

MLD Considered Harmful

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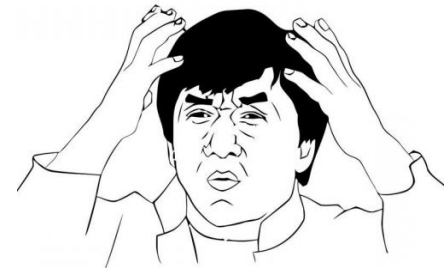
Who Am I



- Old-school network security guy with some background in provider operations.
- Involved with LIR administration in some enterprise LIRs
 - Including the one with probably the coolest org handle: ORG-HACK1-RIPE.
- IPv6 since 1999 and regularly blogging about it at www.insinuator.net/tag/ipv6.

Agenda

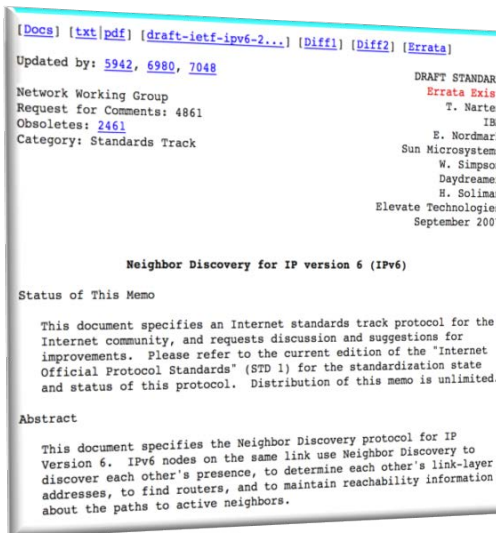
- The Object of Interest
- How We Tackled It
- What We Observed
- What All This Means



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
2	0.000013	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
3	0.008497	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
4	0.008506	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
5	0.023971	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
6	0.023984	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
7	0.025772	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
8	0.025777	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
9	0.261958	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
10	0.261967	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
11	600.048733	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
12	600.048746	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
13	600.063445	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
14	600.063458	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
15	600.075012	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
16	600.075020	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
17	600.077356	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
18	600.077366	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
19	600.264367	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
20	600.264378	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
21	1199.407524	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
22	1199.407537	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
23	1199.423790	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
24	1199.423802	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2
25	1199.428513	Windows7.1-linklocal	ff02::16	ICMPv6	90	Multicast Listener Report Message v2

Why This Talk (I)

Why This Talk (II)



RFC 4861 Neighbor Discovery for IP version 6 (IPv6), sect. 7.2.1

Descriptive or prescriptive (“normative”)??



- “Joining the solicited-node multicast address **is done** using a Multicast Listener Discovery such as [MLD] or [MLDv2] protocols.”

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IPv6 Node Requirements

December 2014

5.10. Multicast Listener Discovery (MLD) for IPv6

Nodes that need to join multicast groups MUST support MLDv1 [RFC2710]. MLDv1 is needed by any node that is expected to receive and process multicast traffic. Note that Neighbor Discovery (as used on most link types -- see [Section 5.2](#)) depends on multicast and requires that nodes join Solicited Node multicast addresses.

MLDv2 [RFC3810] extends the functionality of MLDv1 by supporting Source-Specific Multicast. The original MLDv2 protocol [RFC3810] supporting Source-Specific Multicast [RFC4607] supports two types of "filter modes". Using an INCLUDE filter, a node indicates a multicast group along with a list of senders for the group from which it wishes to receive traffic. Using an EXCLUDE filter, a node indicates a multicast group along with a list of senders from which it wishes to exclude receiving traffic. In practice, operations to block source(s) using EXCLUDE mode are rarely used but add considerable implementation complexity to MLDv2. Lightweight MLDv2 [RFC5790] is a simplified subset of the original MLDv2 specification that omits EXCLUDE filter mode to specify undesired source(s).

Complexity

Here's another gem for you: MLD

Why This Talk (III)

From:

https://www.troopers.de/wp-content/uploads/2013/11/TROOPERS14-Why_IPv6_Security_is_so_hard-Structural_Deficits_of_IPv6_and_their_Implications-Enno_Rey.pdf

3/17/14

#36 | www.ernw.de

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#6 | www.ernw.de

So here's a Protocol...



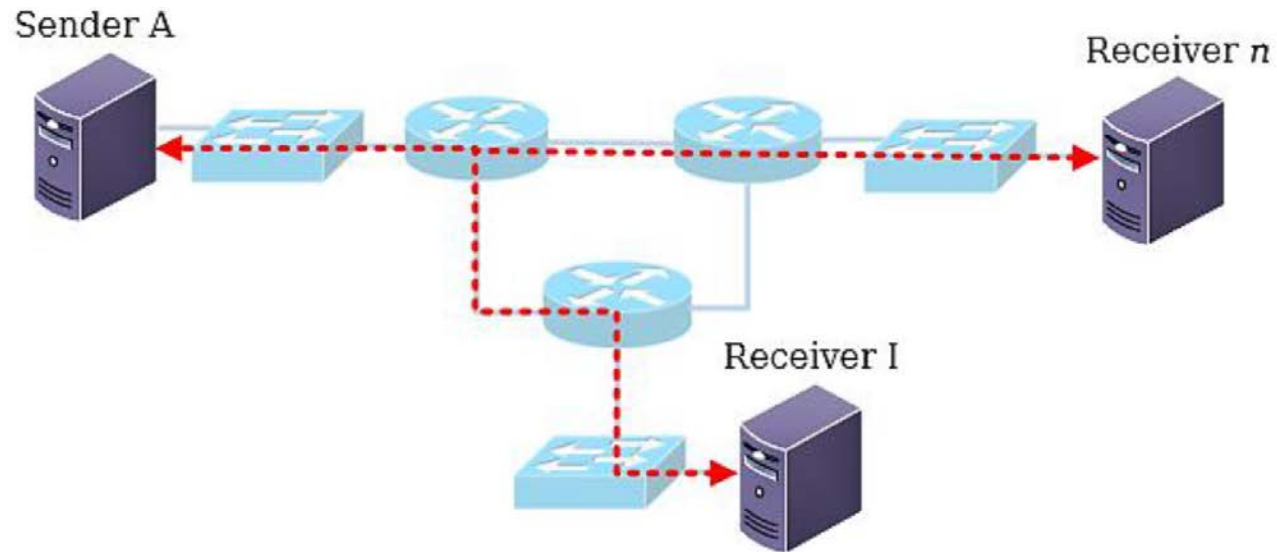
- Apparently every IPv6 stack has to support.
might have enabled by default (most do).
- It's not really clear if it is always needed or not.
- It's a complex beast (as we will see).
- Not much public security research.
→ we tried to contribute.

MLD Fundamentals



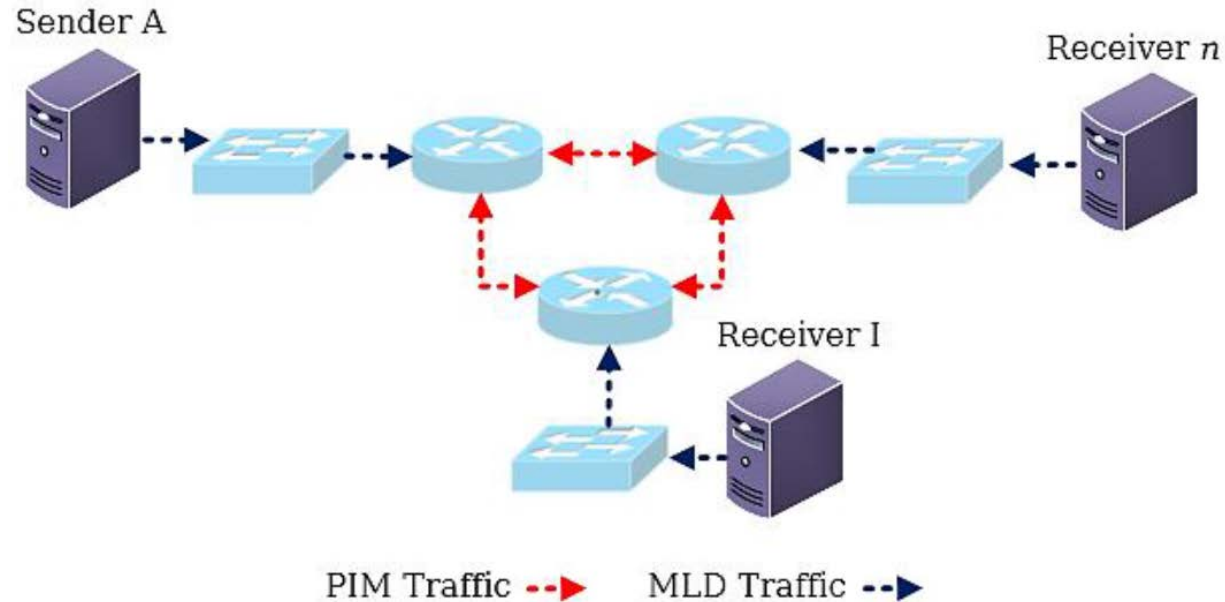
Multicast in a Nutshell (I)

Communication between a [group of] source[s] and several receivers.



Multicast in a Nutshell (II)

Receiver[s] have to signal to the routers that they're interested in certain channels.



IPv6 Multicast Listener Protocol (MLD)



- Replaces IPv4's IGMP
 - MLDv1 (RFC 2710) based on IGMPv2.
 - MLDv2 based on IGMPv3.
- Queriers & Hosts
 - Querier: network device (usually a router) that sends *query* message to discover which network devices are members of a given multicast group.
 - Receiver: node that sends *report* messages to inform querier about a group membership.

MLD Version 1



- All MLD versions are based on ICMPv6.
- First defined in RFC 2710, derived from IPv4's IGMPv2.
- Used by IPv6 routers for discovering directly attached multicast listeners.
- In its original form MLD doesn't learn the exact identity or number of multicast listeners.

MLD Version 2



- Specified in **RFC 3810** and equivalent to IGMPv3.
- Designed to be **interoperable** with **MLDv1**.
- Adds support for "source filtering". The nodes can report interest in traffic **only from a set** of source addresses or **from all except a set of** source addresses.

MLDv1 Message Types

- Query (ICMPv6 Type 130)

General: Multicast address field set to 0 to learn which multicast addresses have listeners on an attached link.

Group/multicast-address specific.

- Report (131)

Sender of this message (= a “receiver”) indicates which specific IPv6 multicast addresses it listens to.

- Done (132)

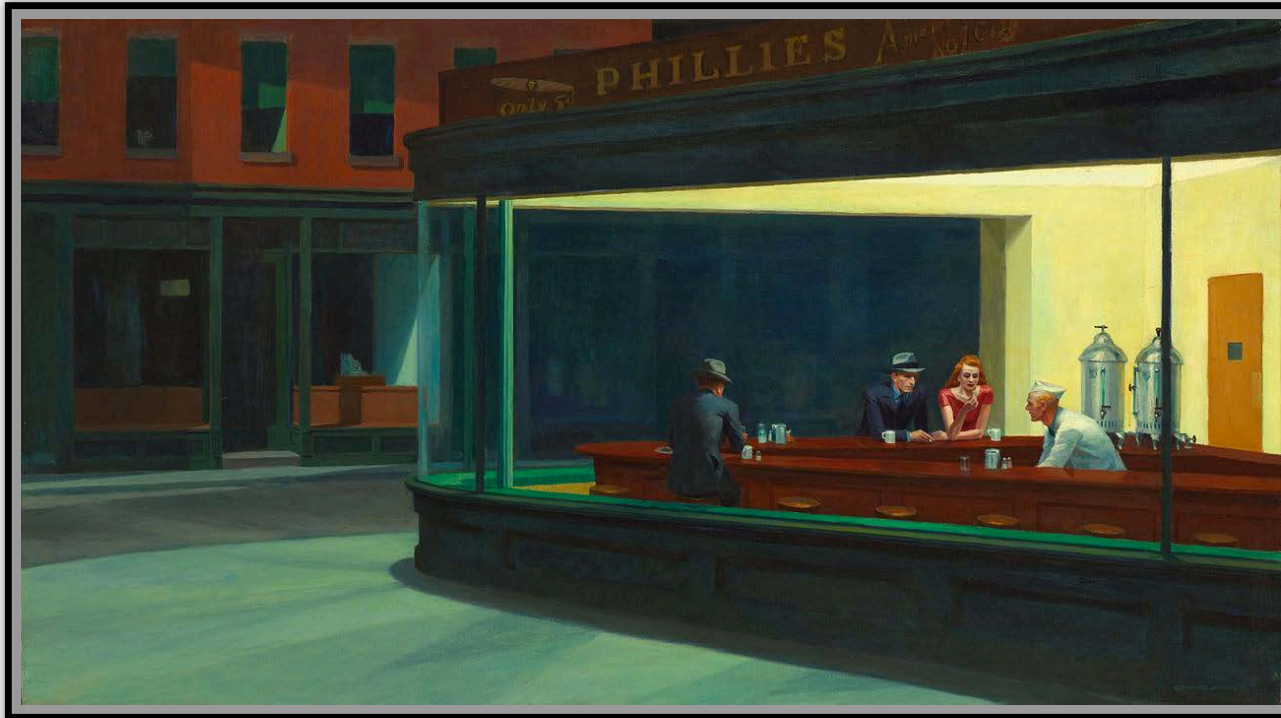
Sender of message (= a [former] “receiver”) indicates which address it no longer listens to.



MLDv2 Messages



- **General Queries:** ICMPv6 Type 130
 - Sent to FF02::1.
- **Specific Queries:** ICMPv6 Type 130
 - Inclusion of Address-and-Source-Specific queries.
 - All specific queries are sent to the multicast address being queried.
- **MLDv2 Reports :** ICMPv6 Type 143
 - Sent to FF02::16 (all MLDv2-capable routers).
 - No more MLD *Done* messages.



One
Particularly
Interesting
Functionality:

Last Call
aka [The *last listener query*]

MLD Snooping



- Switch based, somewhat proprietary feature that constrains multicast traffic to only the ports that have receivers attached.
- The switch builds an MLD based table that basically maps a multicast group to all the switch ports that have requested it.

Security (?) Precautions



- All MLD messages must be sent with:
 - A *link-local* IPv6 source address.
 - An IPv6 Hop Limit of 1.
 - A *Router Alert Option* in the Hop-by-Hop extension header.
- Non compliant messages are supposed to be dropped.
- Besides the above MLD does not have any built-in/inherent security properties.

IPv6's Trust Model

- On the *local link* we're all brothers.



Convenient RFC Conditions



- A node **MUST** process any *Query* whose destination address matches **any** of the addresses assigned to the receiving interface, unicast or multicast.

- **Result:**

This allows one-to-one communication with the routers and listeners.

Convenient RFC Conditions (II)



- A router in querier mode enters the non-querier state upon receiving a query from a lower IPv6 address than its own. It thus ceases to send queries.
- **Result:**
 - In most networks we can easily become a *Querier*.
 - “Win the election”.

Convenient RFC Conditions (III)



- In the presence of MLDv1 Routers, MLDv2 hosts **MUST** operate in version 1 compatibility mode.
- In the presence of MLDv1 Multicast Address Listeners, an MLDv2 node **MAY** allow its MLDv2 Report to be suppressed by a Version 1 Report.
- **Result:** We can easily force MLDv1 to be used.

In the 90s we called this a “forced dialect downgrade”...

Implementation Facts

- MLD is pre-enabled in Windows, Linux and FreeBSD Operating Systems. It is **NOT** in OpenBSD.
- MLD Reports are sent even before the Neighbor Discovery Process starts.
- To cover the possibility of the initial Report being lost or corrupted, it is recommended to be resent once or twice after short delays.



Implementation Facts (II)



- All of them join several multicast groups:
 - Each OS joins the corresponding Solicited-Node Multicast Address.
 - Windows joins **FF02::1:3** (Link Local Multicast Name Resolution).
 - FreeBSD joins Node Information Queries multicast groups (**experimental** RFC 4620).

Trivial Host Discovery and Fingerprinting

OS	Multicast Group	Service
IOS 15.4(3) M	ff02::2	All IPv6 routers on the Link
	ff02::d	PIM routers
	ff02::16	All MLDv2 capable routers
	ff02::1:2	All DHCP servers and relay agents
FreeBSD 10.0	ff02::2:ff2e:b774	IPv6 Node Information <i>Query</i>
	ff02::2:2eb7:74fa	IPv6 Node Information <i>Query</i> (Invalid)
Ubuntu 14.04	ff02::FB	Zero Configuration Networking
Windows 8.1	ff02::C	SSDP
	ff02::1:3	LLMNR

Security Discussion

What we looked at



- Implementation problems

Yes, fuzzing.

We mean, what else ;-)

- RFC compliance issues

These may sound lame... but we'll see that they can serve as a stepping stone for the next category.

- Design flaws & unwanted/-expected protocol behavior.

Devices Used in the Lab



- Routers: mainly Cisco 1921, IOS15.4(3)M, plus an ASR 1002.
- Switches: Cisco Catalyst 2960-S IOS 15.2(1)E3.
- As hosts: several Windows (server, desktop), some Linuces, FreeBSD and OpenBSD.

Tools

Our approach

Chiron

Abusing the protocol

Added MLD capabilities

→ <http://www.secfu.net/tools-scripts/>



Dizzy

Fuzzing

Latest version:

<http://www.insinuator.net/2014/02/fresh-meet-from-the-coding-front>



Description files for MLD developed




Results



Huge MLD Reports, Router Resource Depletion

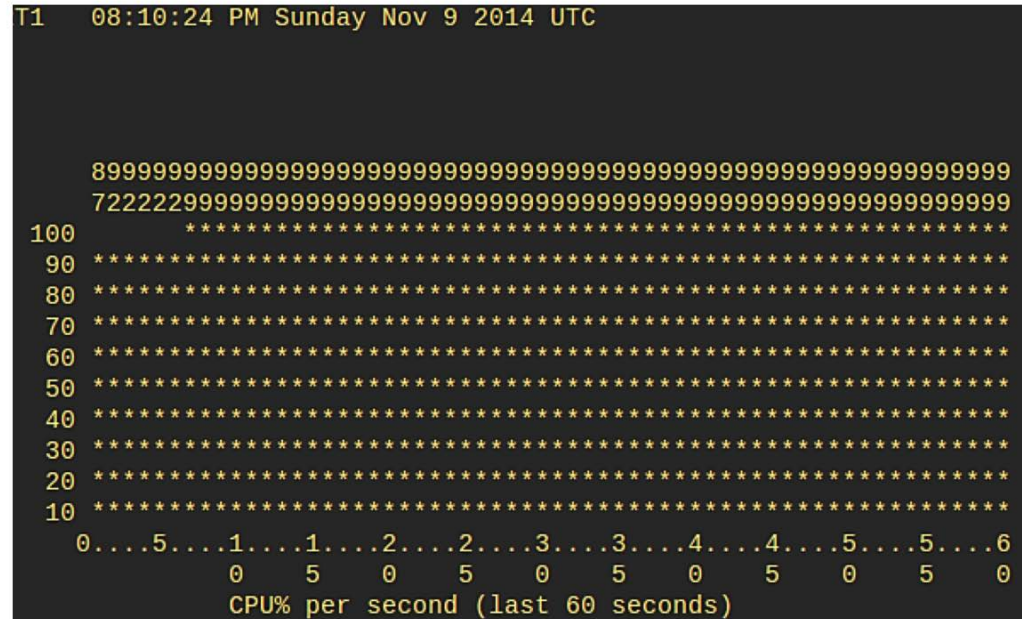
```
user@ubuntu: ~  
My traceroute [v0.85]  
ubuntu (::) Fri Jan 16 16:43:24 2015  
Keys: Help Display mode Restart statistics Order of fields quit  
Packets  
Host Loss% Snt Last Avg Best Wrst StDev  
1. 2001:db8:1::ec:1 0.0% 71 0.6 0.6 0.3 1.0 0.0  
2. 2001:db8:2::ec:1 0.0% 71 0.9 0.8 0.6 2.6 0.2
```



```
user@ubuntu: ~  
My traceroute [v0.85]  
ubuntu (::) Fri Jan 16 16:36:04 2015  
Keys: Help Display mode Restart statistics Order of fields quit  
Packets  
Host Loss% Snt Last Avg Best Wrst StDev  
1. 2001:db8:1::ec:1 0.0% 73 22.1 7.2 0.4 78.2 11.5  
2. 2001:db8:2::ec:1 8.2% 73 0.8 4.5 0.6 80.0 13.5
```

Heavy Resource Consumption (II)

Here, the router is a Cisco ASR 1002.
There's **only one** attacker on the *local-link*...



Amplification Attacks

Against the routers on the *local-link* using MLD Queries.



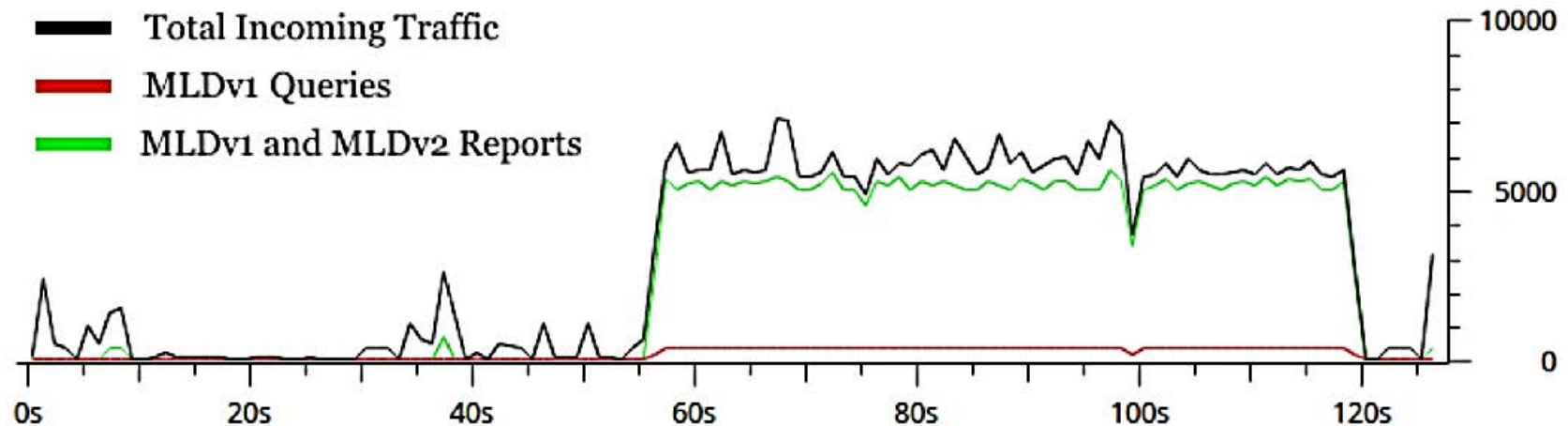
- Windows 8.1 hosts join at least four groups and send two Reports per group.

Amplification factor goes up to **8 x Number of machines** for Windows hosts.

- For example, in a segment with 200 hosts a single spoofed Query can trigger 1600 Reports all sent immediately to the router.
 - Amplification factor: 1,600!
- What if we flood the link with such Queries?

MLDv1 Traffic Amplification

- 1,3kb/s become 49,8kb/s on the router's side, **~3830%** the initial traffic

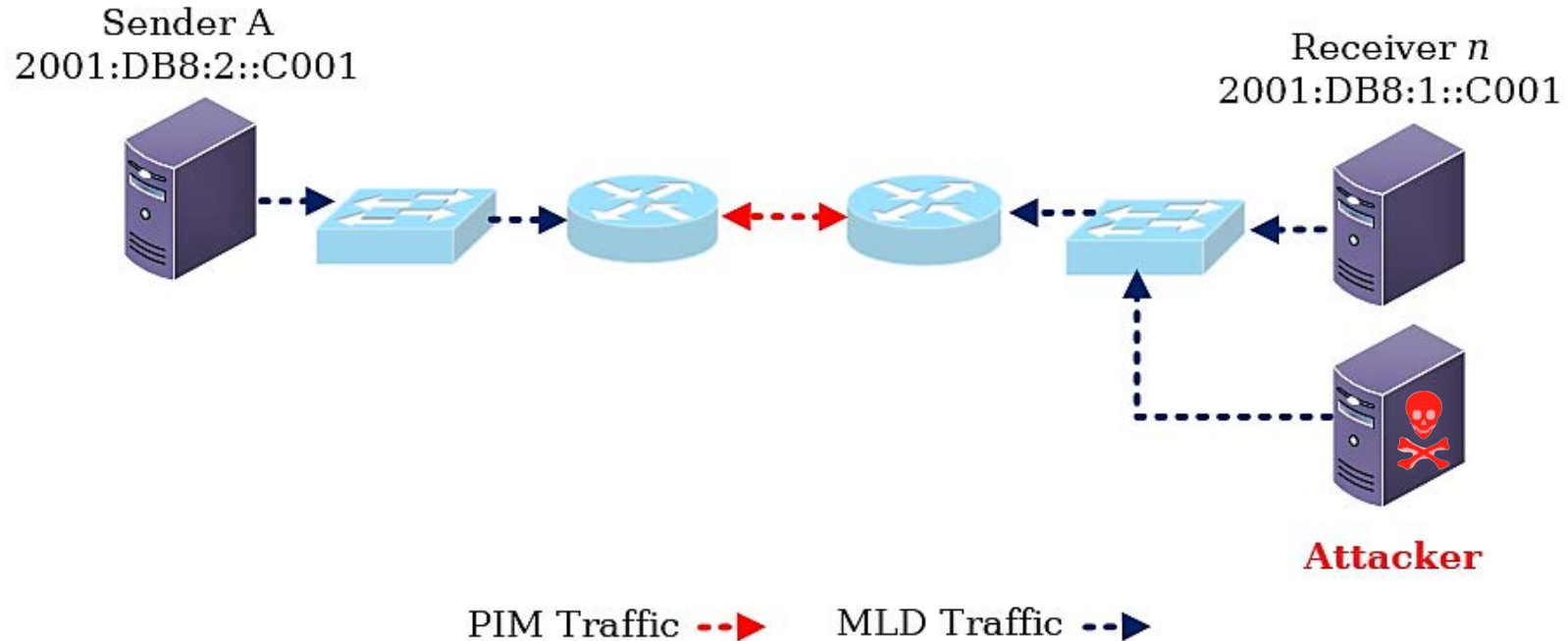


How to Attack MLD – Prerequisites



- Cisco IOS15.4(3)M accepts:
 - MLDv1 and MLDv2 Queries sent to FF02::2.
 - MLDv2 Queries to FF02::16 and its unicast address.
 - MLDv1 and MLDv2 Queries to its link-local address.
 - MLDv2 Reports sent to FF02::2 and FF02::16.
 - MLDv1 Dones sent to the FF02::2, FF02::16, link-local and unicast addresses.
- **Result:** We have several ways to interact with the routers in a **one-to-one** manner.

A Closer Look at Practical Attacks



Attack Vector (I)

MLDv1 and MLDv2



- Take over the Querier Role.
- Send spoofed MLDv1 Done or MLDv2 Reports to remove a listener from a multicast group.
- Send a spoofed Last Listener Query to the routers, they believe this to be a real Last Listener Query.
- Periodically send Generic Queries to the routers (FF02::2, FF02::16 or their unicast addresses).

Attack Vector (II)

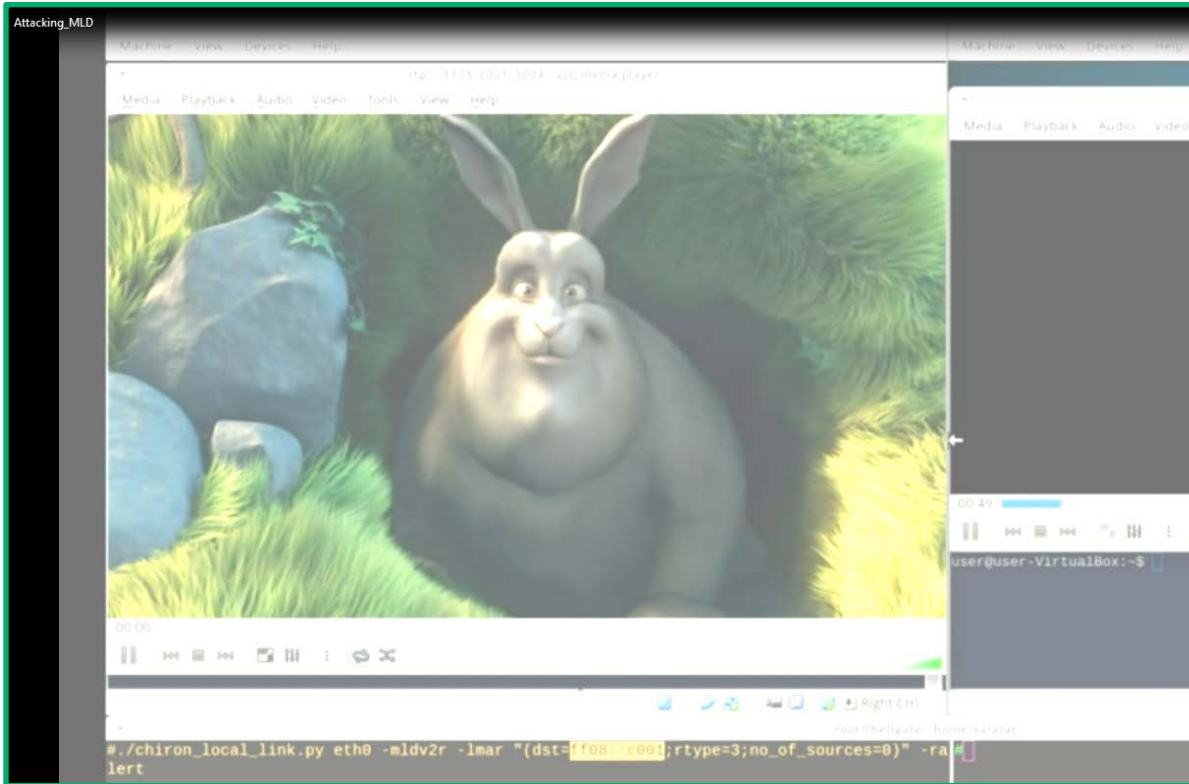
MLDv1



- Become Querier through MLDv1 Queries, forcing use of MLDv1. Same can be done by sending MLDv1 Reports.
- Send MLDv1 Done messages.
The Querier (or you) sends a “last call” Query.
- Send MLDv1 Report to the unicast address of the legitimate listeners to trigger Report suppression on their side.
- Legitimate routers do not receive any Reports and thus traffic to the group is no longer forwarded.



Real Life Scenario:
**Shareholders'
Meeting**



https://www.ernw.de/download/Attacking_MLD.mp4

Mitigation



Sysadmin Perspective



- └ Filter MLD Queries on the switch port level
 - └ Like “MLD Guard” (not – yet – existent).
 - └ = Port based ACL filtering ICMPv6 type 130
 - └ `deny icmp any any mld-query`
- └ Alternatively, in a MLD snooping scenario statically configure a port as an **mrouter** port.

Sysadmin Perspective (II)



- On routers specify a limit on the rate that MLD Reports should be accepted from each host. MUST drop all the reports that exceed this limit.
- Consider “no ipv6 mld router” if there’s no inter-domain multicast routing in the environment.

Sysadmin Perspective (III)



- At switches with MLD-snooping enabled:
 - You might use *static-group* to protect critical multicast based services (e.g. DHCPv6)
 - Keep operational impact/effort in mind ;-)
 - MLD snooping listener message suppression is enabled by default → forwards **only one** MLD report per response to multicast router queries.
 - If technically possible, limit the rate at which MLD messages are accepted by nodes.

In the Standards Space



- **MLDv2:** Routers shouldn't accept Queries destined to **FF02::2**, **FF02::16**, or unicast addresses (link-local or global).
- **MLDv1:** Nodes **MUST** not accept Reports to their unicast addresses (not even for debugging purposes).
- **Both:** Do not permit querier role take over by simply using a “lower” IPv6 address.

Standards Space

Filtering of MLD by port-/VLAN-based
ACL would currently (May 2016) look like

```
deny icmp any any mld-query
```

At some point "mld_guard" might be
available in vendor space.

[\[Docs\]](#) [\[txt\]](#) [\[pdf\]](#) [\[xml\]](#) [\[html\]](#) [\[Tracker\]](#) [\[Email\]](#) [\[Diff1\]](#) [\[Diff2\]](#) [\[Nits\]](#)

Versions: [00](#) [01](#)

IP Multicast

Internet-Draft

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December 24, 2015

MLD Security

draft-vyncke-pim-mld-security-01

Abstract

The latest version of Multicast Listener Discovery protocol is defined in [RFC 3810](#), dated back in 2004, while the first version of MLD, which is still in use and has not been deprecated, is defined in [RFC 2710](#) and is dated back in 1999. New security research has exhibited new vulnerabilities in MLD, both remote and local attack vectors. This document describes those vulnerabilities and proposes specific mitigation techniques.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Provider Space

Role of MLD on CPEs?



- RFC 7084 Basic Requirements for IPv6 Customer Edge Routers states (sect. 3.2):
"For IPv6 multicast traffic, the IPv6 CE router may act as a Multicast Listener Discovery (MLD) proxy [RFC4605] and may support a dynamic multicast routing protocol."
- Supposedly, as of today, most CPEs don't perform any MLD related roles.
Even if they did, Homenet is not the space where relevant attacks would happen anyway. As opposed to data center/hosting...

Conclusions



- With IPv6 there comes a helper protocol called MLD
 - It's complex & somewhat flawed, we think.
 - It's ubiquitous.
 - There's quite some potential for abuse
 - Local amplification attacks.
 - Disruption of network services.
- Taking proper care of it is basic infrastructure hygiene in IPv6 networks.
 - Namely in enterprise and in hosting space.

There's never enough time...

THANK YOU...



...for yours!

Tool & Slides:

<https://www.insinuator.net>

<http://www.secfu.net/tools-scripts/>

Questions?



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His thesis:

https://www.its.fh-muenster.de/doc/Security_Implications_of_MLD_in_IPv6_Networks.pdf

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