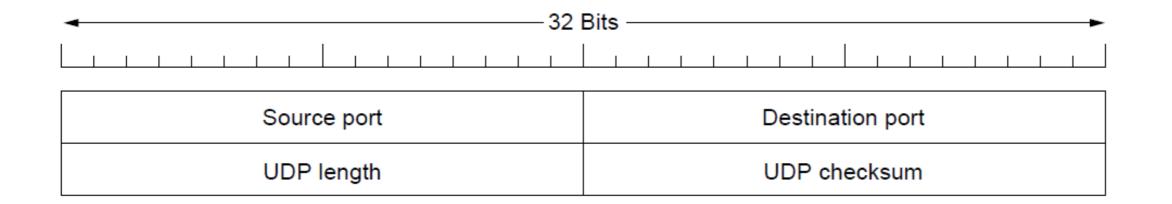
• TCP: Receives bytes to send from process and sends them reliably to the receiving process



UDP

- User Datagram Protocol (UDP)
 - Only adds socket addressing to the networking layer
 - Useful if you do not want the overhead of connection establishment and maintenance

UDP Header



Length: Includes the 8B UDP Checksum: Calculated from a pseudoheader (part of IP header) UDP header (without check -sum)

Data

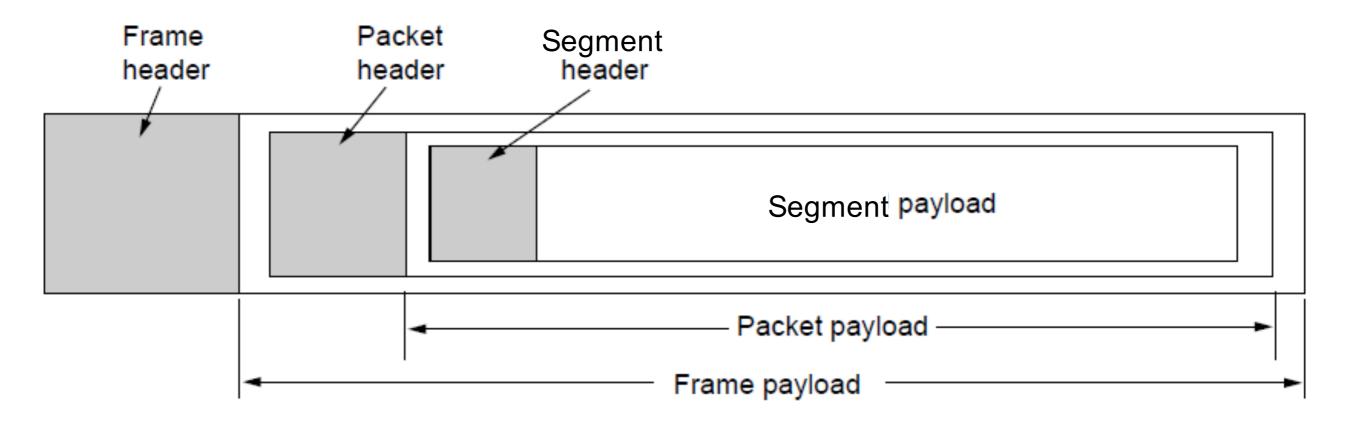
Transport Service Primitives

• Typical primitives provided to application programs

| Primitive | Packet sent | Meaning |
|------------|------------------------------|--|
| Listen | - | Block until some process tries to connect |
| Connect | Connection Request | Actively attempt to establish a connection |
| Send | Data | Send information |
| Receive | - | Block until a data packet arrives |
| Disconnect | Disconnection Request | Request a release of the connection |

Transport services provided to application layer

 Transport layer embeds segments in packets that are embedded in frames



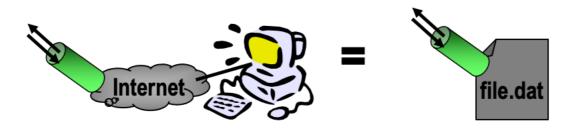
Berkeley Sockets

- Developed for Unix 4.2BSD (1983)
 - Still used for internet programming especially on Unix systems
 - Windows has winsock

| Primitive | Meaning | |
|-----------|---|--|
| SOCKET | Create a new communication end point | |
| BIND | Attach a local address to a socket | |
| LISTEN | Announce willingness to accept connections; give queue size | |
| ACCEPT | Block the caller until a connection attempt arrives | |
| CONNECT | Actively attempt to establish a connection | |
| SEND | Send some data over the connection | |
| RECEIVE | Receive some data from the connection | |
| CLOSE | Release the connection | |

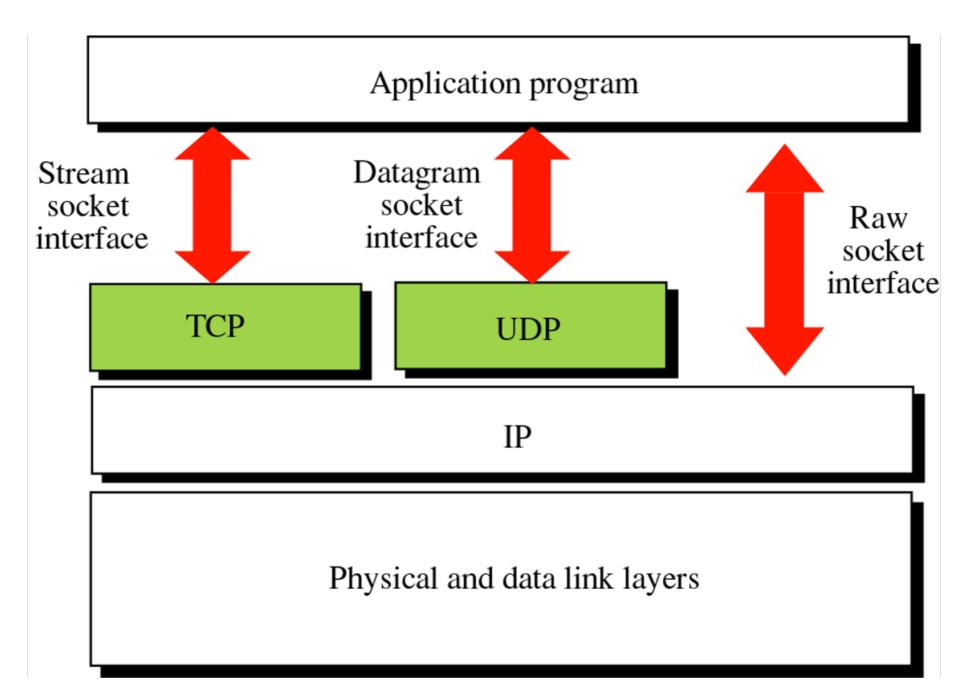
Berkeley Socket

- Basic Idea:
 - Network connection is like a file
 - Read from / Write to like to a file



- Socket procedures in Unix are systems calls
 - Implemented in the "top half" of the kernel
- Windows implemented as a library (DLL)

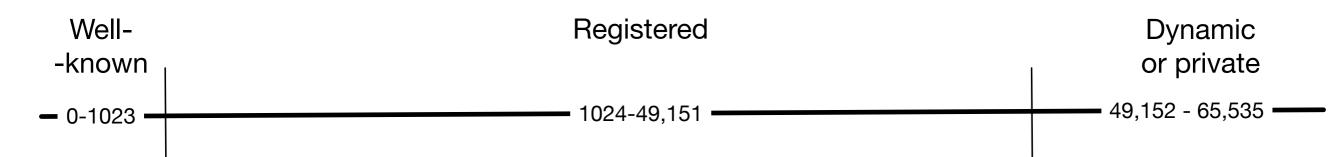
Berkeley Sockets



Transport Addresses

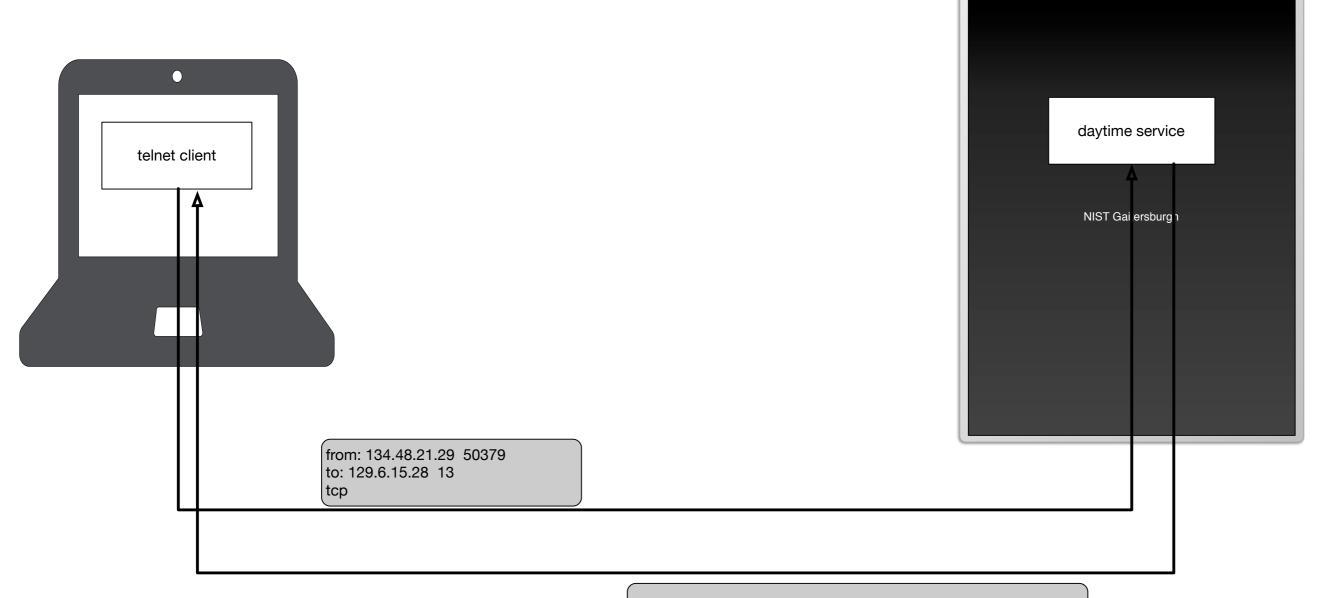
- Transport layer allows communications between processes
- Implemented via ports
 - Each host is identified by IP address
 - Each process is identified by a port number

- Internet Corporation for Assigned Names and Numbers (ICANN)
 - Well-known ports: Assigned by ICANN
 - Registered ports: Neither assigned nor controlled, but can be registered to prevent duplication
 - Dynamic ports: used as temporary or private port numbers



- Example:
 - telnet (needs to be installed on MacOS and Windows OS)
 - telnet 129.6.15.28 13
 - Connects to the daytime service at NIST Gaitersburg on port 13
- In MacOS / UNIX, you can find port assignments in
 - /etc/services

```
thomasschwarz — -bash — 80×24
Connected to time-a-g.nist.gov.
Escape character is '^]'.
58074 17-11-17 02:10:08 00 0 0 532.0 UTC(NIST) *
Connection closed by foreign host.
MSCSs-MacBook-Pro-2:~ thomasschwarz$ clear
MSCSs-MacBook-Pro-2:~ thomasschwarz$ telnet 129.6.15.28 13
Trying 129.6.15.28...
Connected to time-a-g.nist.gov.
Escape character is '^]'.
Connection closed by foreign host.
MSCSs-MacBook-Pro-2:~ thomasschwarz$ telnet 129.6.15.28 13
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MSCSs-MacBook-Pro-2:~ thomasschwarz$
```



from: 129.6.15.28 13 to: 134.48.21.29 50379 tcp, daytime service Daytime: \n58074 17-11-17 03:21:00 00 0 0 528.4 UTC(NIST) * \n

from: 134.48.21.29 50379 to: 129.6.15.28 13 tcp

- Destination address selects the server
- Destination port address selects the service (here day-time-server)
- Source address & port are needed to find the destination for the response

from: 129.6.15.28 13 to: 134.48.21.29 50379 tcp, daytime service Daytime: \n58074 17-11-17 03:21:00 00 0 0 528.4 UTC(NIST) * \n

| Last Login: Fri Nov 5 02:03:37 on trys000 thomasschwar2@Peter-Canisus ~ % cat /etc/services # Network services, Internet style # Network services, Internet style # Network services, Internet style # Network services, Internet style # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # Note that it is presently the policy of IANA to assign a # # The latest IANA port assignments/port-numbers # # http://www.iana.org/assignments/port-numbers # # http://www.iana.org/assignments/port-numbers # # The Namis cand/or Private Ports are those from 0 through 1023. # FreesESD: src/etc/services, v1.89 2002/12/17 23:59:10 eri # # FreesESD: src/etc/services, | | 0 | thomasschwarz — -zsh — 80×38 | | 0 | thomasschwarz — -zsh — 80×38 |
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| <pre># The Registered Ports are those from 1024 through 49151 # Mark Farlin <mfarlin@peerlogic.com> # The Dynamic and/or Private Ports are those from 49152 throceansoft-lm oceansoft-lm oceansoft-lm oceansoft-lm oceansoft-lm oceansoft-lm f* From: @(#)services 5.8 (Berkeley) 5/9/91 csdmbase 1467/udp # Ocean Software License Manager # From: @(#)services 5.8 (Berkeley) 5/9/91 csdmbase 1467/udp # CSDMBASE # From: @(#)services 5.8 (Berkeley) 5/9/91 csdmbase 1467/udp # CSDMBASE # WELL KNOWN PORT NUMBERS csdm 1468/udp # CSDMBASE # WELL KNOWN PORT NUMBERS csdm 1468/udp # CSDM # csdmbase csdm 1468/udp # CSDM csdm 1468/udp # CSDMBASE # well tropux 1/udp # TCP Port Service Multiplexer aal-lm 1469/udp # Active Analysis Limited License Manager mark Lottor <mkl@nisc.sri.com> # David Snocken +44 (71)437-7009 mark Lottor <mkl@nisc.sri.com> # David Snocken +44 (71)437-7009 mark Lottor <mkl@nisc.sri.com> # David Snocken +44 (71)437-7009 compressnet 2/udp # Management Utility uaiact 1470/udp # Universal Analytics compressnet 3/udp # Compression Process csdmbase 1471/udp # csdmbase compressnet 3/udp # Compression Process csdmbase 1471/udp # csdmbase # Aftip Unassigned # Robert Stabl <stabl@informatik.uni-muenchen.de> # 4/udp Unassigned # Robert Stabl <stabl@informatik.uni-muenchen.de> # 4/udp Unassigned # Robert Stabl <stabl@informatik.uni-muenchen.de> # 4/udp Unassigned # Robert Stabl <stabl@informatik.uni-muenchen.de> # Aftip Unassigned # Robert Stabl <stabl@informatik.uni-muenchen.de> #</stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></mkl@nisc.sri.com></mkl@nisc.sri.com></mkl@nisc.sri.com></mfarlin@peerlogic.com></pre> | # | _ . | | | | |
| <pre># The Dynamic and/or Private Ports are those from 49152 thr oceansoft-lm</pre> | | | - | | 1465/tcp | • |
| <pre># oceansoft-lm 1466/tcp # Ocean Software License Manager Randy Leonard <randy@oceansoft.com> # From: @(#)services 5.8 (Berkeley) 5/9/91 csdmbase 1467/tcp # CSDMBASE # From: @(#)services 5.8 (Berkeley) 5/9/91 csdmbase 1467/tcp # CSDMBASE # WELL KNOWN PORT NUMBERS csdm 1468/tcp # CSDM # csdmbase 1467/tcp # CSDMBASE # WELL KNOWN PORT NUMBERS csdm 1468/tcp # CSDM # rtmp 1/ddp # TCP Port Service Multiplexer aal-lm 1468/tcp # Active Analysis Limited License Manager tcpmux 1/dp # TCP Port Service Multiplexer aal-lm 1469/tcp # Active Analysis Limited License Manager tcpmux 1/tcp # TCP Port Service Multiplexer aal-lm 1469/tcp # Active Analysis Limited License Manager mark Lottor <mkl@nisc.sri.com> # David Snocken +44 (71)437-7009 mbp 2/ddp #Name Binding Protocol uaiact 1470/udp # Universal Analytics compressnet 2/tcp # Management Utility uaiact 1470/udp # Universal Analytics compressnet 3/udp # Compression Process csdmbase 1471/udp # csdmbase # Bernie Volz <volz@process.com> csdm 1472/tcp # csdm echo 4/ddp #AppleTalk Echo Protocol csdm 1472/tcp # csdm # 4/tcp Unassigned # Robert Stabl <stabl@informatik.uni-muenchen.de> # 4/tcp Unassigned # Robert Stabl <stabl@informatik.uni-muenchen.de> # 4/udp Unassign</stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></volz@process.com></mkl@nisc.sri.com></randy@oceansoft.com></pre> | - | | - | | 1466 / | · • |
| <pre># \$FreeBSD: src/etc/services,v 1.89 2002/12/17 23:59:10 eri# Randy Leonard <randy@oceansoft.com> # From: @(#)services 5.8 (Berkeley) 5/9/91 csdmbase csdmbase csdmbase csdmbase csdmbase csdmbase 1467/tcp # CSDMBASE # csdm 1467/tcp # CSDMBASE # csdm 1468/tdp # CSDMBASE # csdm 1468/tdp # CSDMBASE # csdm 1468/tdp # CSDMBASE # rtmp 1/ddp #Routing Table Maintenance Proto# Robert Stabl <stabl@informatik.uni=muenchen.de> tcpmux 1/tdp # TCP Port Service Multiplexer aal-lm 1469/tdp # Active Analysis Limited License Manager # mark Lottor <mkl@nisc.sri.com> # David Snocken +44 (71)437-7009 nbp 2/ddp #Name Binding Protocol uaiact 1470/tdp # Universal Analytics compressnet 2/tcp # Management Utility # Mark R. Ludwig <mark-ludwig@uai.com> compressnet 3/tdp # Compression Process csdmbase 1471/tdp # csdmbase compressnet 3/tdp # Compression Protocol csdm 1472/tcp # csdm echo 4/ddp #AppleTalk Echo Protocl csdm 1472/tcp # csdm # 4/tcp Unassigned # Robert Stabl <stabl@informatik.uni=muenchen.de> # Active Analysis Limited License Manager # Gamten Utility # Gamten Utility # Gamten # Compression Process csdmbase 1471/tdp # csdmbase compressnet 3/tdp # Compression Process csdmbase 1471/tcp # csdmbase # Gamten # Gobert Stabl <stabl@informatik.uni=muenchen.de> # A/tcp Unassigned # Robert Stabl <stabl@informatik.uni=muenchen.de> # Gamten # Gobert Stabl <stabl@informatik.uni=muenchen.de> # Gamten # Gamten</stabl@informatik.uni=muenchen.de></stabl@informatik.uni=muenchen.de></stabl@informatik.uni=muenchen.de></stabl@informatik.uni=muenchen.de></stabl@informatik.uni=muenchen.de></stabl@informatik.uni=muenchen.de></stabl@informatik.uni=muenchen.de></stabl@informatik.uni=muenchen.de></mark-ludwig@uai.com></mkl@nisc.sri.com></stabl@informatik.uni=muenchen.de></randy@oceansoft.com></pre> | • | nd/or Priv | ate Ports are those from 49152 th | | | - |
| #From: @(#)services5.8 (Berkeley) 5/9/91csdmbase csdmbase1467/udp# CSDMBASE#WELL KNOWN PORT NUMBERScsdm1467/udp# CSDMBASE#WELL KNOWN PORT NUMBERScsdm1468/udp# CSDM#I/ddp#Routing Table Maintenance Proto#Robert Stabl <stabl@informatik.uni-muenchen.de>tcpmux1/udp# TCP Port Service Multiplexer aal-lmaal-lm1469/udp# Active Analysis Limited License Managertcpmux1/udp# TCP Port Service Multiplexer Mark Lottor <mkl@nisc.sri.com>#David Snocken Mark Lottor <mkl@nisc.sri.com>#nbp2/ddp#Management Utilityuaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utility#Mark R. Ludwig@uai.com>compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbaseecho4/ddp#AppleTalk Echo Protocolcsdm1472/udp# csdmecho4/udpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassigned#Robert Stabl<tabl@informatik.uni-muenchen.de>#4/udpManagement Utility#Garth MarkMark.uni-muenchen.de>#4/udp#Robert Stabl<tabl@informatik.uni-muenchen.de>#4/udp#Robert Stabl<tabl@informatik.uni-muenchen.de>#4/udp#Garth Mayville@maplesoft.on.ca></tabl@informatik.uni-muenchen.de></tabl@informatik.uni-muenchen.de></tabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></mkl@nisc.sri.com></mkl@nisc.sri.com></stabl@informatik.uni-muenchen.de> | | | | | 1466/tcp | <u> </u> |
| #csdmbase1467/tcp# CSDMBASE# WELL KNOWN PORT NUMBERScsdm1468/udp# CSDM#1/ddp#Routing Table Maintenance Proto#Robert Stabl <stabl@informatik.uni-muenchen.de>tcpmux1/udp# TCP Port Service Multiplexer aal-lm1469/udp# Active Analysis Limited License Managertcpmux1/tcp# TCP Port Service Multiplexer aal-lm1469/udp# Active Analysis Limited License Manager#Mark Lottor <mkl@nisc.sri.com> #David Snocken +44 (71)437-7009nbp2/ddp# Management Utilityuaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilitywaict1470/udp# Universal Analyticscompressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdm1472/udp# csdmbase#Bernie Volz <volz@process.com>csdm1472/udp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/udp# csdm#4/ucpUnassigned#Robert Stabl @informatik.uni-muenchen.de>#4/udpUnassignedpenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/udp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></volz@process.com></mkl@nisc.sri.com></stabl@informatik.uni-muenchen.de> | | | - | | 4467 () | |
| # WELL KNOWN PORT NUMBERScsdm1468/udp# CSDM#.csdm1468/tcp# CSDMrtmp1/ddp#Routing Table Maintenance Proto#Robert Stabl <stabl@informatik.uni-muenchen.de>tcpmux1/udp# TCP Port Service Multiplexer aal-lm1469/udp# Active Analysis Limited License Managertcpmux1/tcp# TCP Port Service Multiplexer aal-lm1469/udp# Active Analysis Limited License Managertcpmux1/tcp# TCP Port Service Multiplexer aal-lm1469/udp# Active Analysis Limited License Managermbp2/ddp#Name Binding Protocoluaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet2/udp# Management Utility#Mark R. Ludwig <mark-ludwig@uai.com>compressnet3/udp# Compression Processcsdm1471/udp# csdmbasecompressnet3/udp# Compression Processcsdm1472/udp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/udp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassigned#Robert Stabl##4/udpUnassigned#Robert Stabl<stabl@informatik.uni-muenchen.de>#5/udp# Remote Job Entryopenmath1473/udp# OpenMathrje5/udp# Remote Job Entry#Garth Mayville <mayville@maplesoft< td=""><td># From:@</td><td>(#)service</td><td>s 5.8 (Berkeley) 5/9/91</td><td></td><td></td><td></td></mayville@maplesoft<></stabl@informatik.uni-muenchen.de></stabl@informatik.uni-muenchen.de></mark-ludwig@uai.com></stabl@informatik.uni-muenchen.de> | # From:@ | (#)service | s 5.8 (Berkeley) 5/9/91 | | | |
| #csdm1468/tcp# CSDMrtmp1/ddp#Routing Table Maintenance Proto#Robert Stabl <stabl@informatik.uni-muenchen.de>tcpmux1/udp# TCP Port Service Multiplexer aal-lm1469/udp# Active Analysis Limited License Managertcpmux1/tcp# TCP Port Service Multiplexer aal-lm1469/tcp# Active Analysis Limited License Manager#Mark Lottor <mkl@nisc.sri.com>#David Snocken +44 (71)437-7009nbp2/ddp# Management Utilityuaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/udp# Compression Processcsdmbase1472/udp# csdmbase#Bernie Volz <volz@process.com>csdm1472/udp# csdm#4/tcpUnassignedopenmath1473/udp# OpenMath#4/udpUnassignedopenmath1473/tcp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></volz@process.com></mkl@nisc.sri.com></stabl@informatik.uni-muenchen.de> | # | | | | | |
| Trtmp1/ddp#Routing Table Maintenance Proto#Robert Stabl <stabl@informatik.uni-muenchen.de>tcpmux1/udp# TCP Port Service Multiplexer aal-lm1469/udp# Active Analysis Limited License Managertcpmux1/tcp# TCP Port Service Multiplexer aal-lm1469/tcp# Active Analysis Limited License Manager#Mark Lottor <mkl@nisc.sri.com>#David Snocken +44 (71)437-7009nbp2/ddp#Name Binding Protocoluaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdmbase1471/tcp# csdmbase#Bernie Volz <volz@process.com>csdm1472/udp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/tcp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com></mkl@nisc.sri.com></stabl@informatik.uni-muenchen.de> | | ORT NUMBERS | | | | |
| tcpmux1/udp# TCP Port Service Multiplexeraal-lm1469/udp# Active Analysis Limited License Managertcpmux1/tcp# TCP Port Service Multiplexeraal-lm1469/tcp# Active Analysis Limited License Manager#Mark Lottor <mkl@nisc.sri.com>#David Snocken +44 (71)437-7009nbp2/ddp# Management Utilityuaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet2/tcp# Management Utility#Mark R. Ludwig <mark-ludwig@uai.com>compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdm1472/udp# csdmbase#Bernie Volz <volz@process.com>csdm1472/udp# csdm#4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/udpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com></mark-ludwig@uai.com></mkl@nisc.sri.com> | | | | | • | |
| tcpmux1/tcp# TCP Port Service Multiplexeraal-lm1469/tcp# Active Analysis Limited License Manager#Mark Lottor <mkl@nisc.sri.com>#David Snocken +44 (71)437-7009nbp2/ddp#Name Binding Protocoluaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet2/tcp# Management Utility#Mark R. Ludwig <mark-ludwig@uai.com>compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdm1472/udp# csdmbase#Bernie Volz <volz@process.com>csdm1472/tcp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com></mark-ludwig@uai.com></mkl@nisc.sri.com> | • | | | | | - |
| #Mark Lottor <mkl@nisc.sri.com>#David Snocken +44 (71)437-7009nbp2/ddp#Name Binding Protocoluaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet2/tcp# Management Utility#Mark R. Ludwig <mark-ludwig@uai.com>compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdm1472/udp# csdmgenneVolz <volz@process.com>csdm1472/tcp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com></mark-ludwig@uai.com></mkl@nisc.sri.com> | · · | • | | | • | |
| nbp2/ddp#Name Binding Protocoluaiact1470/udp# Universal Analyticscompressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet2/tcp# Management Utility#Mark R. Ludwig <mark-ludwig@uai.com>compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdmbase1471/tcp# csdmbasegenieVolz <volz@process.com>csdm1472/udp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com></mark-ludwig@uai.com> | • | 1/tcp | - | | 1469/100 | , , , , , , , , , , , , , , , , , , , |
| compressnet2/udp# Management Utilityuaiact1470/tcp# Universal Analyticscompressnet2/tcp# Management Utility#Mark R. Ludwig <mark-ludwig@uai.com>compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdmbase1471/tcp# csdmbasecompressnet3/tcp# Compression Processcsdm1472/udp# csdmbase#Bernie Volz <volz@process.com>csdm1472/tcp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com></mark-ludwig@uai.com> | | 2 ()) | - | | 1470 /uda | |
| compressnet2/tcp# Management Utility#Mark R. Ludwig <mark-ludwig@uai.com>compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdmbase1471/tcp# csdmbase#Bernie Volz <volz@process.com>csdm1472/udp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com></mark-ludwig@uai.com> | • | • | 5 | | • | |
| compressnet3/udp# Compression Processcsdmbase1471/udp# csdmbasecompressnet3/tcp# Compression Processcsdmbase1471/tcp# csdmbase#Bernie Volz <volz@process.com>csdm1472/udp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com> | • | - | 2 | | 1470/102 | - |
| compressnet3/tcp# Compression Processcsdmbase#Bernie Volz <volz@process.com>csdm1471/tcp# csdmbaseecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com> | • | | | | 1171 /uda | |
| #Bernie Volz <volz@process.com>csdm1472/udp# csdmecho4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de></volz@process.com> | • | • | • | | • | |
| echo4/ddp#AppleTalk Echo Protocolcsdm1472/tcp# csdm#4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de> | • | 3/тср | • | | • | |
| #4/tcpUnassigned#Robert Stabl <stabl@informatik.uni-muenchen.de>#4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca></stabl@informatik.uni-muenchen.de> | | A / al al a | - | | | |
| #4/udpUnassignedopenmath1473/udp# OpenMathrje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca> | | • | •• | | | |
| rje5/udp# Remote Job Entryopenmath1473/tcp# OpenMathrje5/tcp# Remote Job Entry#Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca> | | • | 5 | | | - |
| rje 5/tcp # Remote Job Entry # Garth Mayville <mayville@maplesoft.on.ca></mayville@maplesoft.on.ca> | | • | 5 | | • | • |
| | | • | - | # | 1475/tcp | • |
| # Jon Postel <postel@isi.edu> lelerinder 14/4/udp # Telerinder</postel@isi.edu> | | 5/TCP | | # tolofindor | 1474 /udo | |
| | # | | Joh Postet <postel@isi.edu></postel@isi.edu> | | 14/4/uup | |

Finding Open Ports

TCP *:62127 (LISTEN)

TCP *:7000 (LISTEN)

TCP *:7000 (LISTEN)

TCP *:5000 (LISTEN)

TCP *:5000 (LISTEN)

TCP localhost:27017 (LISTEN)

TCP localhost:49787 (LISTEN)

- To find open ports:
 - Can use a port scanner over the network that systematically tries out all ports
 - Can use systems tools
 - MacOS:

```
thomasschwarz@Peter-Canisius ~ % lsof -i -P | grep -i "listen"
rapportd
            527 thomasschwarz
                                5u IPv4 0xc604072814ca13a1
                                                                 0t0 TCP *:62127 (LISTEN)
            527 thomasschwarz
                                9u IPv6 0xc604072814573699
rapportd
                                                                 0t0
ControlCe 1666 thomasschwarz
                                12u IPv4 0xc604072801237e41
                                                                 0t0
ControlCe
         1666 thomasschwarz
                                13u IPv6 0xc6040727f7e8ad79
                                                                 0t0
ControlCe
          1666 thomasschwarz
                                16u IPv4 0xc6040727f968c381
                                                                  0t0
ControlCe
          1666 thomasschwarz
                                17u IPv6 0xc6040728037e4b39
                                                                  0t0
           1736 thomasschwarz
                                10u IPv4 0xc604072814a513a1
mongod
                                                                 0t0
Google
          62219 thomasschwarz
                              136u IPv4 0xc604072814c9fe41
                                                                  0+0
```

Finding Open Ports

- On Windows:
 - netstat
 - nbtstat

Socket Address

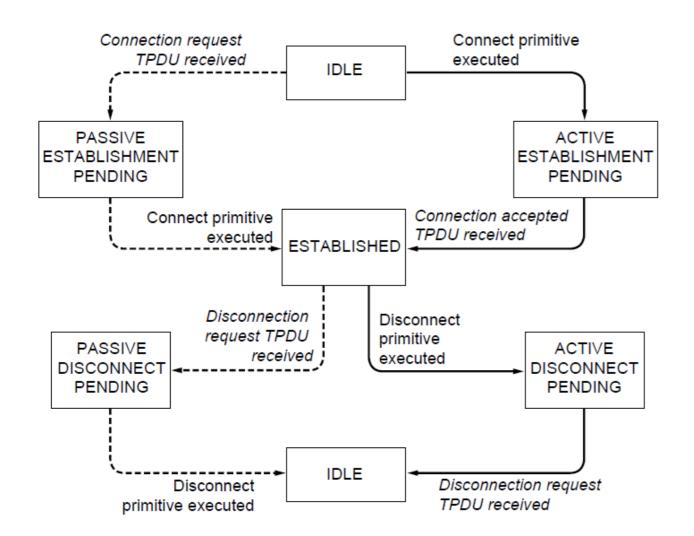
• The combination of IP address and port number is the socket address

Transport Service Primitives

- Primitives that applications might call to transport data for a simple connection-oriented service:
 - Client calls connect, send, receive, disconnect
 - Server calls listen, receive, send, disconnect

| Primitive | Segment <mark>sent</mark> | Meaning |
|------------|---------------------------|--|
| LISTEN | (none) | Block until some process tries to connect |
| CONNECT | CONNECTION REQ. | Actively attempt to establish a connection |
| SEND | DATA | Send information |
| RECEIVE | (none) | Block until a DATA packet arrives |
| DISCONNECT | DISCONNECTION REQ. | This side wants to release the connection |

Transport Service Primitives



Solid lines (right) show client state sequence

Dashed lines (left) show server state sequence

Transitions in italics are due to segment arrivals.

Addressing

- How does an application find port numbers?
 - Portmapper (which listens at a well known port)
 - User sends service name and gets port address
 - Services must register with the portmapper
 - Initial connection protocol
 - Each machine with services has a process server that acts as proxy for less heavily used servers
 - inetd on Unix systems
 - Listens to a range of ports waiting for connection requests
 - Process server spawns requested server (if necessary)