Computer Networks and Distributed Systems: RMI and UDP

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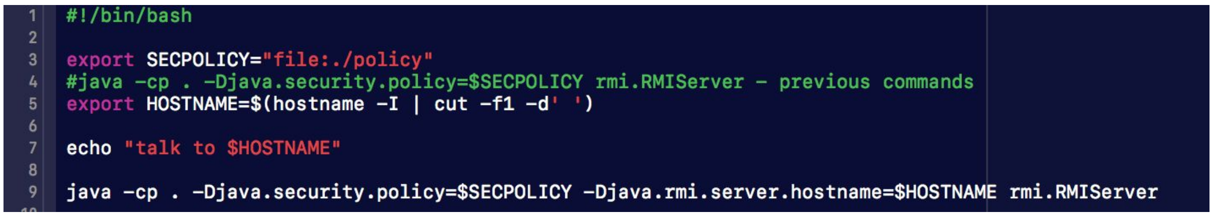
RMI Analysis

Having developed the client and server side sources files, these were then compiled on separate and distant computers in the EE labs. In order for them to be run, a modification had to be made to the server side executable (rmiserver.sh) as the security policy was different from the one designed for the DoC labs. Below is a screenshot of the new bash script:



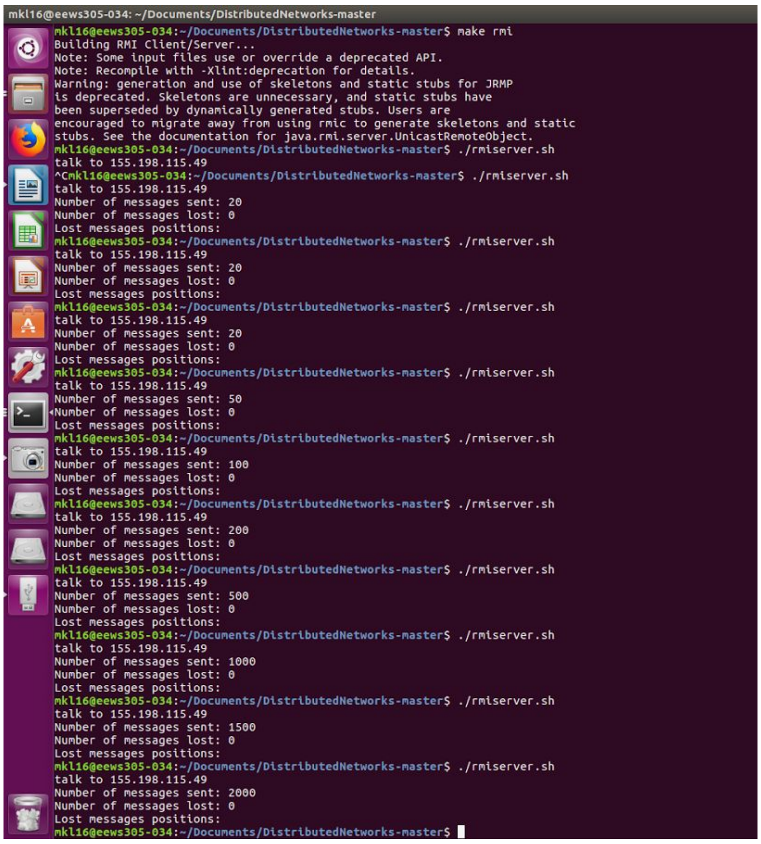
```bash
#!/bin/bash

export SECPOLICY="file:./policy"
#java -cp . -Djava.security.policy=$SECPOLICY rmi.RMIServer - previous commands
export HOSTNAME=$(hostname -I | cut -f1 -d' ')

echo "talk to $HOSTNAME"

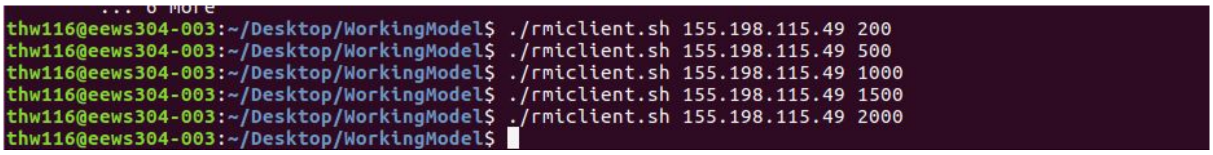
java -cp . -Djava.security.policy=$SECPOLICY -Djava.rmi.server.hostname=$HOSTNAME rmi.RMIServer
```

This allowed the programs to run successfully. The below shows the terminal output of the results from the computer running the RMI Server. The IP Address was found by using the command "ifconfig" command. Each test sent increasing numbers of messages [20, 50, 100, 200, 500, 1000, 1500, 2000.] The outputs written to the command line stem from a printResult function created in the server file (Appedix: RMI Server.) As you can seen, no messages were dropped at any point of the testing. The latency between the sending and receiving of the messages was also minimal.



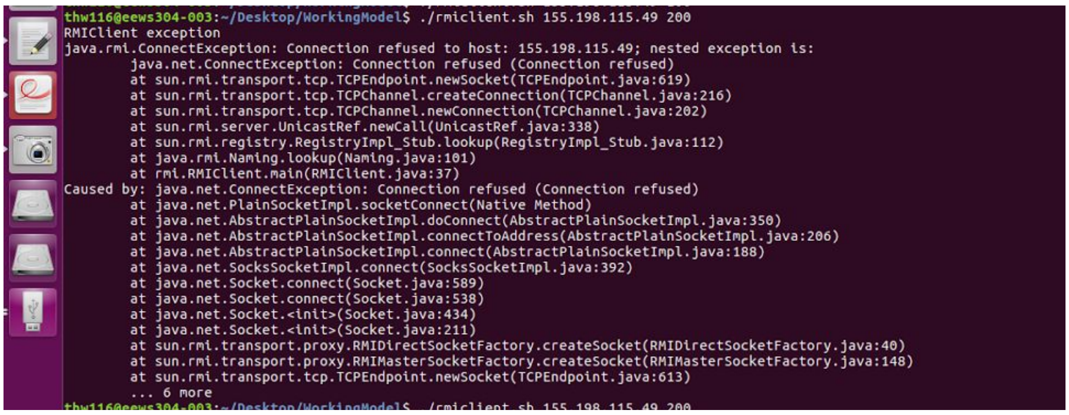
```
mkl16@eews305-034: ~/Documents/DistributedNetworks-master
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ make rmi
Building RMI Client/Server...
Note: Some input files use or override a deprecated API.
Note: Recompile with -Xlint:deprecation for details.
Warning: generation and use of skeletons and static stubs for JRMP
is deprecated. Skeletons are unnecessary, and static stubs have
been superseded by dynamically generated stubs. Users are
encouraged to migrate away from using rmic to generate skeletons and static
stubs. See the documentation for java.rmi.server.UnicastRemoteObject.
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
^Cmkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 20
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 20
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 20
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 50
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 100
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 200
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 500
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 1000
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 1500
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$ ./rmiserver.sh
talk to 155.198.115.49
Number of messages sent: 2000
Number of messages lost: 0
Lost messages positions:
mkl16@eews305-034:~/Documents/DistributedNetworks-master$
```

Below is an extract from the terminal outputs from the client side. The first argument is the IP Address and the second is the number of messages to be sent.



```
thw116@eews304-003:~/Desktop/WorkingModel$ ./rmiclient.sh 155.198.115.49 200
thw116@eews304-003:~/Desktop/WorkingModel$ ./rmiclient.sh 155.198.115.49 500
thw116@eews304-003:~/Desktop/WorkingModel$ ./rmiclient.sh 155.198.115.49 1000
thw116@eews304-003:~/Desktop/WorkingModel$ ./rmiclient.sh 155.198.115.49 1500
thw116@eews304-003:~/Desktop/WorkingModel$ ./rmiclient.sh 155.198.115.49 2000
thw116@eews304-003:~/Desktop/WorkingModel$ 
```

We did experience a marshalling exception on client side after the message sending and print out on server side had been completed. This was due to the our system.exit(0) command within printResult, which caused client side to exit early. We decided to keep this functionality as the results on server side would not be affected.

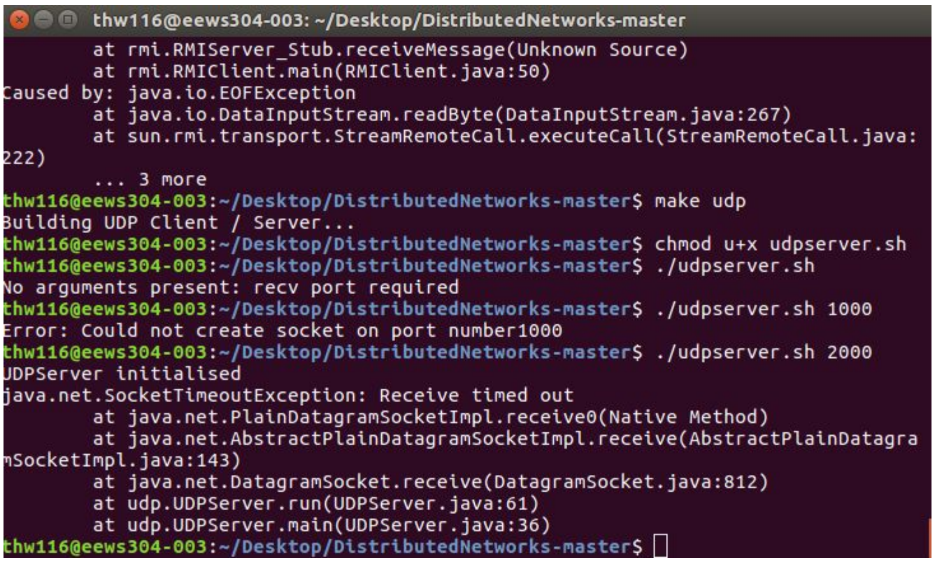


```
thw116@eews304-003:~/Desktop/WorkingModel$ ./rmiclient.sh 155.198.115.49 200
RMIClient exception
java.rmi.ConnectException: Connection refused to host: 155.198.115.49; nested exception is:
        java.net.ConnectException: Connection refused (Connection refused)
        at sun.rmi.transport.tcp.TCPEndpoint.newSocket(TCPEndpoint.java:619)
        at sun.rmi.transport.tcp.TCPChannel.createConnection(TCPChannel.java:216)
        at sun.rmi.transport.tcp.TCPChannel.newConnection(TCPChannel.java:202)
        at sun.rmi.server.UnicastRef.newCall(UnicastRef.java:338)
        at sun.rmi.registry.RegistryImpl_Stub.lookup(RegistryImpl_Stub.java:112)
        at java.rmi.Naming.lookup(Naming.java:101)
        at rmi.RMIClient.main(RMIClient.java:37)
Caused by: java.net.ConnectException: Connection refused (Connection refused)
        at java.net.PlainSocketImpl.socketConnect(Native Method)
        at java.net.AbstractPlainSocketImpl.doConnect(AbstractPlainSocketImpl.java:350)
        at java.net.AbstractPlainSocketImpl.connectToAddress(AbstractPlainSocketImpl.java:206)
        at java.net.AbstractPlainSocketImpl.connect(AbstractPlainSocketImpl.java:188)
        at java.net.SocksSocketImpl.connect(SocksSocketImpl.java:392)
        at java.net.Socket.connect(Socket.java:589)
        at java.net.Socket.connect(Socket.java:538)
        at java.net.Socket.<init>(Socket.java:434)
        at java.net.Socket.<init>(Socket.java:211)
        at sun.rmi.transport.proxy.RMIDirectSocketFactory.createSocket(RMIDirectSocketFactory.java:40)
        at sun.rmi.transport.proxy.RMIMasterSocketFactory.createSocket(RMIMasterSocketFactory.java:148)
        at sun.rmi.transport.tcp.TCPEndpoint.newSocket(TCPEndpoint.java:613)
        ... 6 more
thw116@eews304-003:~/Desktop/WorkingModel$ ./rmiclient.sh 155.198.115.49 200
```

Occasionally, we failed to initialise the server before the client. Although this meant the process failed, it demonstrated that our exceptions were catching the fact that the connection was refused and that e.printStackTrace was functioning. This can be seen in the screenshot above.

UDP Analysis

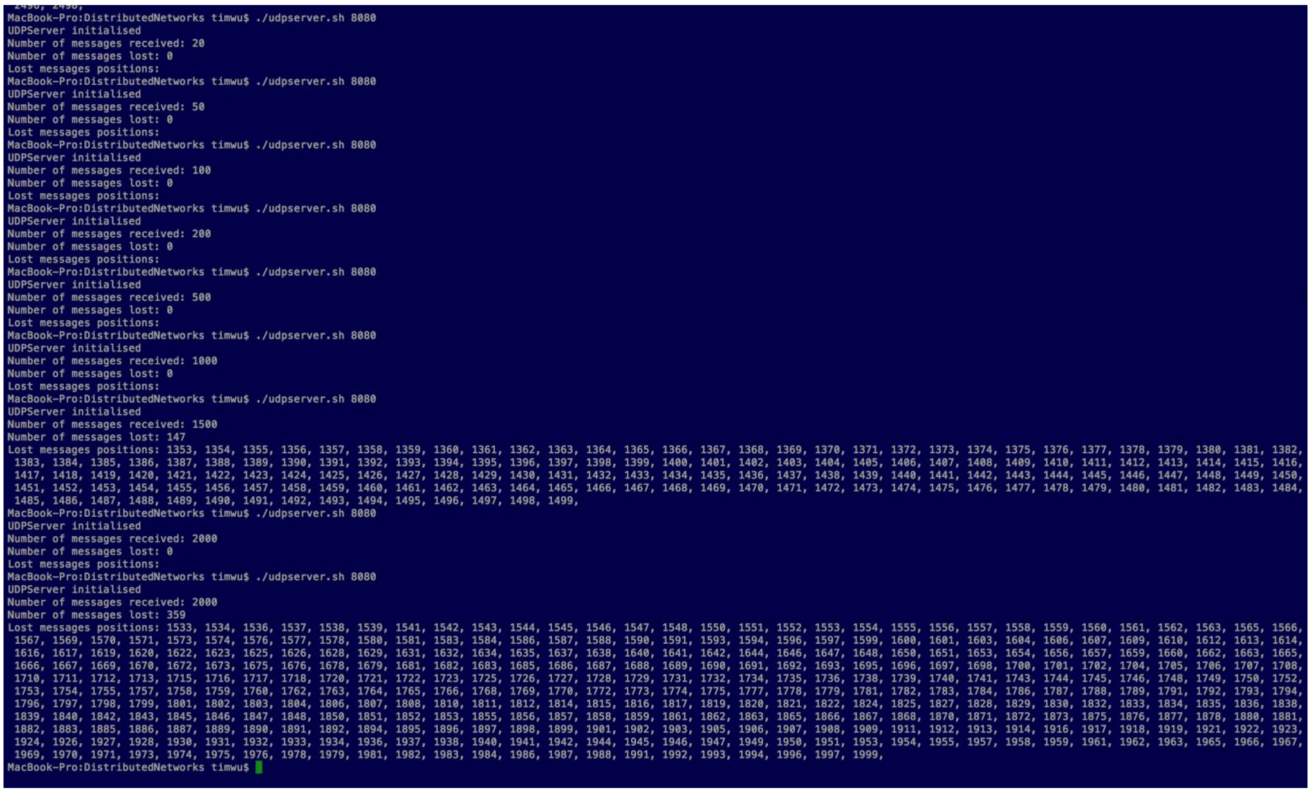
Following the same methods as the RMI testing, we begun testing with the UDP.



```
thw116@eews304-003: ~/Desktop/DistributedNetworks-master
        at rmi.RMIServer_Stub.receiveMessage(Unknown Source)
        at rmi.RMIClient.main(RMIClient.java:50)
Caused by: java.io.EOFException
        at java.io.DataInputStream.readByte(DataInputStream.java:267)
        at sun.rmi.transport.StreamRemoteCall.executeCall(StreamRemoteCall.java:
222)
        ... 3 more
thw116@eews304-003:~/Desktop/DistributedNetworks-master$ make udp
Building UDP Client / Server...
thw116@eews304-003:~/Desktop/DistributedNetworks-master$ chmod u+x udpserver.sh
thw116@eews304-003:~/Desktop/DistributedNetworks-master$ ./udpserver.sh
No arguments present: recv port required
thw116@eews304-003:~/Desktop/DistributedNetworks-master$ ./udpserver.sh 1000
Error: Could not create socket on port number1000
thw116@eews304-003:~/Desktop/DistributedNetworks-master$ ./udpserver.sh 2000
UDPServer initialised
java.net.SocketTimeoutException: Receive timed out
        at java.net.PlainDatagramSocketImpl.receive0(Native Method)
        at java.net.AbstractPlainDatagramSocketImpl.receive(AbstractPlainDatagra
mSocketImpl.java:143)
        at java.net.DatagramSocket.receive(DatagramSocket.java:812)
        at udp.UDPServer.run(UDPServer.java:61)
        at udp.UDPServer.main(UDPServer.java:36)
thw116@eews304-003:~/Desktop/DistributedNetworks-master$ 
```

The above shows the terminal output on the UDP server during the first viable run. We had incorrectly declared an out of bounds port number initially so there was a failure to create the socket. After another attempt, we achieved success, as indicated by the system print out of "USPServer initialised." We then left this on for 30 seconds to test the socket timeout we had implemented. This can be shown to be working as well, with the timeout outputted to terminal via a stack trace print.

The below shows the terminal output of the results from the computer running the UDP Server. Each test sent increasing numbers of messages [20, 50, 100, 200, 500, 1000, 1500, 2000.] The outputs written to the command line stem from a printResult function created in the server file (Appedix: RMI Server.)

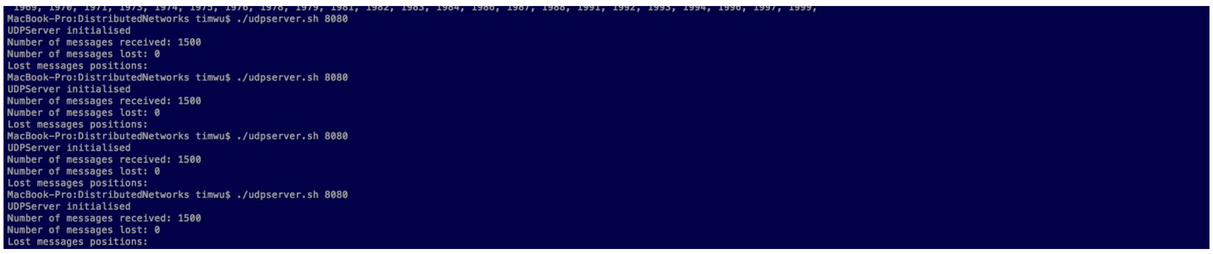


```
 2496, 2498,
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 20
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 50
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 100
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 200
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 500
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 1000
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 1500
Number of messages lost: 147
Lost messages positions: 1353, 1354, 1355, 1356, 1357, 1358, 1359, 1360, 1361, 1362, 1363, 1364, 1365, 1366, 1367, 1368, 1369, 1370, 1371, 1372, 1373, 1374, 1375, 1376, 1377, 1378, 1379, 1380, 1381, 1382,
 1383, 1384, 1385, 1386, 1387, 1388, 1389, 1390, 1391, 1392, 1393, 1394, 1395, 1396, 1397, 1398, 1399, 1400, 1401, 1402, 1403, 1404, 1405, 1406, 1407, 1408, 1409, 1410, 1411, 1412, 1413, 1414, 1415, 1416,
 1417, 1418, 1419, 1420, 1421, 1422, 1423, 1424, 1425, 1426, 1427, 1428, 1429, 1430, 1431, 1432, 1433, 1434, 1435, 1436, 1437, 1438, 1439, 1440, 1441, 1442, 1443, 1444, 1445, 1446, 1447, 1448, 1449, 1450,
 1451, 1452, 1453, 1454, 1455, 1456, 1457, 1458, 1459, 1460, 1461, 1462, 1463, 1464, 1465, 1466, 1467, 1468, 1469, 1470, 1471, 1472, 1473, 1474, 1475, 1476, 1477, 1478, 1479, 1480, 1481, 1482, 1483, 1484,
 1485, 1486, 1487, 1488, 1489, 1490, 1491, 1492, 1493, 1494, 1495, 1496, 1497, 1498, 1499,
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 2000
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 2000
Number of messages lost: 359
Lost messages positions: 1533, 1534, 1536, 1537, 1538, 1539, 1541, 1542, 1543, 1544, 1545, 1546, 1547, 1548, 1550, 1551, 1552, 1553, 1554, 1555, 1556, 1557, 1558, 1559, 1560, 1561, 1562, 1563, 1565, 1566,
 1567, 1569, 1570, 1571, 1573, 1574, 1576, 1577, 1578, 1580, 1581, 1583, 1584, 1586, 1587, 1588, 1590, 1591, 1593, 1594, 1596, 1597, 1599, 1600, 1601, 1603, 1604, 1606, 1607, 1609, 1610, 1612, 1613, 1614,
 1616, 1617, 1619, 1620, 1622, 1623, 1625, 1626, 1628, 1629, 1631, 1632, 1634, 1635, 1637, 1638, 1640, 1641, 1642, 1644, 1646, 1647, 1648, 1650, 1651, 1653, 1654, 1656, 1657, 1659, 1660, 1662, 1663, 1665,
 1666, 1667, 1669, 1670, 1672, 1673, 1675, 1676, 1678, 1679, 1681, 1682, 1683, 1685, 1686, 1687, 1688, 1689, 1690, 1691, 1692, 1693, 1695, 1696, 1697, 1698, 1700, 1701, 1702, 1704, 1705, 1706, 1707, 1708,
 1710, 1711, 1712, 1713, 1715, 1716, 1717, 1718, 1720, 1721, 1722, 1723, 1725, 1726, 1727, 1728, 1729, 1731, 1732, 1734, 1735, 1736, 1738, 1739, 1740, 1741, 1743, 1744, 1745, 1746, 1748, 1749, 1750, 1752,
 1753, 1754, 1755, 1757, 1758, 1759, 1760, 1762, 1763, 1764, 1765, 1766, 1768, 1769, 1770, 1772, 1773, 1774, 1775, 1777, 1778, 1779, 1781, 1782, 1783, 1784, 1786, 1787, 1788, 1789, 1791, 1792, 1793, 1794,
 1796, 1797, 1798, 1799, 1801, 1802, 1803, 1804, 1806, 1807, 1808, 1810, 1811, 1812, 1814, 1815, 1816, 1817, 1819, 1820, 1821, 1822, 1824, 1825, 1827, 1828, 1829, 1830, 1832, 1833, 1834, 1835, 1836, 1838,
 1839, 1840, 1842, 1843, 1845, 1846, 1847, 1848, 1850, 1851, 1852, 1853, 1855, 1856, 1857, 1858, 1859, 1861, 1862, 1863, 1865, 1866, 1867, 1868, 1870, 1871, 1872, 1873, 1875, 1876, 1877, 1878, 1880, 1881,
 1882, 1883, 1885, 1886, 1887, 1889, 1890, 1891, 1892, 1894, 1895, 1896, 1897, 1898, 1899, 1901, 1902, 1903, 1905, 1906, 1907, 1908, 1909, 1911, 1912, 1913, 1914, 1916, 1917, 1918, 1919, 1921, 1922, 1923,
 1924, 1926, 1927, 1928, 1930, 1931, 1932, 1933, 1934, 1936, 1937, 1938, 1940, 1941, 1942, 1944, 1945, 1946, 1947, 1949, 1950, 1951, 1953, 1954, 1955, 1957, 1958, 1959, 1961, 1962, 1963, 1965, 1966, 1967,
 1969, 1970, 1971, 1973, 1974, 1975, 1976, 1978, 1979, 1981, 1982, 1983, 1984, 1986, 1987, 1988, 1991, 1992, 1993, 1994, 1996, 1997, 1999,
MacBook-Pro:DistributedNetworks timwu$ 
```

As can be seen from the picture, at 1500 messages+, UDP began to lose messages. Surprisingly, the initial run of 2000 messages was entirely successful. However, another run demonstrated that there was also the possibility that it would lose messages at that level. The position of the messages lost are also printed in the screenshot.

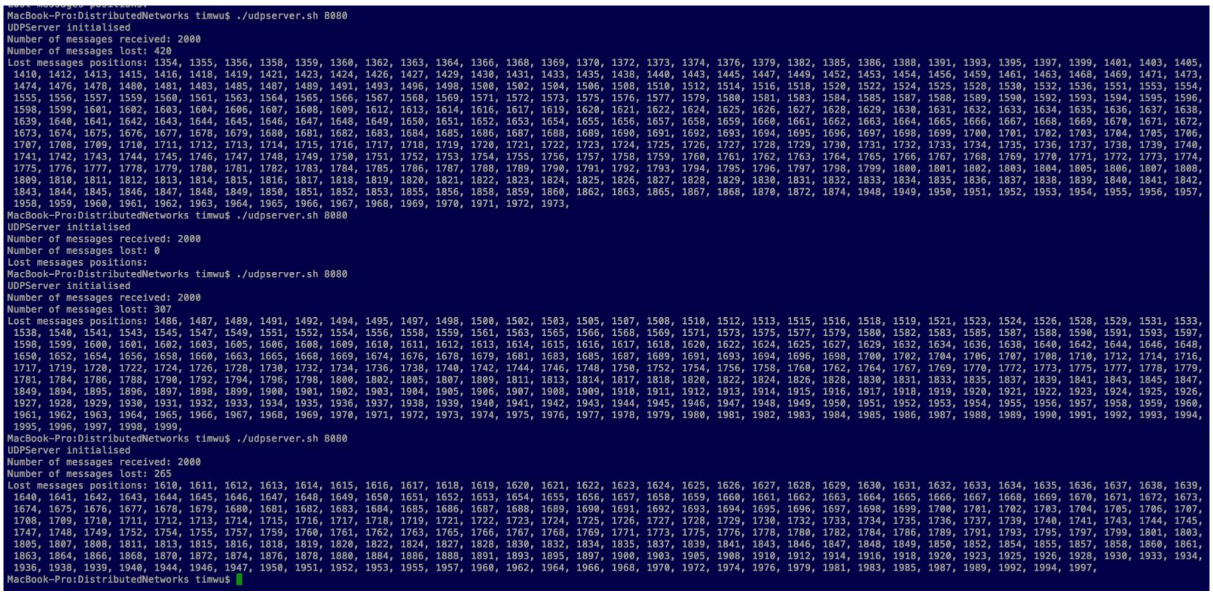
Out of curiosity, we decided to repeat a few tests with 1500+ messages and explore past the 2000 message limit. The results are shown below:

1500 messages



```
 1969, 1970, 1971, 1973, 1974, 1975, 1976, 1978, 1979, 1981, 1982, 1983, 1984, 1986, 1987, 1988, 1991, 1992, 1993, 1994, 1996, 1997, 1999,
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 1500
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 1500
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 1500
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 1500
Number of messages lost: 0
Lost messages positions:
```

2000 messages



```
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 2000
Number of messages lost: 420
Lost messages positions: 1354, 1355, 1356, 1358, 1359, 1360, 1362, 1363, 1364, 1366, 1368, 1369, 1370, 1372, 1373, 1374, 1376, 1379, 1382, 1385, 1386, 1388, 1391, 1393, 1395, 1397, 1399, 1401, 1403, 1405,
 1410, 1412, 1413, 1415, 1416, 1418, 1419, 1421, 1423, 1424, 1426, 1427, 1429, 1430, 1431, 1433, 1435, 1438, 1440, 1443, 1445, 1447, 1449, 1452, 1453, 1454, 1456, 1459, 1461, 1463, 1468, 1469, 1471, 1473,
 1474, 1476, 1478, 1480, 1481, 1483, 1485, 1487, 1489, 1491, 1493, 1496, 1498, 1500, 1502, 1504, 1506, 1508, 1510, 1512, 1514, 1516, 1518, 1520, 1522, 1524, 1525, 1528, 1530, 1532, 1536, 1551, 1553, 1554,
 1555, 1556, 1557, 1559, 1560, 1561, 1563, 1564, 1565, 1566, 1567, 1568, 1569, 1571, 1572, 1573, 1575, 1576, 1577, 1579, 1580, 1581, 1583, 1584, 1585, 1587, 1588, 1589, 1590, 1592, 1593, 1594, 1595, 1596,
 1598, 1599, 1601, 1602, 1603, 1604, 1606, 1607, 1608, 1609, 1612, 1613, 1614, 1616, 1617, 1619, 1620, 1621, 1622, 1624, 1625, 1626, 1627, 1628, 1629, 1630, 1631, 1632, 1633, 1634, 1635, 1636, 1637, 1638,
 1639, 1640, 1641, 1642, 1643, 1644, 1645, 1646, 1647, 1648, 1649, 1650, 1651, 1652, 1653, 1654, 1655, 1656, 1657, 1658, 1659, 1660, 1661, 1662, 1663, 1664, 1665, 1666, 1667, 1668, 1669, 1670, 1671, 1672,
 1673, 1674, 1675, 1676, 1677, 1678, 1679, 1680, 1681, 1682, 1683, 1684, 1685, 1686, 1687, 1688, 1689, 1690, 1691, 1692, 1693, 1694, 1695, 1696, 1697, 1698, 1699, 1700, 1701, 1702, 1703, 1704, 1705, 1706,
 1707, 1708, 1709, 1710, 1711, 1712, 1713, 1714, 1715, 1716, 1717, 1718, 1719, 1720, 1721, 1722, 1723, 1724, 1725, 1726, 1727, 1728, 1729, 1730, 1731, 1732, 1733, 1734, 1735, 1736, 1737, 1738, 1739, 1740,
 1741, 1742, 1743, 1744, 1745, 1746, 1747, 1748, 1749, 1750, 1751, 1752, 1753, 1754, 1755, 1756, 1757, 1758, 1759, 1760, 1761, 1762, 1763, 1764, 1765, 1766, 1767, 1768, 1769, 1770, 1771, 1772, 1773, 1774,
 1775, 1776, 1777, 1778, 1779, 1780, 1781, 1782, 1783, 1784, 1785, 1786, 1787, 1788, 1789, 1790, 1791, 1792, 1793, 1794, 1795, 1796, 1797, 1798, 1799, 1800, 1801, 1802, 1803, 1804, 1805, 1806, 1807, 1808,
 1809, 1810, 1811, 1812, 1813, 1814, 1815, 1816, 1817, 1818, 1819, 1820, 1821, 1822, 1823, 1824, 1825, 1826, 1827, 1828, 1829, 1830, 1831, 1832, 1833, 1834, 1835, 1836, 1837, 1838, 1839, 1840, 1841, 1842,
 1843, 1844, 1845, 1846, 1847, 1848, 1849, 1850, 1851, 1852, 1853, 1855, 1856, 1858, 1859, 1860, 1862, 1863, 1865, 1867, 1868, 1870, 1872, 1874, 1948, 1949, 1950, 1951, 1952, 1953, 1954, 1955, 1956, 1957,
 1958, 1959, 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973,
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 2000
Number of messages lost: 0
Lost messages positions:
MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 2000
Number of messages lost: 307
Lost messages positions: 1486, 1487, 1489, 1491, 1492, 1494, 1495, 1497, 1498, 1500, 1502, 1503, 1505, 1507, 1508, 1510, 1512, 1513, 1515, 1516, 1518, 1519, 1521, 1523, 1524, 1526, 1528, 1529, 1531, 1533,
 1538, 1540, 1541, 1543, 1545, 1547, 1549, 1551, 1552, 1554, 1556, 1558, 1559, 1561, 1563, 1565, 1566, 1568, 1569, 1571, 1573, 1575, 1577, 1579, 1580, 1582, 1583, 1585, 1587, 1588, 1590, 1591, 1593, 1597,
 1598, 1599, 1600, 1601, 1602, 1603, 1605, 1606, 1608, 1609, 1610, 1611, 1612, 1613, 1614, 1615, 1616, 1617, 1618, 1620, 1622, 1624, 1625, 1627, 1629, 1632, 1634, 1636, 1638, 1640, 1642, 1644, 1646, 1648,
 1650, 1652, 1654, 1656, 1658, 1660, 1663, 1665, 1668, 1669, 1674, 1676, 1678, 1679, 1681, 1683, 1685, 1687, 1689, 1691, 1693, 1694, 1696, 1698, 1700, 1702, 1704, 1706, 1707, 1708, 1710, 1712, 1714, 1716,
 1717, 1719, 1720, 1722, 1724, 1726, 1728, 1730, 1732, 1734, 1736, 1738, 1740, 1742, 1744, 1746, 1748, 1750, 1752, 1754, 1756, 1758, 1760, 1762, 1764, 1767, 1769, 1770, 1772, 1773, 1775, 1777, 1778, 1779,
 1781, 1784, 1786, 1788, 1790, 1792, 1794, 1796, 1798, 1800, 1802, 1805, 1807, 1809, 1811, 1813, 1814, 1817, 1818, 1820, 1822, 1824, 1826, 1828, 1830, 1831, 1833, 1835, 1837, 1839, 1841, 1843, 1845, 1847,
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 1927, 1928, 1929, 1930, 1931, 1932, 1933, 1934, 1935, 1936, 1937, 1938, 1939, 1940, 1941, 1942, 1943, 1944, 1945, 1946, 1947, 1948, 1949, 1950, 1951, 1952, 1953, 1954, 1955, 1956, 1957, 1958, 1959, 1960,
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Number of messages received: 2000
Number of messages lost: 265
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MacBook-Pro:DistributedNetworks timwu$
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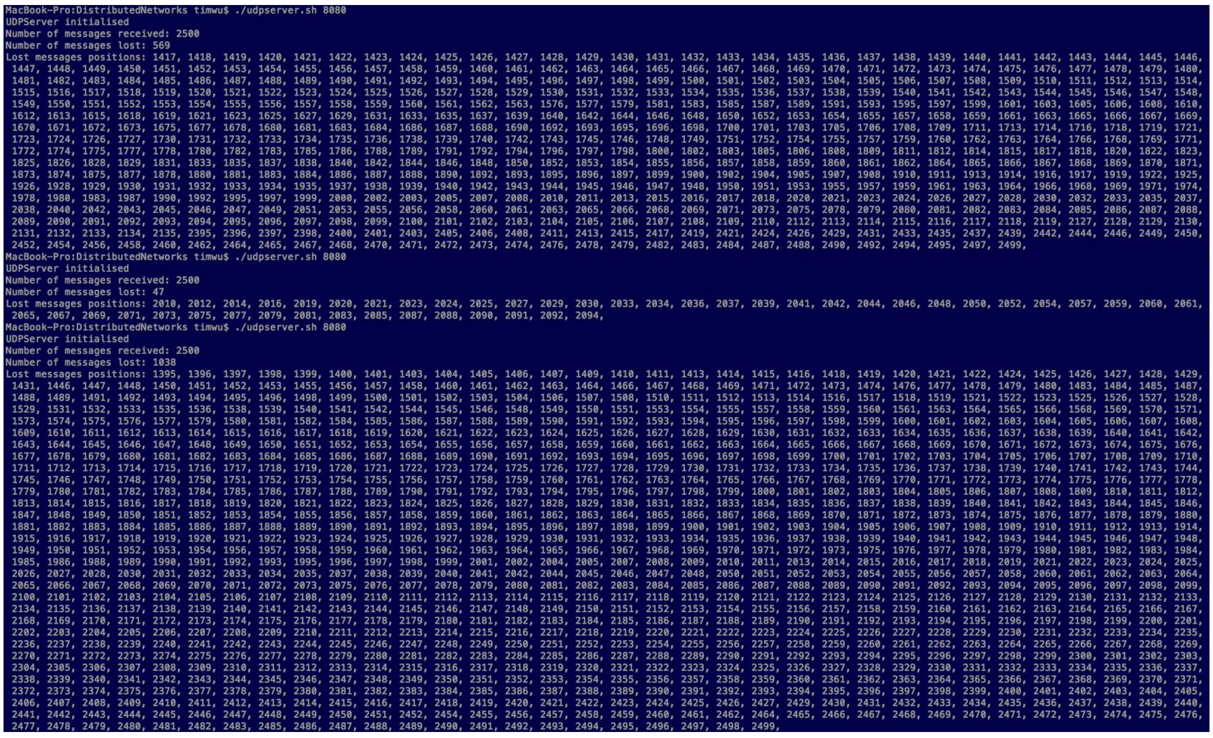
A few examples from 2500 messages



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MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
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Number of messages lost: 569
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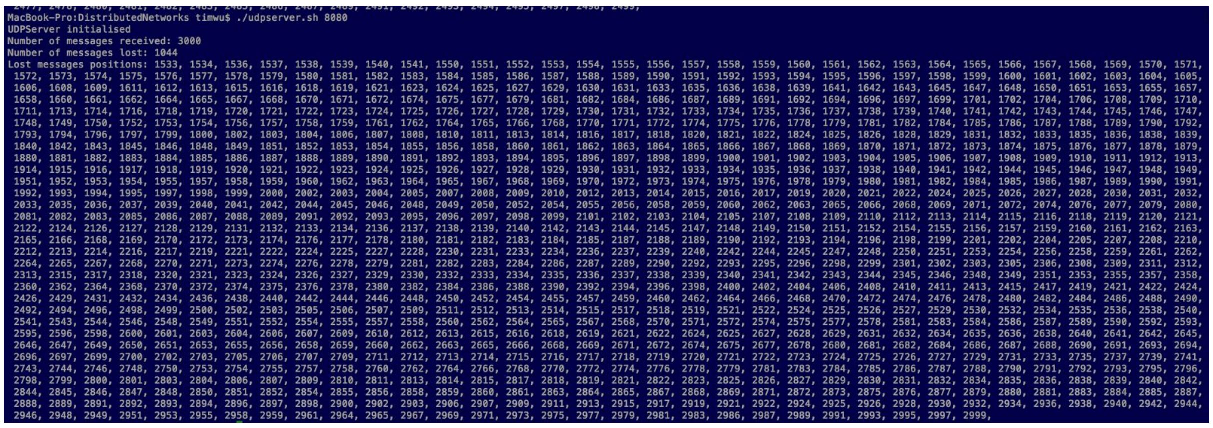
An example from 3000 messages



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Number of messages lost: 1044
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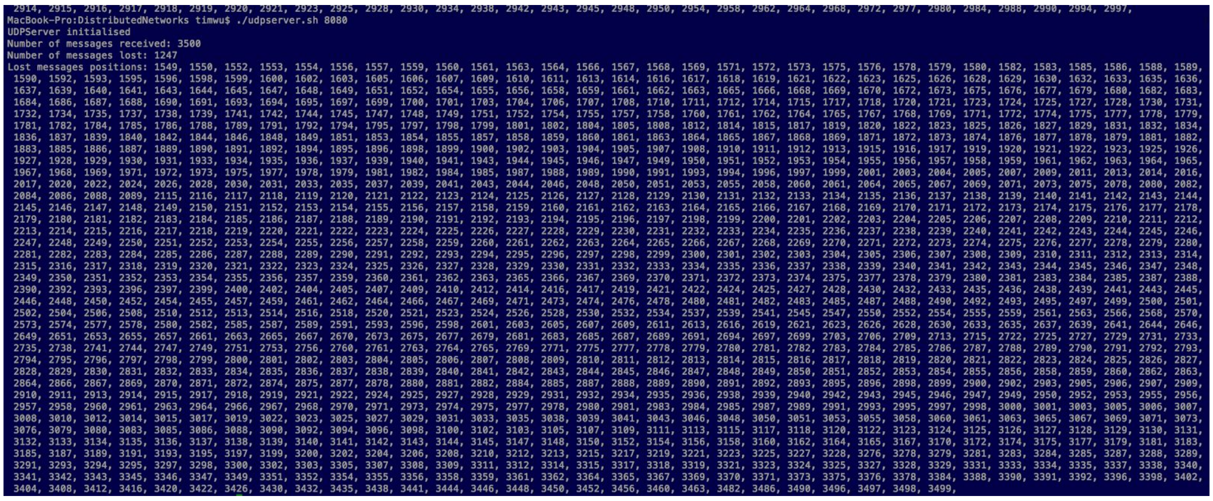
```

An example from 3500 messages



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MacBook-Pro:DistributedNetworks timwu$ ./udpserver.sh 8080
UDPServer initialised
Number of messages received: 3500
Number of messages lost: 1247
Lost messages positions: 1549, 1550, 1552, 1553, 1554, 1556, 1557, 1559, 1560, 1561, 1563, 1564, 1566, 1567, 1568, 1569, 1571, 1572, 1573, 1575, 1576, 1578, 1579, 1580, 1582, 1583, 1585, 1586, 1588, 1589,
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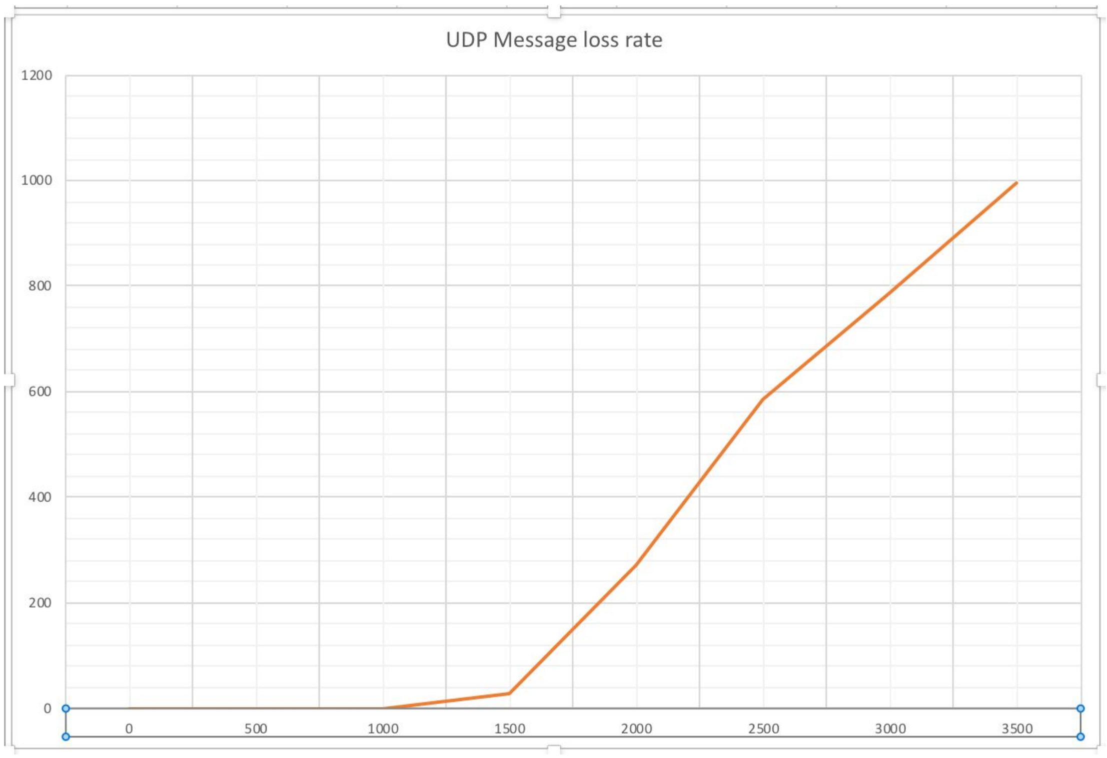
```

	Messages Lost				
Messages Sent	**1500**	**2000**	**2500**	**3000**	**3500**
Attempt 1	147	359	569	1044	1247
Attempt 2	0	420	47	0	1271
Attempt 3	0	0	1038	456	1356
Attempt 4	0	307	618	1201	1107
Attempt 5	0	265	660	1234	0
Average	29.4	270.2	586.4	787	996.2

Plotting the averages against messages, it is clear to see there is direct correlation between number of messages sent and messages lost after around 1500. Since the earliest a message was lost was roughly position 1350, we can assume this is the point messages start having the possibility of being lost.

Below is a graph of the results, with the y-axis being messages lost and x-axis the total messages sent.



We then decided to retest RMI with more messages (2000+.) No messages were lost. (Tested up to 5000 messages.)

We then decided to investigate the patterns of message loss. We had already observed that message loss began at roughly the 1350 position mark. We decided to take the range [position of first message lost - end of total messages position] and divide them into four equal sections, observing how many losses fell into each quarter. Below are a few tables of results from the data in the screenshots. Datasets were taken from the 3500 messages tests as they were the largest.

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Percentage of messages lost	22.8	23.5	28.5	25.1
	33.2	25.6	27.7	15.0
	31.2	28.5	19.7	20.0
	26.1	30.6	24.2	19.0
Average	28.3	27.0	25.0	19.8

As can be seen by the results, there is a slight inverse correlation between the number of the quarter and the percentage of messages lost i.e. less messages were lost the closer towards the end of message sending (bar the initial messages which were lossless.)

Overall Summary

Relative reliability of the different communication mechanisms
From the experiments, it is possible to see that RMI is equally reliable than UDP up to ~1350 messages. However, with larger numbers of messages the UDP server lost up to 50% of the message past position 1350 and the server itself was very unreliable - there were multiple times where the 30 second socket timeout was called before the messages finished processing. Nonetheless, these results match what we would theoretically expect from the two methods.

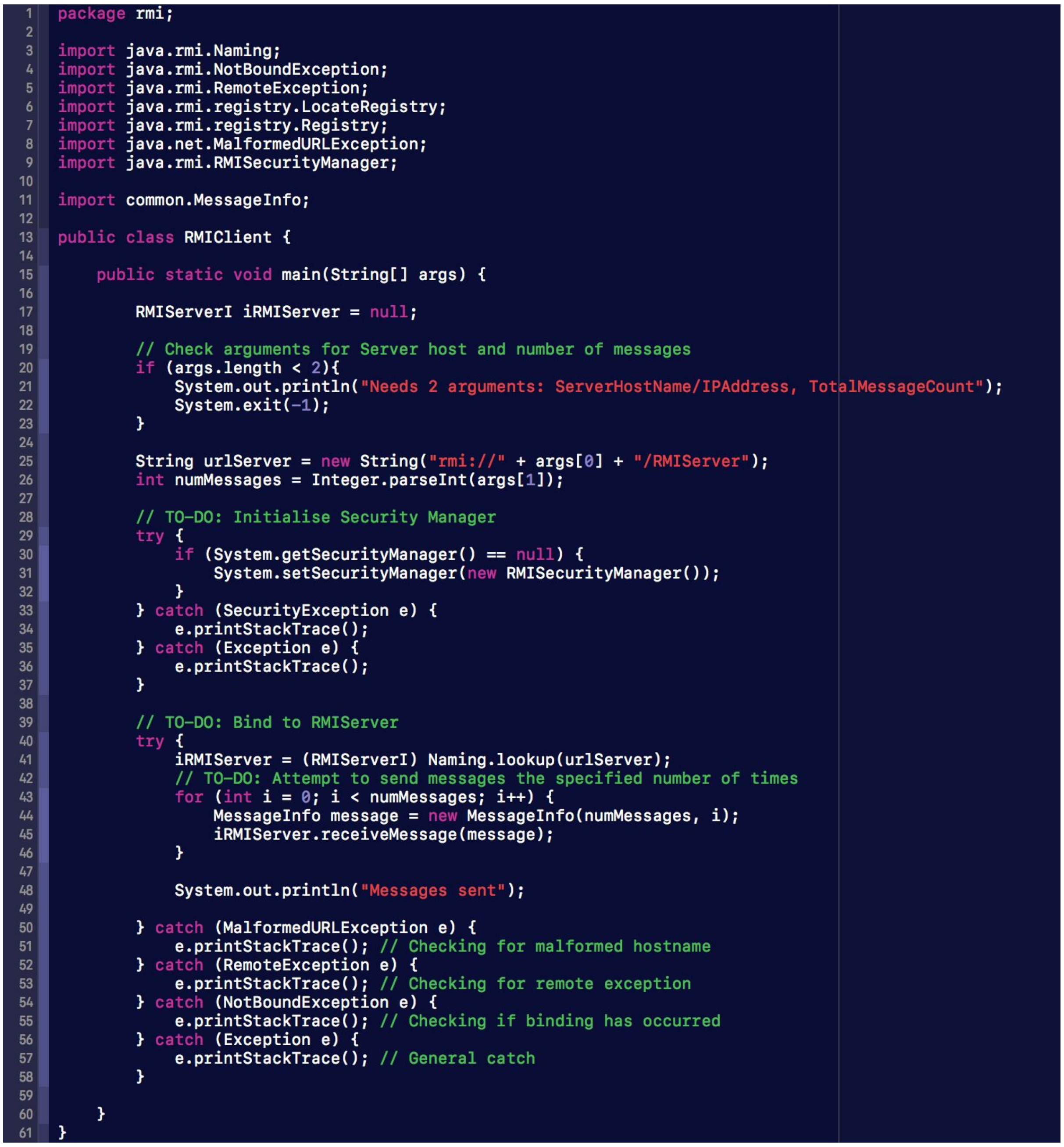
Interestingly, results from others seemed to suggest that setting a threadsleep function within the sending loop of the UDP function i.e. slowing down the rate of sending messages, fixed the message loss. This makes sense as it would act as a rudimentary form of flow control. However, we decided not to implement this as the main advantage of UDP is its speed.

Implementation feasibility
For the client side program, although UDP required more actual coding and implementation than RMI, we found it easier to understand and actually code this. Since we were building each part in the UDP (structuring datagram, implementing buffer handling etc.) It was more intuitive to understand what was required next and how to structure the program. Although the stub in RMI is designed to simplify and hide away the communication details from us, we ran into many issues with incompatible server types during binding - this was eventually fixed by importing and using the Naming package.

The same type of experience occurred when developing the server side programs. Although, we had the additional task of developing a function which had to extract the data out and process it in UDP, it was conceptually more intuitive and therefore easier to implement than the RMI rebinding function. However, since we now have the experience of doing both, in the future it could be argued that RMI would be easier to build since we now possess adequate understanding of the processes.

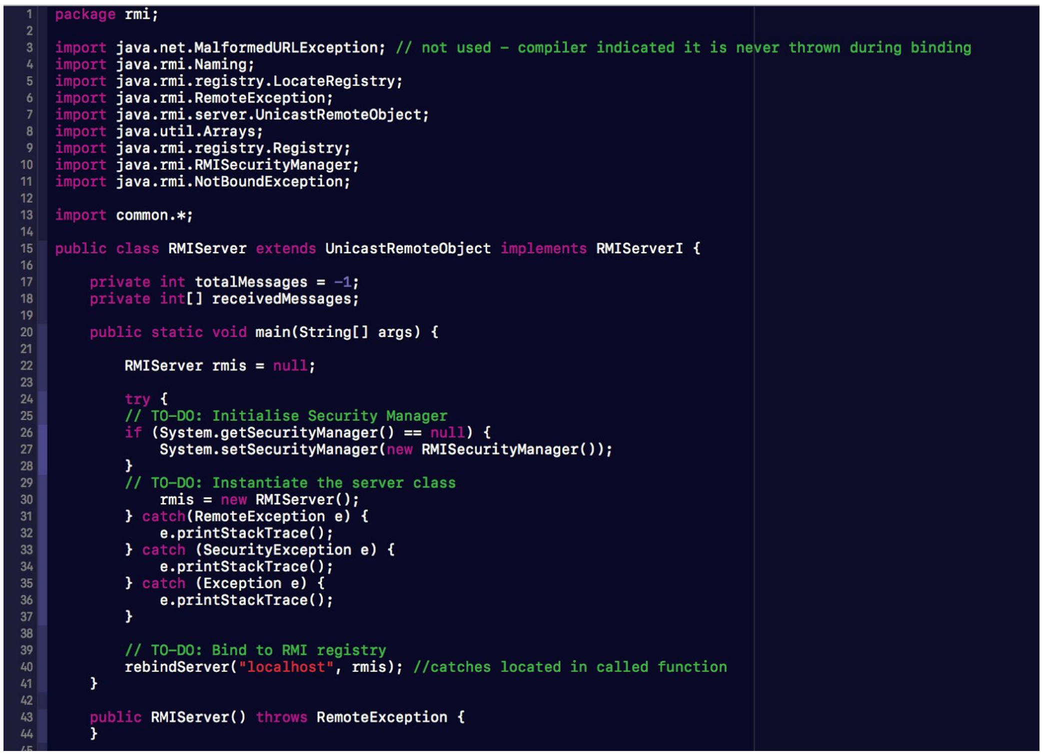
Appendix:
The following code can be found in the following GitHub repository:
https://github.com/twutang/DistributedNetworks

RMI Client

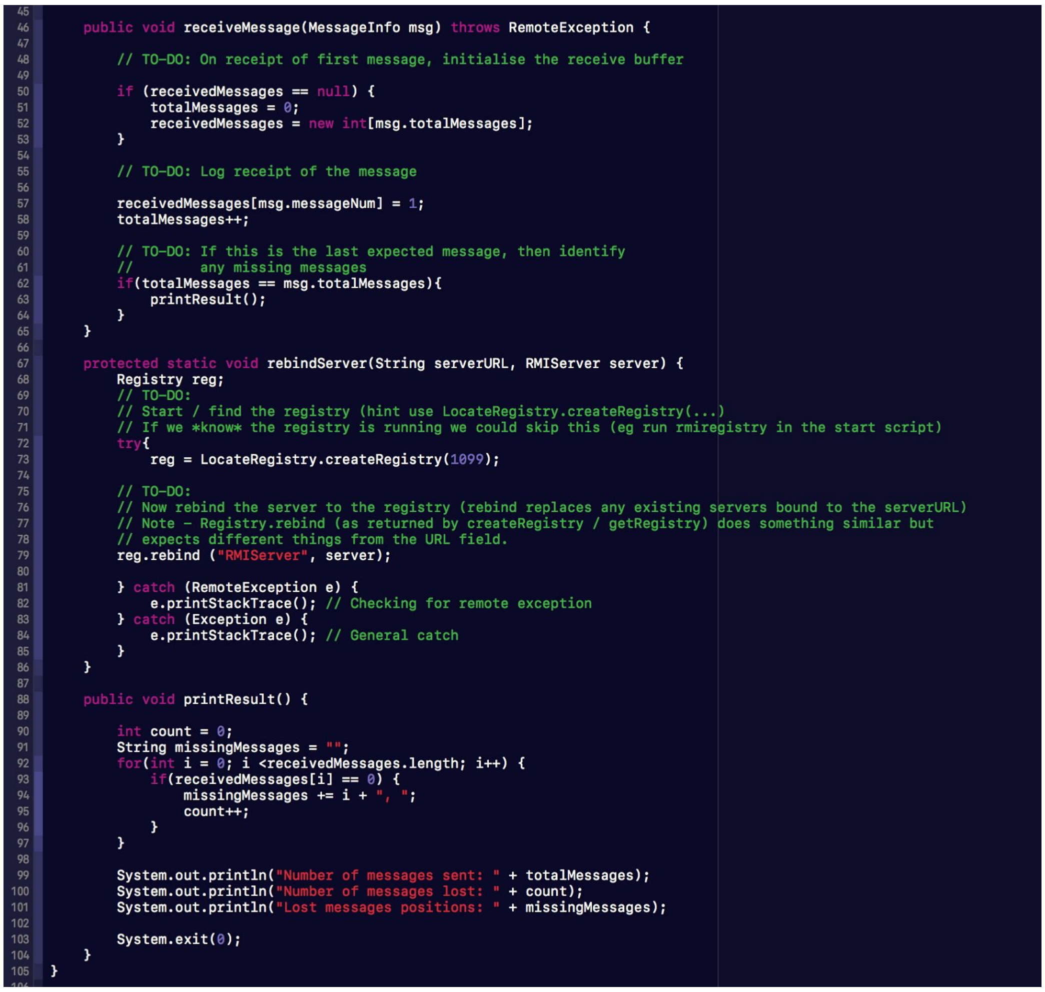


```java
package rmi;

import java.rmi.Naming;
import java.rmi.NotBoundException;
import java.rmi.RemoteException;
import java.rmi.registry.LocateRegistry;
import java.rmi.registry.Registry;
import java.net.MalformedURLException;
import java.rmi.RMISecurityManager;

import common.MessageInfo;

public class RMIClient {

    public static void main(String[] args) {

        RMIServerI iRMIServer = null;

        // Check arguments for Server host and number of messages
        if (args.length < 2){
            System.out.println("Needs 2 arguments: ServerHostName/IPAddress, TotalMessageCount");
            System.exit(-1);
        }

        String urlServer = new String("rmi://" + args[0] + "/RMIServer");
        int numMessages = Integer.parseInt(args[1]);

        // TO-DO: Initialise Security Manager
        try {
            if (System.getSecurityManager() == null) {
                System.setSecurityManager(new RMISecurityManager());
            }
        } catch (SecurityException e) {
            e.printStackTrace();
        } catch (Exception e) {
            e.printStackTrace();
        }

        // TO-DO: Bind to RMIServer
        try {
            iRMIServer = (RMIServerI) Naming.lookup(urlServer);
            // TO-DO: Attempt to send messages the specified number of times
            for (int i = 0; i < numMessages; i++) {
                MessageInfo message = new MessageInfo(numMessages, i);
                iRMIServer.receiveMessage(message);
            }

            System.out.println("Messages sent");

        } catch (MalformedURLException e) {
            e.printStackTrace(); // Checking for malformed hostname
        } catch (RemoteException e) {
            e.printStackTrace(); // Checking for remote exception
        } catch (NotBoundException e) {
            e.printStackTrace(); // Checking if binding has occurred
        } catch (Exception e) {
            e.printStackTrace(); // General catch
        }

    }
}
```

RMI Server

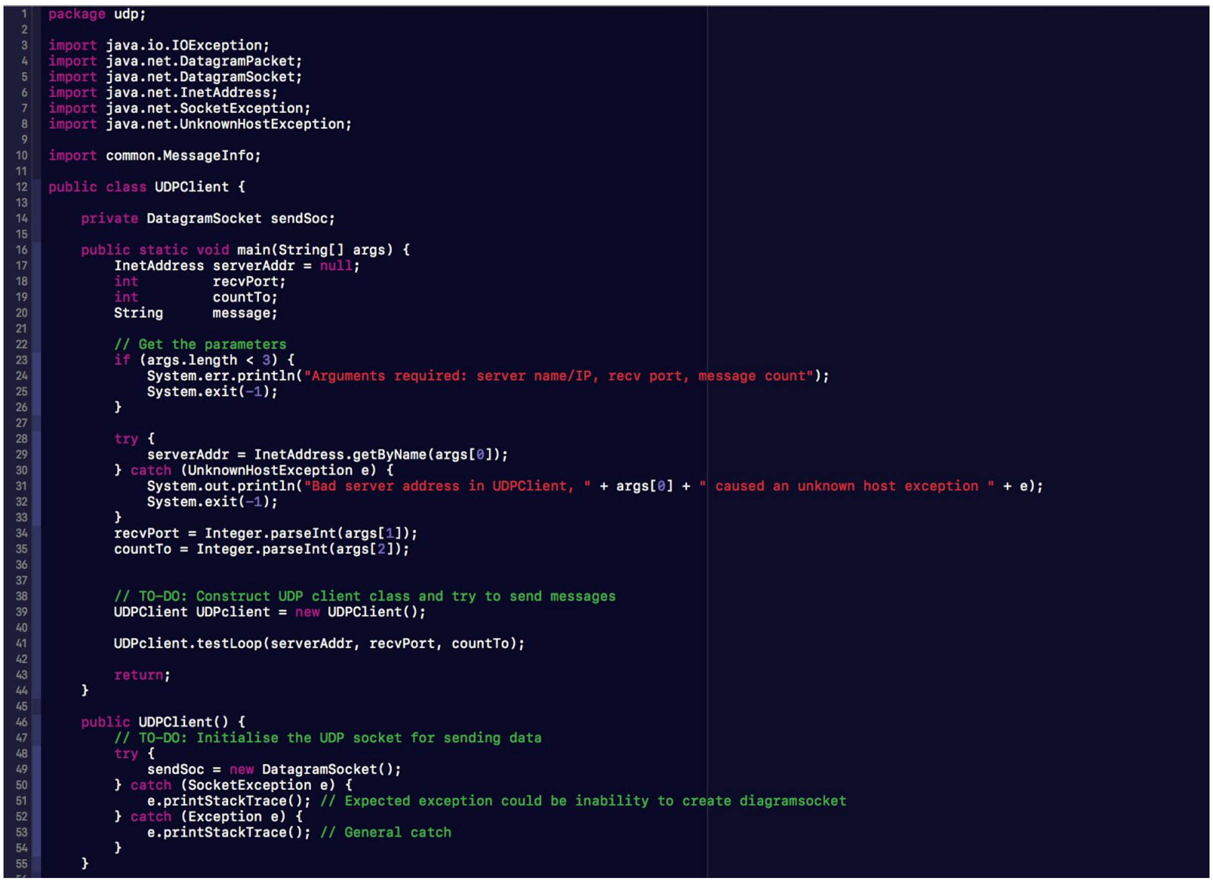


```java
package rmi;

import java.net.MalformedURLException; // not used - compiler indicated it is never thrown during binding
import java.rmi.Naming;
import java.rmi.registry.LocateRegistry;
import java.rmi.RemoteException;
import java.rmi.server.UnicastRemoteObject;
import java.util.Arrays;
import java.rmi.registry.Registry;
import java.rmi.RMISecurityManager;
import java.rmi.NotBoundException;

import common.*;

public class RMIServer extends UnicastRemoteObject implements RMIServerI {

    private int totalMessages = -1;
    private int[] receivedMessages;

    public static void main(String[] args) {

        RMIServer rmis = null;

        try {
        // TO-DO: Initialise Security Manager
        if (System.getSecurityManager() == null) {
            System.setSecurityManager(new RMISecurityManager());
        }
        // TO-DO: Instantiate the server class
            rmis = new RMIServer();
        } catch(RemoteException e) {
            e.printStackTrace();
        } catch (SecurityException e) {
            e.printStackTrace();
        } catch (Exception e) {
            e.printStackTrace();
        }

        // TO-DO: Bind to RMI registry
        rebindServer("localhost", rmis); //catches located in called function
    }

    public RMIServer() throws RemoteException {
    }
```

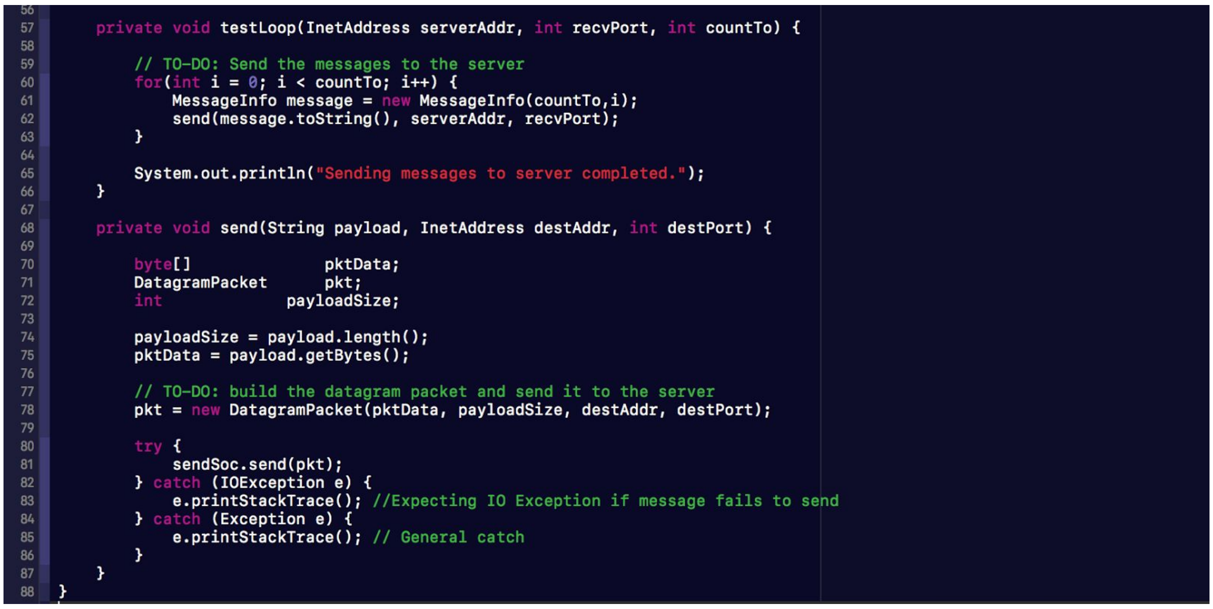


```java

    public void receiveMessage(MessageInfo msg) throws RemoteException {

        // TO-DO: On receipt of first message, initialise the receive buffer

        if (receivedMessages == null) {
            totalMessages = 0;
            receivedMessages = new int[msg.totalMessages];
        }

        // TO-DO: Log receipt of the message

        receivedMessages[msg.messageNum] = 1;
        totalMessages++;

        // TO-DO: If this is the last expected message, then identify
        //        any missing messages
        if(totalMessages == msg.totalMessages){
            printResult();
        }
    }

    protected static void rebindServer(String serverURL, RMIServer server) {
        Registry reg;
        // TO-DO:
        // Start / find the registry (hint use LocateRegistry.createRegistry(...)
        // If we *know* the registry is running we could skip this (eg run rmiregistry in the start script)
        try{
            reg = LocateRegistry.createRegistry(1099);

        // TO-DO:
        // Now rebind the server to the registry (rebind replaces any existing servers bound to the serverURL)
        // Note - Registry.rebind (as returned by createRegistry / getRegistry) does something similar but
        // expects different things from the URL field.
        reg.rebind ("RMIServer", server);

        } catch (RemoteException e) {
            e.printStackTrace(); // Checking for remote exception
        } catch (Exception e) {
            e.printStackTrace(); // General catch
        }
    }

    public void printResult() {

        int count = 0;
        String missingMessages = "";
        for(int i = 0; i <receivedMessages.length; i++) {
            if(receivedMessages[i] == 0) {
                missingMessages += i + ", ";
                count++;
            }
        }

        System.out.println("Number of messages sent: " + totalMessages);
        System.out.println("Number of messages lost: " + count);
        System.out.println("Lost messages positions: " + missingMessages);

        System.exit(0);
    }
}
```

UDP Client

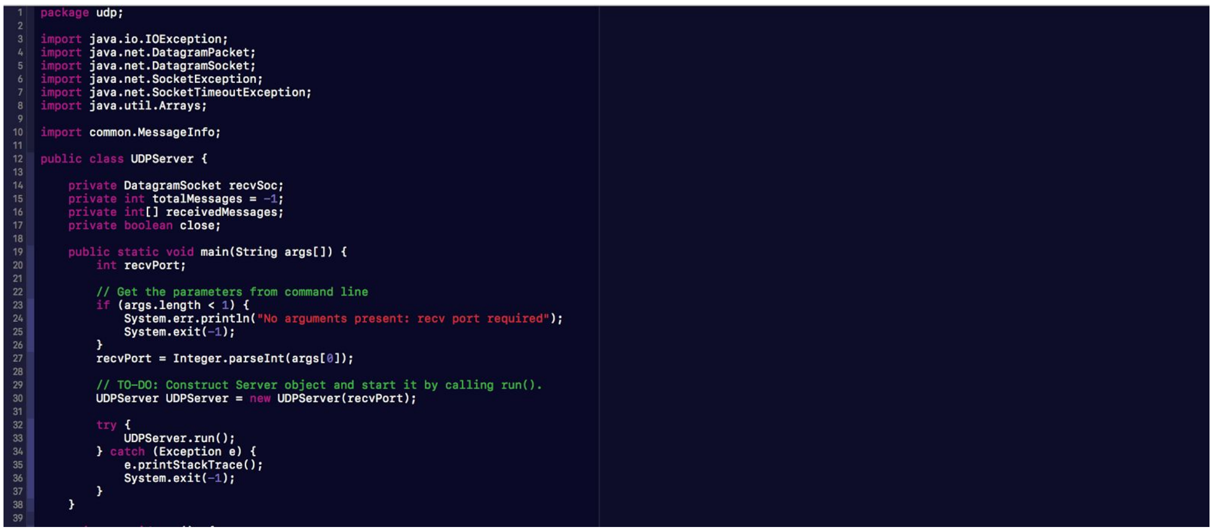


```java
package udp;

import java.io.IOException;
import java.net.DatagramPacket;
import java.net.DatagramSocket;
import java.net.InetAddress;
import java.net.SocketException;
import java.net.UnknownHostException;

import common.MessageInfo;

public class UDPClient {

    private DatagramSocket sendSoc;

    public static void main(String[] args) {
        InetAddress serverAddr = null;
        int         recvPort;
        int         countTo;
        String      message;

        // Get the parameters
        if (args.length < 3) {
            System.err.println("Arguments required: server name/IP, recv port, message count");
            System.exit(-1);
        }

        try {
            serverAddr = InetAddress.getByName(args[0]);
        } catch (UnknownHostException e) {
            System.out.println("Bad server address in UDPClient, " + args[0] + " caused an unknown host exception " + e);
            System.exit(-1);
        }
        recvPort = Integer.parseInt(args[1]);
        countTo = Integer.parseInt(args[2]);


        // TO-DO: Construct UDP client class and try to send messages
        UDPClient UDPclient = new UDPClient();

        UDPclient.testLoop(serverAddr, recvPort, countTo);

        return;
    }

    public UDPClient() {
        // TO-DO: Initialise the UDP socket for sending data
        try {
            sendSoc = new DatagramSocket();
        } catch (SocketException e) {
            e.printStackTrace(); // Expected exception could be inability to create diagramsocket
        } catch (Exception e) {
            e.printStackTrace(); // General catch
        }
    }
```

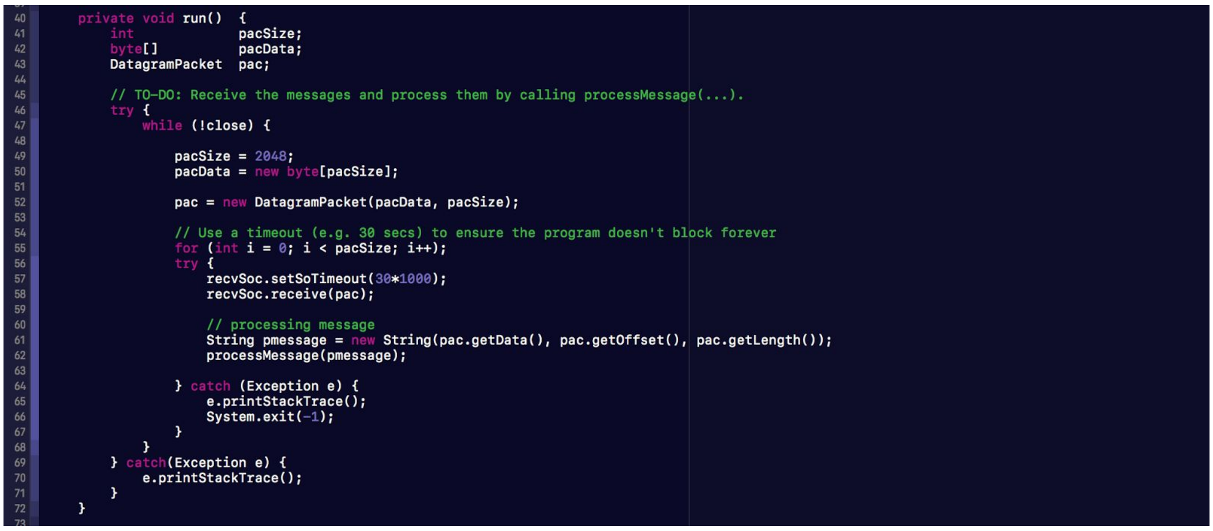


```java
    private void testLoop(InetAddress serverAddr, int recvPort, int countTo) {

        // TO-DO: Send the messages to the server
        for(int i = 0; i < countTo; i++) {
            MessageInfo message = new MessageInfo(countTo,i);
            send(message.toString(), serverAddr, recvPort);
        }

        System.out.println("Sending messages to server completed.");
    }

    private void send(String payload, InetAddress destAddr, int destPort) {

        byte[]              pktData;
        DatagramPacket      pkt;
        int             payloadSize;

        payloadSize = payload.length();
        pktData = payload.getBytes();

        // TO-DO: build the datagram packet and send it to the server
        pkt = new DatagramPacket(pktData, payloadSize, destAddr, destPort);

        try {
            sendSoc.send(pkt);
        } catch (IOException e) {
            e.printStackTrace(); //Expecting IO Exception if message fails to send
        } catch (Exception e) {
            e.printStackTrace(); // General catch
        }
    }
}
```

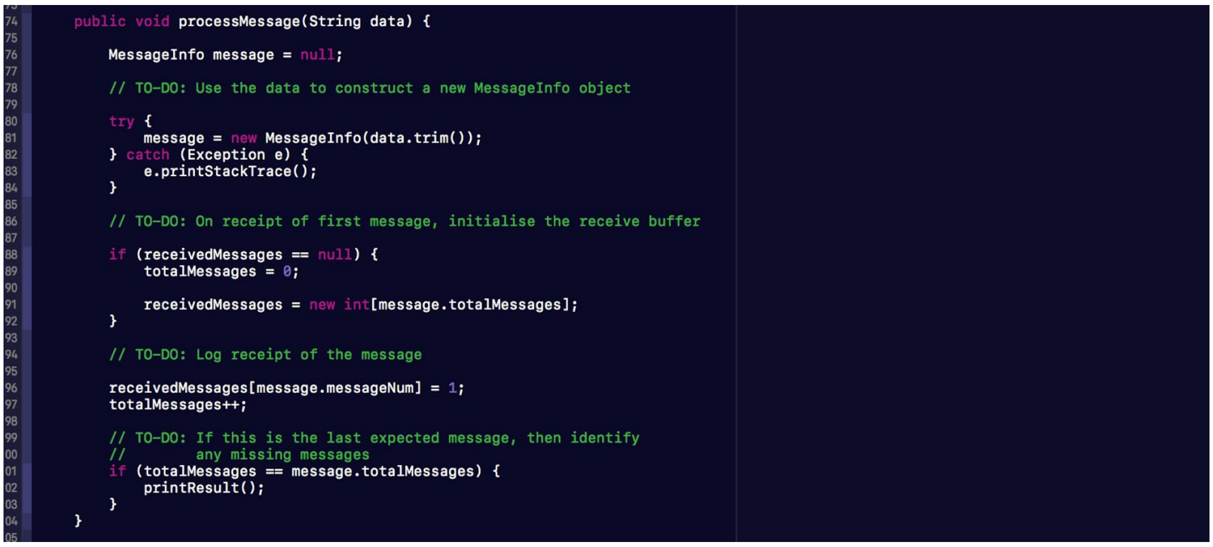
UDP Server (2 pages)



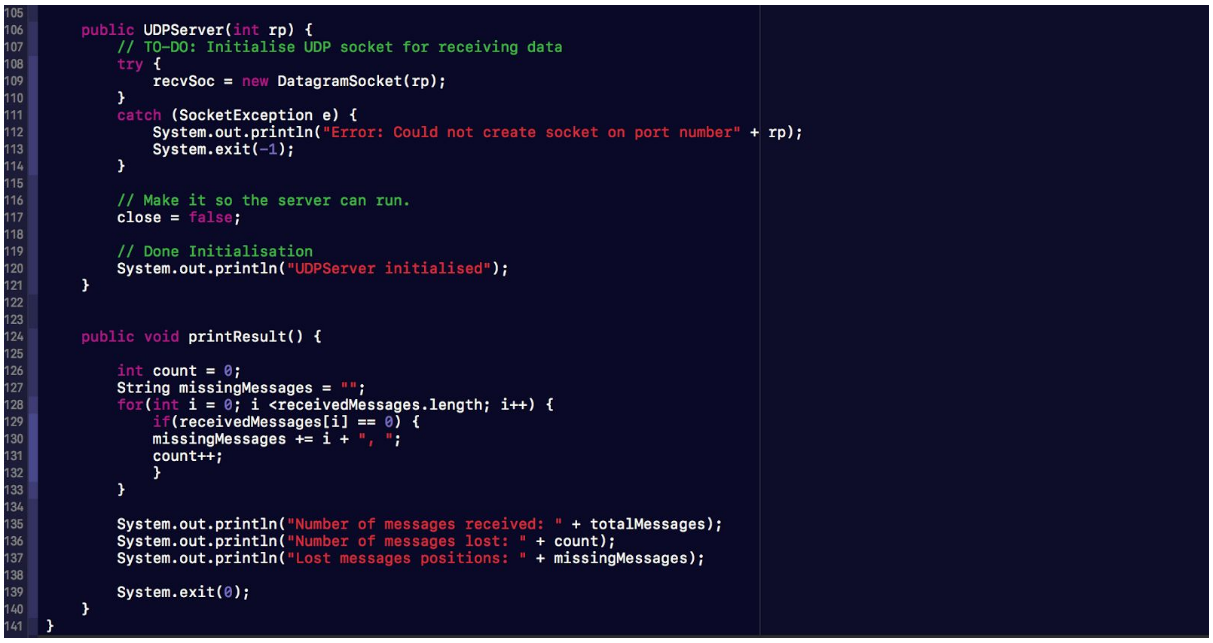
```java
package udp;

import java.io.IOException;
import java.net.DatagramPacket;
import java.net.DatagramSocket;
import java.net.SocketException;
import java.net.SocketTimeoutException;
import java.util.Arrays;

import common.MessageInfo;

public class UDPServer {

    private DatagramSocket recvSoc;
    private int totalMessages = -1;
    private int[] receivedMessages;
    private boolean close;

    public static void main(String args[]) {
        int recvPort;

        // Get the parameters from command line
        if (args.length < 1) {
            System.err.println("No arguments present: recv port required");
            System.exit(-1);
        }
        recvPort = Integer.parseInt(args[0]);

        // TO-DO: Construct Server object and start it by calling run().
        UDPServer UDPServer = new UDPServer(recvPort);

        try {
            UDPServer.run();
        } catch (Exception e) {
            e.printStackTrace();
            System.exit(-1);
        }
    }
```



```java
    private void run()  {
        int             pacSize;
        byte[]          pacData;
        DatagramPacket  pac;

        // TO-DO: Receive the messages and process them by calling processMessage(...).
        try {
            while (!close) {

                pacSize = 2048;
                pacData = new byte[pacSize];

                pac = new DatagramPacket(pacData, pacSize);

                // Use a timeout (e.g. 30 secs) to ensure the program doesn't block forever
                for (int i = 0; i < pacSize; i++);
                try {
                    recvSoc.setSoTimeout(30*1000);
                    recvSoc.receive(pac);

                    // processing message
                    String pmessage = new String(pac.getData(), pac.getOffset(), pac.getLength());
                    processMessage(pmessage);

                } catch (Exception e) {
                    e.printStackTrace();
                    System.exit(-1);
                }
            }
        } catch(Exception e) {
            e.printStackTrace();
        }
    }
```



```java
    public void processMessage(String data) {

        MessageInfo message = null;

        // TO-DO: Use the data to construct a new MessageInfo object

        try {
            message = new MessageInfo(data.trim());
        } catch (Exception e) {
            e.printStackTrace();
        }

        // TO-DO: On receipt of first message, initialise the receive buffer

        if (receivedMessages == null) {
            totalMessages = 0;

            receivedMessages = new int[message.totalMessages];
        }

        // TO-DO: Log receipt of the message

        receivedMessages[message.messageNum] = 1;
        totalMessages++;

        // TO-DO: If this is the last expected message, then identify
        //        any missing messages
        if (totalMessages == message.totalMessages) {
            printResult();
        }
    }
```



```java
    public UDPServer(int rp) {
        // TO-DO: Initialise UDP socket for receiving data
        try {
            recvSoc = new DatagramSocket(rp);
        }
        catch (SocketException e) {
            System.out.println("Error: Could not create socket on port number" + rp);
            System.exit(-1);
        }

        // Make it so the server can run.
        close = false;

        // Done Initialisation
        System.out.println("UDPServer initialised");
    }


    public void printResult() {

        int count = 0;
        String missingMessages = "";
        for(int i = 0; i <receivedMessages.length; i++) {
            if(receivedMessages[i] == 0) {
            missingMessages += i + ", ";
            count++;
            }
        }

        System.out.println("Number of messages received: " + totalMessages);
        System.out.println("Number of messages lost: " + count);
        System.out.println("Lost messages positions: " + missingMessages);

        System.exit(0);
    }
}
```