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Evaluation of IPv6 Capabilities of Commercial IPAM Solutions

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1 INTRODUCTION

The allocation of addresses from the central Internet Protocol version 4 (IPv4) pool has reached its final depletion. The last blocks of IPv4 addresses have been allocated to the Regional Internet Registries (RIRs). (1) This address space exhaustion and the introduction of IPv6 in enterprise networks results in new challenges, evolving the practice of current network management functions. (2) Moreover, different address types like Privacy Extensions and especially their tracking lead to various requirements as for an IP address management solution.

The term IP Address Management (IPAM) defines a technology that can be subdivided into three main categories:

Managing and tracking an IP address inventory, including allocation of private and public IPv6 address space to subnets, address pools, devices, users and locations. Branches are opened, offices move, making IP networks constantly change and the tracking of allocated or available IP addresses increasingly complex. (2)

Secondly, providing DHCP services to dynamically assign and track these IP address pools to nodes, location or any kind of device on the network is another function defining an IPAM solution.

The last key function of an IPAM solution is the management of IP name services. Using names instead of IP addresses simplifies IP communication for humans. (2)

These features result in several requirements. In the context of a Bachelor Thesis, ERNW specified certain requirements from a security perspective. These have been used to evaluate commercial IP Address Management solutions from major vendors. All requirements can be found in Chapter 2. All IP Address Management Solutions and the used test scenarios will be introduced in Chapter 3. Chapter 4 will provide all results that have been achieved by evaluating all IPAM solutions and will provide an itemized statement of all requirements as well as the corresponding fulfillment.

2 DEFINITION OF REQUIREMENTS

The comparison of IPv4 and IPv6 clarifies that not only IPv6 address assignment has become more complex, but also the distribution of additional information such as the default gateway, DNS information or the Maximum Transmission Unit result in a multitude of different requirements. These have to be met from an IP address management solution in order to ensure not only a certain security standard, but also a centralized management in corporate networks. The tracking of different addresses supported by an IPv6 device discovery, integrating in an existing network infrastructure and monitor deployed services such as DNS and DHCP, either by an own appliance or with other instances are just minor requirements to an IP address management solution. It is obvious that certain requirements had to be elaborated and divided into various categories. In the following sections, a description of different requirement is given, which must be met by an IPAM solution to provide certain security standards, or other requirements that are supporting, but not essential needed features, providing abilities for day-to-day IP administrative tasks.

2.1 Mandatory Requirements

IPv6 temporary addresses that expire after a certain lifetime provide unquestionable privacy to the host (and user) and moreover, they hide information that otherwise can allow targeted attacks, for instance a wide-scale Internet-scale hit list. [3]

Not only from an administrative perspective it is advantageous to track such addresses and thus providing an overview of all hosts in the network, but moreover and more important from a security perspective. Tracking addresses with certain lifetimes helps identifying malicious hosts and users as well as helping preventing (further) attacks. An IP address management must provide a centralized management platform combining administrative - and network forensic features and must implement features that allow the tracking of all dynamic address assignments by polling the neighbor cache from network devices. Due to security issues like unencrypted traffic, full support of the Simple Network Management Protocol (SNMP) version 3 must be given for this task. An IPAM solution must also provide the possibility to display the connected switch port including the device's name or Cisco Discovery Protocol (CDP) -type info for all addresses. As dynamic address assignments can either be stateful, stateless or static, an IPAM solution must implement a function to easily identify systems that have various address types. Sorting all different types of addresses must be also supported. As last mandatory requirement, all addresses must be displayed in RFC 5952 compliant manner. [4]

The following list will give an overview about all mandatory requirements: [5]

- Track all dynamic IPv6 address assignments by polling the neighbor cache from network devices
- Support of SNMPv3
- Display connected switch port including devices' names or CDP type info for all addresses
- Sorting addresses according to their categories
- Full support of RFC 5952

2.2 Recommended Requirements

As already introduced, an IP address management also defines the management of IP inventory, including the allocation of private or public IPv6 address space. Furthermore, an IPAM solution should not only provide a centralized management for DNS and DHCPv6 services deployed by its own appliance, but moreover, it should integrate into an existing IPv6 network infrastructure and should provide monitoring functions for the above mentioned services deployed by other instances.

The following list provides an overview over all recommended requirements:

- Management of IP address inventory including the allocation of private and public IPv6 address space
- Integration into existing network infrastructure and provide monitoring capabilities of existing deployed service like DNS and DHCP

2.3 Optional Requirements

As alternatives for existing functional requirements, the following optional requirements have been specified:

- Support other methods than SNMP to gather neighbor cache information by accessing network devices or single hosts via Secure Shell (SSH) and execute appropriate "show" commands
- Ability to easily identify systems that have several types of addresses. For instance static assigned and stateless auto-configured addresses
- Ability to display addresses in other formats, in reports or exported files (e.g. Comma Separated Values (CSV) files)

3 IP ADDRESS MANAGEMENT SOLUTIONS

The selection that led to the IP Address Management solution introduced below is based on two recommendation whitepapers by Gartner and Forrester, both information technology research and advisory companies. [6], [7]

3.1 Alcatel Lucent VitalQIP

With their “runIP” IP address management solution, Alcatel Lucent VitalQIP offers a centralized management solution with built-in DNS and DHCP services, and additionally the possibility to manage and monitor existing “runIP Management Stations” deploying DNS and DHCP. The runIP appliance and the runIP Management Stations are available in a physical and a virtual format and are shipped with the required TCP/IP configuration preconfigured. Alcatel claims to be “in step with IPv6”. [8]

Evaluated Version

- VitalQIP-8_0PR2

3.2 BlueCat Networks

BlueCat offers an IP address management solution (“Proteus”) in both formats, physical as well as virtual. With this IPAM solution, BlueCat provides the possibility to manage not only Windows DNS and DHCP services, but also services deployed by its own “Adonis” appliance, also either physical or virtual. BlueCat Networks claims to provide full support for IPv6. [9]

Evaluated Version

- Proteus (IPAM appliance): 4.06-213.GA.bcn
- Adonis (DNS, DHCPv6 appliance): 7.0.0-247.GA.bcn

3.3 BT Diamond

BT Diamond offers a software-based IP Address Management solution that can either be installed on a Windows or Linux operating system, as well as on its own Sapphire hardware appliances and claims to provide support IPv6. [10]

Evaluated Version

- IPControl Version 6.0

3.4 Infoblox

Infoblox provides an IP address management that allows managing of existing network infrastructure (DNS and DHCP services deployed by Microsoft servers) and additionally, deploying DNS and DHCP services by its own appliance. In contrast to BlueCat, Infoblox offers all IPAM related functions as well as the deployment of DNS and DHCP services in a single solution, either in a physical or virtual format. Like BlueCat Networks, also Infoblox claims to provide full support for IPv6. [11]

Evaluated Version

- NIOS 6.10

3.5 Men&Mice

Offers a software-based IPAM solution that overlays existing DNS and DHCP services in Windows or Linux environments. DNS and DHCP services can also be deployed with an own appliance provided either in hardware or virtual format. Men&Mice claims to support both protocols. [12]

Evaluated Version

- Men&Mice Suite 6.6

3.6 IP Address Management Windows Server 2012R2

With its Server 2012R2 operating system, Microsoft provides a built-in IP address management solution that allows the allocation of IPv6 address space as well as managing DNS and DHCP services from other Microsoft server instances. On their TechNet website, Microsoft claims to provide support for stateless IPv6 address utilization monitoring. [13]

Evaluated Version

- Built-in IP Address Management in Windows Server 2012R2

The IPAM solutions from Alcatel, BlueCat Networks, and Infoblox have been virtualized with the latest version of the VMWare Player (as state of 09/2014). For the software-based IPAM solution from BTDiamond, a Windows Server 2008R2 operating system has been setup, also virtualized with the VMWare Player. The software-based IP Address Management solution from Men&Mice has been installed on the Windows Server 2012R2, also providing DNS and DHCPv6 services. For the built-in IPAM solution from Microsoft, a second Windows Server 2012R2 has been setup and also virtualized with the VMWare Player.

3.7 Testing Scenarios

As dynamic IPv6 address assignments can either be stateful or stateless, different testing scenarios had to be deployed one for each case.

3.7.1 Test Scenario 1: Stateful Address Auto-configuration

In the first testing scenario, a stateful message exchange is used. In this case, hosts obtain their IPv6 address as well as other configuration either from a Microsoft DHCPv6 server or deployed from an own appliance from the corresponding IPAM solution. In order to inform all clients to get their addresses from the DHCPv6 server, the Managed-Flag has been set in the router advertisement.

3.7.2 Test Scenario 2: Stateless Address Auto-configuration

In the second testing scenario, all clients generate their addresses through stateless address auto-configuration (SLAAC) with information provided in router advertisements. Additional information such as DNS related information are distributed through a DHCPv6 server. For this reason, the Other-Config Flag has been set in the router advertisements.

3.8 Clients

In times of Bring your own device (BYOD), networks do not consist of a single type of operating system anymore. Such heterogeneous network environments usually consist of various systems. For this reason, the following clients have been used in order to provide as much market coverage of operating system as possible:

- Windows 8.1 Professional
- Windows 7 Professional N
- Kali Linux, (Kernel: 3.12)
- Mac OS X Mavericks (10.9)

All operating systems are based on a 64-bit architecture and have been patched with the latest updates (state of 09/2014). All Windows clients have joined the Windows domain deployed by a Windows 2012R2 Domain Controller.

3.9 Layer-2 and Layer-3 Network Devices

Polling the neighbor cache from network devices, specified as a mandatory requirement in Chapter 2, requires a Layer-3 network router. For this reason, the following router has been used:

- Cisco 1921 Layer-3 Network Router

Connecting all components to the same link, the following Layer-2 switch has been used:

- Cisco Catalyst 3560-CG Layer-2 Switch

4 RESULTS

4.1 Alcatel Lucent QIP

4.1.1 Stateful Address Auto-configuration

After the virtual machine of the Alcatel IPAM solution has been installed and initially configured on the system, the solution can be accessed through a web interface. The solution offers the possibility to allocate IPv6 pools, blocks and ranges. Figure 1 indicates a created IPv6 range. The dropdown menu does not allow selecting a preferred DHCPv6 server to dynamically assign the network range. Figure 1 also shows the missing DHCPv6 server.

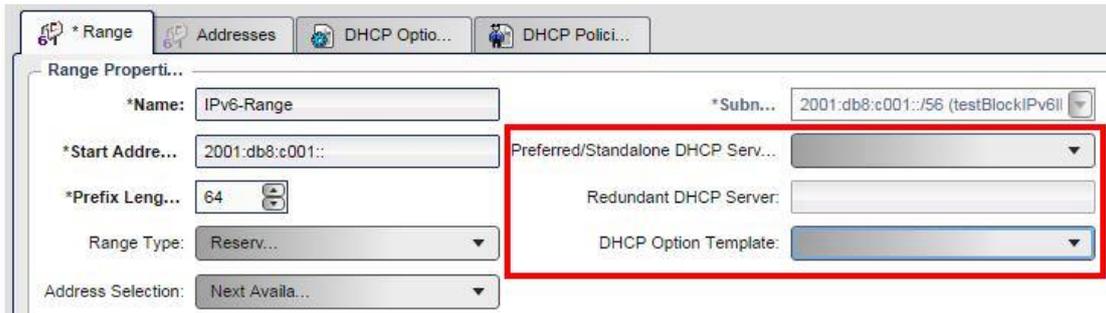


Figure 1 Missing DHCPv6 server Alcatel Lucent QIP

In order to deploy the IPv6 network range, a DHCPv6 server had to be configured. But also by adding a DHCP server, a domain name could not be selected from the corresponding dropdown menu as indicated by Figure 2.

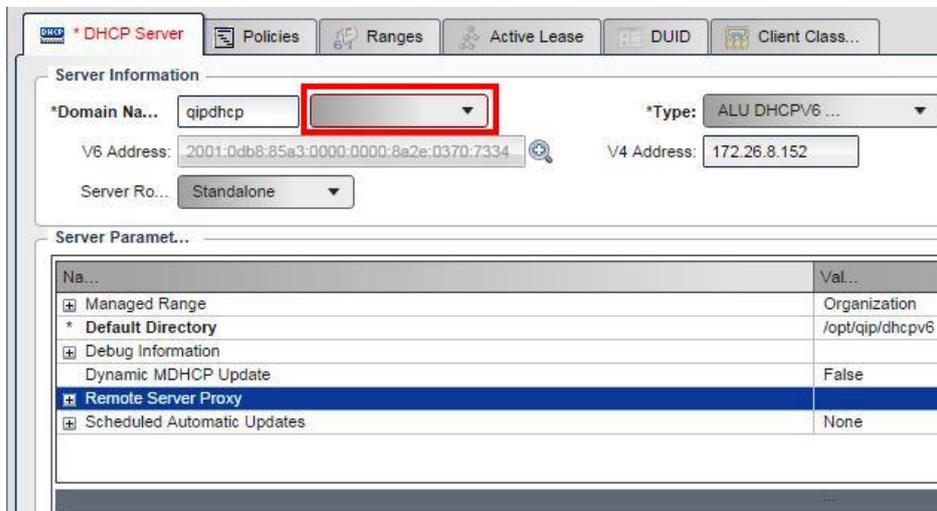


Figure 2 DHCPv6 server Alcatel Lucent QIP

Adding and configuring of a domain controller also required a domain name. As no domain name could be added to the solution, a domain controller could not be configured and deployed. Figure 3 shows a missing domain name in the dropdown menu. Due to these issues, the IPv6 network range shown in Figure 1 could not be assigned and the virtual appliance will not be further examined using stateful auto-configuration.

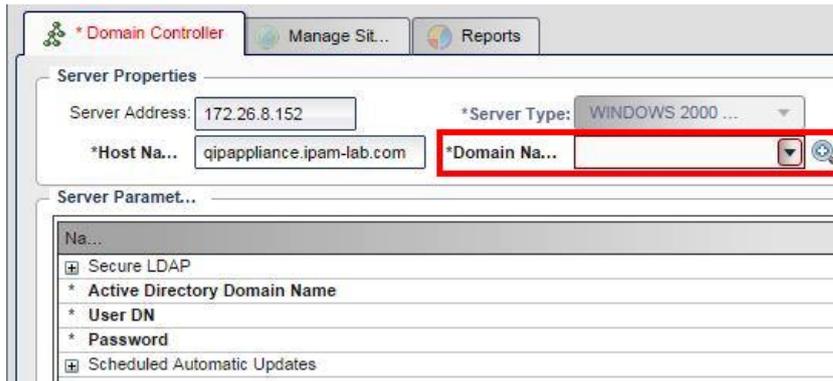


Figure 3 Missing Domain Name Alcatel Lucent QIP Domain Controller

The IPAM solution offers a reporting function that allows exporting data in either a *Hyper Text Markup Language (HTML)* or *Portable Document Format (PDF)* format. Figure 4 shows the missing option to export IPv6 related data.

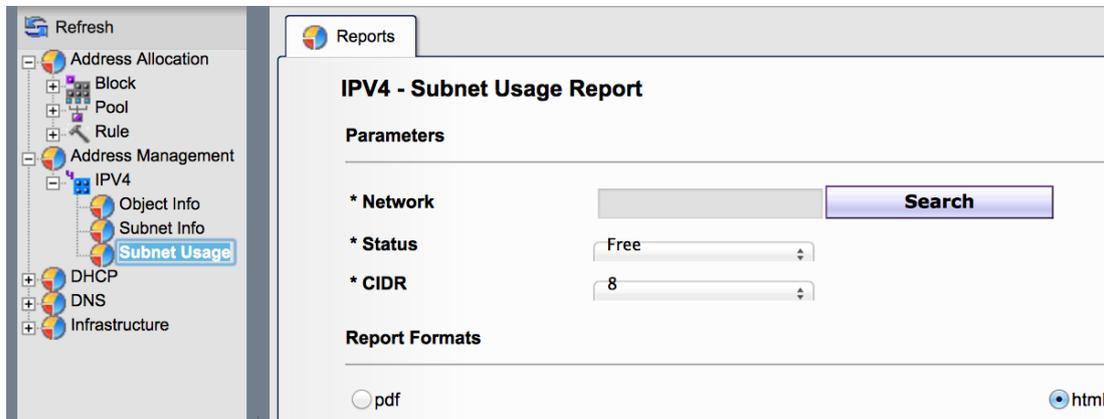


Figure 4 Report function with missing IPv6 data selection

4.1.2 Stateless Address Auto-configuration

As described in section 3.7.2, hosts generate their interface identifier based on information provided in router advertisements. Besides the regular IPv6 address that may either be randomly generated or EUI-64 addresses, hosts generate a second “temporary” IPv6 address called “Privacy Extension”. Tracking such addresses requires polling the IPv6 neighbor cache from network devices. But as the IPAM solution offers no possibility to poll any neighbor cache by using SNMP, the solution will not be evaluated further.

4.1.3 Summary

With the IPAM solution provided by Alcatel, no dynamic IPv6 addresses could be assigned. Furthermore, as SNMP is not supported, the solution offers no possibility to poll any neighbor cache from network devices. Hence, addresses assigned through stateless auto-configuration cannot be tracked. Due to the issue that no domain controller and DHCP server could be deployed, a created network range could not be allocated. Identifying systems with various address types is not supported for this reason. Moreover, exporting IPv6 related data is not supported. IPv6 addresses are displayed in RFC 5952 compliant manner and can be assigned through IPv6 pools and subnets.

4.2 BlueCat Networks

4.2.1 Stateful Address Auto-configuration - DHCPv6 with Adonis appliance

Deploying stateful address auto-configuration with Adonis requires certain steps. First, an IPv6 block has to be set up. Inside this block, a network has to be allocated and another DHCPv6 range has to be defined inside this network. After this configuration is completed, a DHCPv6 role has to be assigned to the Adonis appliance. Once the deployment of the DHCPv6 server has completed successfully, active deployed leases are listed in the interface as Figure 5 indicates.

| DHCPv6 Leases History | | |
|------------------------|---------------------|---------------------|
| Active IP Address ▲ | Lease Time | Expire Time |
| 2001:DB8:C001:CAFE::22 | 18.08.2014 17:29:40 | 19.08.2014 17:29:40 |
| 2001:DB8:C001:CAFE::23 | 18.08.2014 15:44:20 | 19.08.2014 15:44:20 |
| 2001:DB8:C001:CAFE::2B | 18.08.2014 17:33:59 | 19.08.2014 17:51:29 |
| 2001:DB8:C001:CAFE::35 | 18.08.2014 15:44:10 | 19.08.2014 15:44:10 |
| 2001:DB8:C001:CAFE::39 | 18.08.2014 15:45:33 | 19.08.2014 15:45:33 |
| 2001:DB8:C001:CAFE::3E | 18.08.2014 16:06:32 | 19.08.2014 16:06:35 |
| 2001:DB8:C001:CAFE::40 | 18.08.2014 15:43:04 | 19.08.2014 17:29:38 |

Figure 5 Active DHCPv6 Leases

All active IPv6 addresses are displayed and can be sorted ascending or descending. Figure 6 shows all active IPv6 addresses.

| Addresses | | | |
|--------------------------|------------------------------------------------------------------------------------------------------------|---------------------|--|
| New ▼ | | Action ▼ | |
| <input type="checkbox"/> | Active IP Address ▲ | Interface ID | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE:: | 0000:0000:0000:0000 | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE::22 | 0000:0000:0000:0022 | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE::23 | 0000:0000:0000:0023 | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE::2B | 0000:0000:0000:002B | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE::35 | 0000:0000:0000:0035 | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE::39 | 0000:0000:0000:0039 | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE::3E | 0000:0000:0000:003E | |
| <input type="checkbox"/> |  2001:DB8:C001:CAFE::40 | 0000:0000:0000:0040 | |

Figure 6 Active IPv6 addresses

Furthermore, the solution also provides the possibility to get a summarized view with additional information, for instance such as the DUID, by selecting an address deployed through DHCPv6. With the *DHCPv6 Unique Identifier (DUID)*, nodes identify themselves to servers and vice versa. [14] With this unique identifier the corresponding MAC addresses can be derived. Figure 7 shows the summary page of a selected IPv6 address.

| General | |
|---------------------|-------------------------------------------|
| Object ID: | 68 |
| Name: | |
| State: | DHCP Allocated |
| Client DUID: | 00-01-00-01-1B-63-D0-9A-8C-29-37-E5-AD-E0 |
| Client IAID: | 00-00-00-00 |
| Lease Time: | Aug 18, 2014 5:29:40 PM |
| Expire Time: | Aug 19, 2014 5:29:40 PM |

Figure 7 Summary of an allocated IPv6 address

4.2.2 Using Windows as DHCPv6 Server

With their *DDW (DNS and DHCP for Windows)* software, BlueCat Networks also offers an overlaying IPAM solution that allows the management of DNS and DHCP services deployed by a Windows server. After several inquiries to the support of BlueCat Networks, It was recommended not install and use the software. Because of the beta-stadium of the software, this component of the IPAM solution offered by BlueCat will not be further examined.

4.2.3 Stateless Address Auto-configuration

IPv6 devices that generate their interface identifier by using stateless auto-configuration are required to be clearly distinguished from identifiers assigned through stateful auto-configuration. For this reason, BlueCat does not only provide displaying stateful assigned leases as described in Chapter 4.2.1, but it also implements an IPv6 device discovery named *Reconciliation Policy*, which can either be used manually, or automatically with a task scheduler. Once this policy has been configured and started, it polls the neighbor cache form added network devices by using the Simple Network Management Protocol. Although the policy initially uses SNMPv1, SNMPv3 is also supported. Figure 8 shows all addresses from the neighbor cache polled from an *Open Systems Interconnection (OSI)* Layer-3 network device. All IPv6 addresses from all clients used in the evaluation are listed in the "IPv6 Reconciliation" section including also temporary addresses.

| IPv6 Reconciliation | |
|-----------------------------------------------------------------|-------------------|
| Action ▾ | |
| IP Address | MAC Address |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:E568:672D:4380:E20E | 08-00-27-A7-89-E7 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:B850:1A7B:4E40:ABC3 | 00-30-48-D4-52-D0 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:CF7E:56F4:2176:6FD9 | 1C-AF-F7-E3-45-2D |
| <input type="checkbox"/> 2001:DB8:C001:CAFE::2 | 1C-1D-86-69-C9-41 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE::3 | 00-0C-29-61-3D-45 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:211:6BFF:FE73:8653 | 00-11-6B-73-86-53 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:215:5DFF:FE08:9703 | 00-15-5D-08-97-03 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:A00:27FF:FE3B:BE54 | 08-00-27-3B-BE-54 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:3971:6712:454D:2E88 | A0-48-1C-DC-97-66 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE::1 | F0-F7-55-7F-BD-E1 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:4439:4405:ECEA:2263 | 00-15-5D-08-97-02 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:81F4:2BE8:7717:DA4 | 00-11-6B-73-86-53 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:95E7:1521:6BE9:16AD | 00-15-5D-08-97-02 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:2C6A:EF95:691B:F080 | 1C-AF-F7-E3-45-2D |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:A566:5EEF:E821:1B4C | 00-15-5D-08-97-01 |
| <input type="checkbox"/> 2001:DB8:C001:CAFE:B93F:33D3:23E1:6FC1 | 00-15-5D-08-97-01 |

Figure 8 Reconciled IPv6 addresses

By selecting an address, a summary page opens showing all additional information discovered by the reconciliation policy including the connected router port, the client is connected to, first and last detection as well as the MAC address of the device. Figure 9 shows a summary page of a discovered device.

| General | |
|------------------------------------|------------------------------------------------------------|
| IP Address: | 2001:DB8:C001:CAFE:CF7E:56F4:2176:6FD9 |
| Type: | Unknown |
| Reconciliation Result: | Not Reconciled |
| First Detection: | 18.08.2014 15:47:50 |
| Last Detection: | 18.08.2014 23:06:39 |
| FQDN: | |
| MAC Address: | 1C-AF-F7-E3-45-2D |
| Configuration ID: | 5 |
| Connected Router Port: | 2001:DB8:C001:CAFE::2 (ipam_ipv6_switch) : 10 (Vlan10) |
| Connected Switch Port: | |
| Network: | 2001:DB8:C001:CAFE::/64 |
| Overridden: | No |
| Proteus Discovery State: | Not Allocated |
| Time Since First Detection: | 7 Hour(s) 18Minute(s) |

Figure 9 Summary Page Reconciled Address

The Proteus appliance (BlueCat IPAM appliance) also provides a reporting function, which allows exporting all data in a CSV file. Figure 10 shows an extract from all polled IPv6 addresses exported as CSV file including several information such as the MAC address and the connected router port.

| IP Address | MAC Address | First Detection | Last Detection | Connected Router Port |
|----------------------------------------|-------------------|---------------------|---------------------|-------------------------------------------------------------|
| 2001:DB8:C001:CAFE:E568:672D:4380:E20E | 08-00-27-A7-89-E7 | 18.08.2014 23:06:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:B850:1A7B:4E40:ABC3 | 00-30-48-D4-52-D0 | 18.08.2014 15:47:50 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::2 (ipam_ipv6_switch) : 10 (Vlan10) |
| 2001:DB8:C001:CAFE:CF7E:56F4:2176:6FD9 | 1C-AF-F7-E3-45-2D | 18.08.2014 15:47:50 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::2 (ipam_ipv6_switch) : 10 (Vlan10) |
| 2001:DB8:C001:CAFE::2 | 1C-1D-86-69-C9-41 | 18.08.2014 16:09:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE::3 | 00-0C-29-61-3D-45 | 12.08.2014 17:57:31 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:211:68FF:FE73:8653 | 00-11-6B-73-86-53 | 18.08.2014 23:06:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:215:5DFF:FE08:9703 | 00-15-5D-08-97-03 | 18.08.2014 23:06:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:A00:27FF:FE3B:BE54 | 08-00-27-3B-BE-54 | 18.08.2014 23:06:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:3971:6712:454D:2E88 | A0-48-1C-DC-97-66 | 18.08.2014 19:07:37 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE::1 | F0-F7-55-7F-BD-E1 | 18.08.2014 15:47:50 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::2 (ipam_ipv6_switch) : 10 (Vlan10) |
| 2001:DB8:C001:CAFE:4439:4405:ECEA:2263 | 00-15-5D-08-97-02 | 18.08.2014 17:19:02 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:81F4:2BE8:7717:DA4 | 00-11-6B-73-86-53 | 18.08.2014 23:06:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:95E7:1521:6BE9:16AD | 00-15-5D-08-97-02 | 18.08.2014 23:06:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:2C6A:EF95:691B:F080 | 1C-AF-F7-E3-45-2D | 18.08.2014 19:07:37 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::2 (ipam_ipv6_switch) : 10 (Vlan10) |
| 2001:DB8:C001:CAFE:A566:5EEF:E821:1B4C | 00-15-5D-08-97-01 | 18.08.2014 23:06:35 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |
| 2001:DB8:C001:CAFE:B93F:33D3:23E1:6FC1 | 00-15-5D-08-97-01 | 18.08.2014 15:47:50 | 18.08.2014 23:06:35 | 2001:DB8:C001:CAFE::1 (Router) : 3 (GigabitEthernet0/1) |

Figure 10 CSV Export Reconciled IPv6 Addresses

4.2.4 Summary

BlueCat Networks provides an IPv6 IP address management solution that supports both, stateful as well as stateless address auto-configuration. Deploying DHCPv6 with the Adonis appliance allows displaying all leases and the corresponding addresses in the management interface including showing additional information such as the DUID from an IPv6 device. Configuring and running the reconciliation policy discovers addresses that have been assigned through stateless auto-configuration. The possibility to display all active deployed leases offers the opportunity to sort addresses according to their categories. Each address on the neighbor cache of network device is polled via SNMP and listed in the management interface. This allows IPv6 addresses to be tracked either with stateless – and/or stateful auto-configuration with DHCPv6. BlueCat also supports SNMPv3 for this task. Furthermore, information provided in a summary page of reconciled IPv6 devices includes the MAC address of the device as well as the connected router and switch port. All addresses are displayed in uppercase letters. Searching for IPv6 addresses is supported in RFC 5952 compliant manner though. The solution also provides a reporting function, allowing exporting all data as CSV files. Furthermore, the solution offers an IP address inventory that allows allocating private and public address space and blocks in a hierarchical structure.

4.3 BT Diamond

4.3.1 Stateful Address Auto-configuration

The initial configuration dialog indicated by Figure 11 allows choosing between different vendors in a dropdown menu. After Windows 2008 DHCPv6 was chosen, the radio button, which is required to be checked in order to add the DHCPv6 version, deactivates.



Figure 11 Missing DHCPv6 option in BT Diamond DHCP server configuration dialog

The solution offers the opportunity to create IPv6 blocks and network elements. Inside these allocated blocks, no more sub networks can be assigned. The solution does not provide any functions to allocate private and / or public IPv6 address space. Figure 12 shows an allocated IPv6 block with the missing option for further assignments.



Figure 12 BT Diamond IPv6 block in control

Additionally, the created IPv6 block is not listed in the overview of the solution as indicated by Figure 13.

IPControl™

IP Address Planning and Management System

Version 6.0 Build 57

Address Block Information:

Current Public IPv4 Space: **0**
 Current Private IPv4 Space: **0**
 Current total IPv4 Space: **0**
 Maximum Allowed IPv4 Space: **Unlimited**
 Current Number of IPv6 /64 Blocks: **0**
 Maximum Allowed IPv6 /64 Blocks: **4.294.967.296**

Figure 13 Missing IPv6 address block information BT Diamond IPControl

The solution also offers the capability of exporting all blocks in the following formats: CSV, PDF, XML and as a spreadsheet in the Microsoft Office Excel format. Although an IPv6 block has been created and exported, no data was listed in any of the above-mentioned formats. Figure 14 shows all formats available to export data.

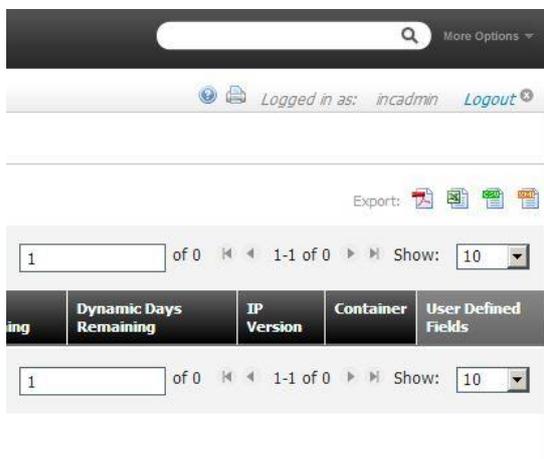


Figure 14 Export formats BT Diamond IPControl

4.3.2 Stateless Address Auto-configuration

The software-based solution from BT Diamond provides a discovery manager to poll information from network devices. This requires adding network elements such as router to the management of the IPAM solution. The following screenshots indicates an added Cisco router with an IPv6 address as such a network element. Figure 15 shows that support of SNMPv3 is also supported by the solution.

Edit Network Element

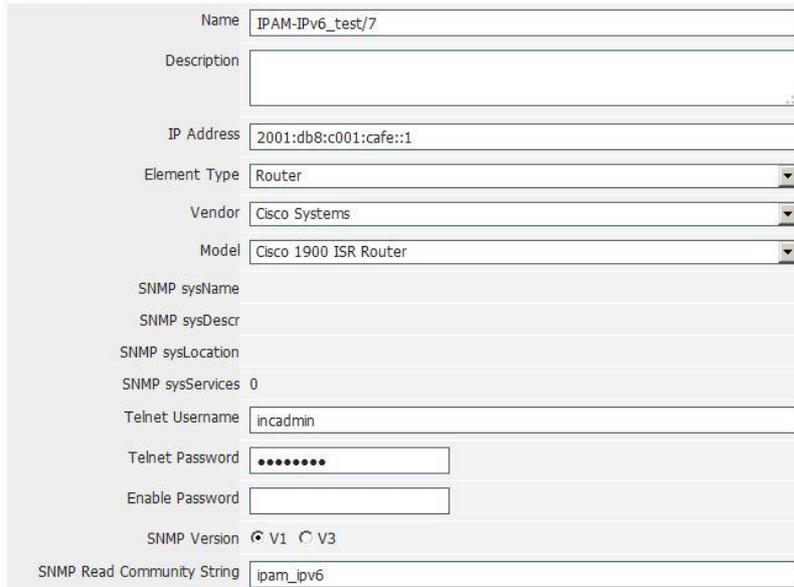


Figure 15 IPv6 Network Element

Although network elements with IPv6 addresses can be added to the discovery manager, the solution only provides support to poll information such as the *Address Resolution Protocol (ARP)* cache from network devices with IPv4 addresses. Polling IPv6 related information such as the neighbor cache is not implemented. Figure 16 shows all available options that can be chosen to gather information from network devices in which the support for polling an IPv6 neighbor cache is not included.

Discovery/Collector Task Definition

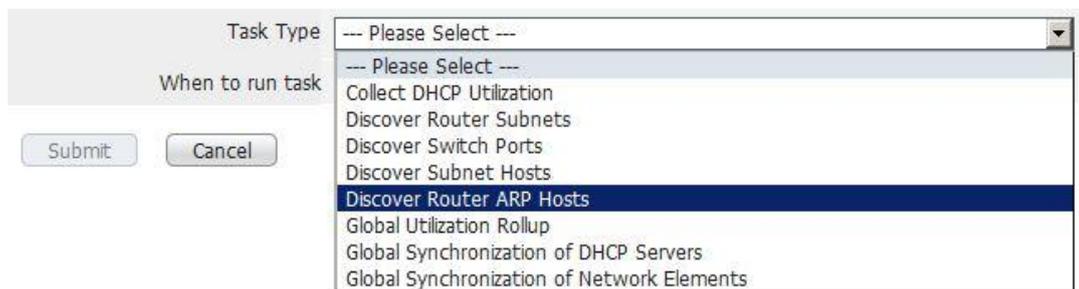


Figure 16 Discovery Manager BTDiamond

4.3.3 Summary

BT Diamond provides an overlaid software-based IPAM solution, which does not fulfill any of the mandatory requirements. Executive agents running on the Windows Server can only be configured with IPv4 addresses. For this reason, network devices with IPv6 addresses cannot be contacted to poll any IPv6 information, for instance the

neighbor cache from these devices. As described in section 4.3.1, the solution provides the possibility to allocate IPv6 blocks but no more assignments such as IPv6 ranges and sub networks can be performed. An implemented function allows exporting data in various formats. Although an IPv6 block has been created and exported, no data was displayed. The address of the IPv6 block is displayed in RFC 5952 compliant manner.

4.4 Infoblox

The DDI (DNS, DHCP and IPAM) appliance from Infoblox allows deploying DNS and DHCPv6 servers as well as adding additional servers such as Microsoft servers to the management of the appliance. In the following, two scenarios are described:

- Stateful address auto-configuration via DHCPv6 with Microsoft 2012R2 server
- Stateful address auto-configuration via DHCPv6 with DDI appliance

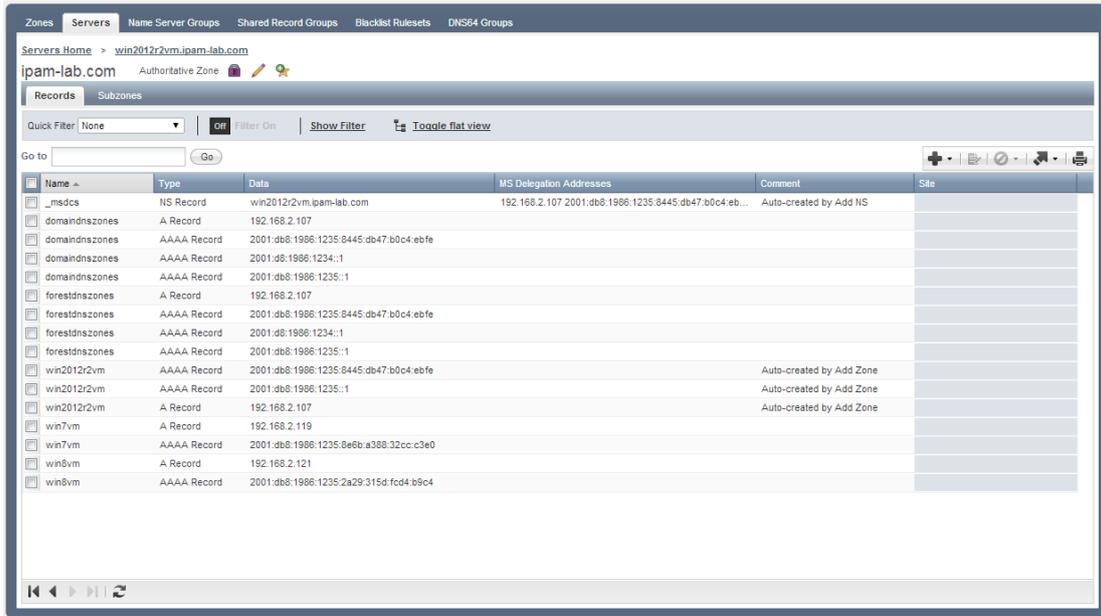
4.4.1 DHCPv6 with Microsoft Windows 2012R2 Server

The DDI appliance allows managing DNS and DHCP services from added Microsoft servers. Figure 17 indicates an existing IPv4 DHCP scope on the Microsoft server and a static IPv6 network range. The existing DHCPv6 scope on the server is not listed.



Figure 17 Missing DHCPv6 utilization

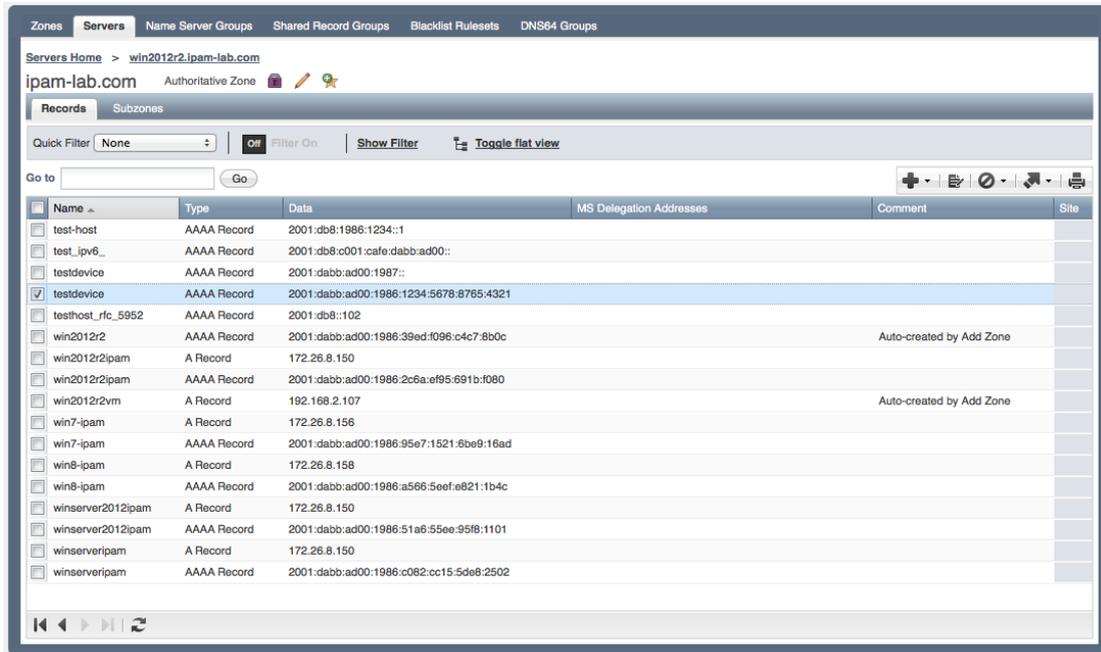
The DDI appliance also provides DNS information about existing zones from Microsoft servers added to the management of the appliance. Existing zones with corresponding A and AAAA records can be displayed by expanding the zone. This allows tracking of dynamic assigned addresses from hosts registered in DNS zones deployed by a Microsoft server. According to the used clients, all Windows clients are listed with the dynamic IPv6 address. Temporary addresses are not listed. Furthermore, clients that have not joined the Windows Domain such as MacOS X as well as Debian clients are not listed. Figure 18 shows all records from the expanded zone.



| Name | Type | Data | MS Delegation Addresses | Comment | Site |
|----------------|-------------|------------------------------------------|--------------------------------------------------------|--------------------------|------|
| _msdcs | NS Record | win2012r2vm.ipam-lab.com | 192.168.2.107 2001:db8:1986:1235:8445:db47:b0c4:ebf... | Auto-created by Add NS | |
| domaindnszones | A Record | 192.168.2.107 | | | |
| domaindnszones | AAAA Record | 2001:db8:1986:1235:8445:db47:b0c4:ebf... | | | |
| domaindnszones | AAAA Record | 2001:db8:1986:1234::1 | | | |
| domaindnszones | AAAA Record | 2001:db8:1986:1235::1 | | | |
| forestdnszones | A Record | 192.168.2.107 | | | |
| forestdnszones | AAAA Record | 2001:db8:1986:1235:8445:db47:b0c4:ebf... | | | |
| forestdnszones | AAAA Record | 2001:db8:1986:1234::1 | | | |
| forestdnszones | AAAA Record | 2001:db8:1986:1235::1 | | | |
| win2012r2vm | AAAA Record | 2001:db8:1986:1235:8445:db47:b0c4:ebf... | | Auto-created by Add Zone | |
| win2012r2vm | AAAA Record | 2001:db8:1986:1235::1 | | Auto-created by Add Zone | |
| win2012r2vm | A Record | 192.168.2.107 | | Auto-created by Add Zone | |
| win7vm | A Record | 192.168.2.119 | | | |
| win7vm | AAAA Record | 2001:db8:1986:1235:6e6b:a368:32cc:c3e0 | | | |
| win8vm | A Record | 192.168.2.121 | | | |
| win8vm | AAAA Record | 2001:db8:1986:1235:2a29:315d:fd4:b9c4 | | | |

Figure 18 DHCPv6 host records

By selecting the DNS Tab in the management interface, the solution lists all DNS entries of the Microsoft DNS server. Figure 19 indicates all addresses that have been assigned through stateless auto-configuration. Clients using EUI-64 interface identifier are not listed.



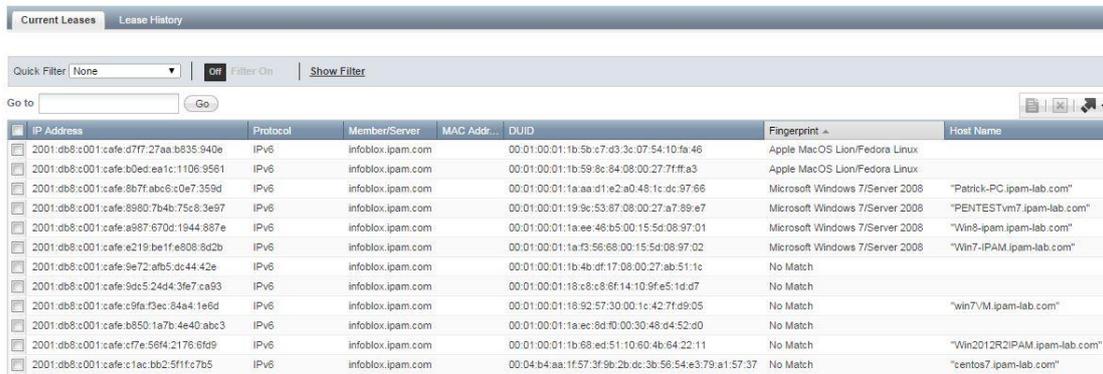
| Name | Type | Data | MS Delegation Addresses | Comment | Site |
|-------------------|-------------|-----------------------------------------|-------------------------|--------------------------|------|
| test-host | AAAA Record | 2001:db8:1986:1234::1 | | | |
| test_ipv6 | AAAA Record | 2001:db8:c001:cafe:dabb:ad00:: | | | |
| testdevice | AAAA Record | 2001:dabb:ad00:1987:: | | | |
| testdevice | AAAA Record | 2001:dabb:ad00:1986:1234:5678:8765:4321 | | | |
| testhost_rfc_5952 | AAAA Record | 2001:db8::102 | | | |
| win2012r2 | AAAA Record | 2001:dabb:ad00:1986:39ed:f096:c4c7:8b0c | | Auto-created by Add Zone | |
| win2012r2ipam | A Record | 172.26.8.150 | | | |
| win2012r2ipam | AAAA Record | 2001:dabb:ad00:1986:2c6a:ef95:691b:f080 | | | |
| win2012r2vm | A Record | 192.168.2.107 | | Auto-created by Add Zone | |
| win7-ipam | A Record | 172.26.8.156 | | | |
| win7-ipam | AAAA Record | 2001:dabb:ad00:1986:95e7:1521:6be9:16ad | | | |
| win8-ipam | A Record | 172.26.8.158 | | | |
| win8-ipam | AAAA Record | 2001:dabb:ad00:1986:a566:5eef:e821:1b4c | | | |
| winserver2012ipam | A Record | 172.26.8.150 | | | |
| winserver2012ipam | AAAA Record | 2001:dabb:ad00:1986:51a6:55ee:95f8:1101 | | | |
| winserveripam | A Record | 172.26.8.150 | | | |
| winserveripam | AAAA Record | 2001:dabb:ad00:1986:c082:cc15:5de8:2502 | | | |

Figure 19 DNS records Microsoft DNS server

4.4.2 DHCPv6 DDI appliance

In the second scenario, the DDI appliance has been setup as a grid master and used to deploy DHCPv6. For this reason, a DHCPv6 range has been configured inside the already existing static IPv6 network and assigned to the grid

master. All active leases deployed from the grid master's DHCPv6 server including all clients are shown in Figure 20 Active leases deployed by DDI appliance With the DUID, not listed MAC addresses from nodes can be inferred.



| IP Address | Protocol | Member/Server | MAC Addr. | DUID | Fingerprint | Host Name |
|----------------------------------------|----------|-------------------|-----------|-------------------------------------------------------|-------------|-----------------------------------------------------------|
| 2001:db8:c001:cafe:d7f7:27aa:b835:940e | IPv6 | infoblox.ipam.com | | 00:01:00:01:1b:5b:c7:d3:3c:07:54:10:fa:46 | | Apple MacOS Lion/Fedora Linux |
| 2001:db8:c001:cafe:b0ed:ea1c:1108:9561 | IPv6 | infoblox.ipam.com | | 00:01:00:01:1b:59:8c:84:08:00:27:7f:fa:3 | | Apple MacOS Lion/Fedora Linux |
| 2001:db8:c001:cafe:8b7f:abc6:c0e7:359d | IPv6 | infoblox.ipam.com | | 00:01:00:01:1a:aa:d1:e2:a0:48:1c:dc:97:66 | | Microsoft Windows 7/Server 2008 "Patrick-PC.ipam-lab.com" |
| 2001:db8:c001:cafe:8980:7b4b:75c8:3e97 | IPv6 | infoblox.ipam.com | | 00:01:00:01:19:9c:53:87:08:00:27:a7:89:e7 | | Microsoft Windows 7/Server 2008 "PENTESTvm7.ipam-lab.com" |
| 2001:db8:c001:cafe:a987:670d:1944:887e | IPv6 | infoblox.ipam.com | | 00:01:00:01:1a:ee:46:b5:00:15:5d:08:97:01 | | Microsoft Windows 7/Server 2008 "Win8-ipam.ipam-lab.com" |
| 2001:db8:c001:cafe:e219:be1fe808:8d2b | IPv6 | infoblox.ipam.com | | 00:01:00:01:1a:f3:56:68:00:15:5d:08:97:02 | | Microsoft Windows 7/Server 2008 "Win7-IPAM.ipam-lab.com" |
| 2001:db8:c001:cafe:9e72:afb5:dc44:42e | IPv6 | infoblox.ipam.com | | 00:01:00:01:1b:4b:df:17:08:00:27:ab:51:1c | | No Match |
| 2001:db8:c001:cafe:9dc5:24d4:3fe7:ca93 | IPv6 | infoblox.ipam.com | | 00:01:00:01:18:c8:c8:6f:14:10:9f:e5:1d:d7 | | No Match |
| 2001:db8:c001:cafe:c9fa:f3ec:84a4:1e6d | IPv6 | infoblox.ipam.com | | 00:01:00:01:18:92:57:30:00:1c:42:7f:d9:05 | | "win7/VM.ipam-lab.com" |
| 2001:db8:c001:cafe:b850:1a7b:4e40:abc3 | IPv6 | infoblox.ipam.com | | 00:01:00:01:1a:ec:8d:f0:00:30:48:d4:52:d0 | | No Match |
| 2001:db8:c001:cafe:c7fe:56f4:2176:649 | IPv6 | infoblox.ipam.com | | 00:01:00:01:1b:68:ed:51:10:60:4b:64:22:11 | | No Match |
| 2001:db8:c001:cafe:c1ac:b02:9f1f:7b5 | IPv6 | infoblox.ipam.com | | 00:04:b4:aa:ff:57:3f:9b:2b:dc:3b:56:54:e3:79:a1:57:37 | | "centos7.ipam-lab.com" |

Figure 20 Active leases deployed by DDI appliance

4.4.3 Network Insight

According to their documentation, Infoblox also offers another appliance that allows discovering IPv6 nodes on the network including the following:

- Routers
- Enterprise Switches
- Firewalls and Security Appliances
- Load Balancers
- Enterprise Printers
- Wireless Access Points
- VoIP Concentrators
- Application Servers
- End hosts

SNMPv3 is also supported for this task. Additionally, if an admin account and credentials are provided, the appliance allows to login to devices via telnet or ssh and query or configure ports. The corresponding data of all discovered devices is automatically loaded into the IPAM database of the DDI (DNS/DHCP/IPAM) appliance.

As the focus of this research project was on all IPAM related functions and appliances, the Network Insight appliance has not been examined.

4.4.4 Summary

Infoblox provides a centralized management platform that also allows deploying DNS and DHCPv6 services. Active leases can be displayed with corresponding DUID, start and end as well as the host name. This allows sorting address according to their category. Temporary addresses that have been assigned with stateless auto-configuration are not listed in the management. All IPv6 addresses are displayed in RFC 5952 compliant manner. Both solutions also provide the possibility to export all addresses in a CSV format. If the Network Insight appliance is added to the grid, all stateless IPv6 addresses can also be tracked by configuring an IPv6 network discovery. All corresponding data is loaded into the IPAM database and can be displayed in the management interface. If privacy extensions are also listed could not be examined.

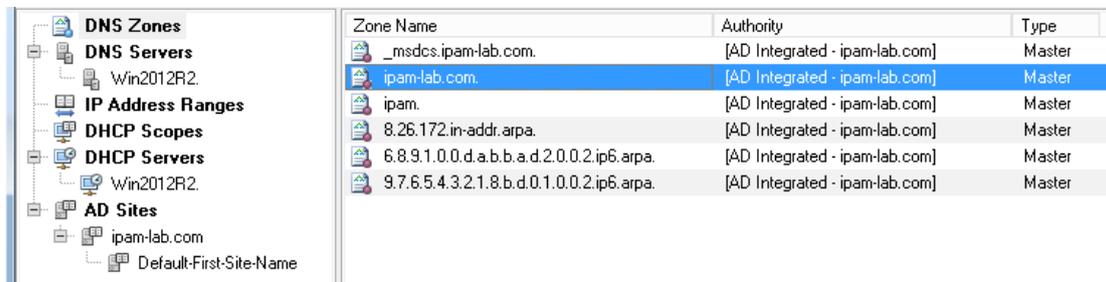
4.5 Men&Mice

4.5.1 Stateful Address Auto-configuration

Men&Mice provides its own DNS and DHCP solutions, but it also supports other corresponding solutions like the ones provided by Microsoft Windows server. In the following, both cases will be examined.

4.5.2 Using Microsoft Windows Server as DNS and DHCPv6 Server

In this test scenario, the Men&Mice IPAM solution has been installed on a Windows DNS and DHCP server. After the installation has completed and the Windows server has been added in the initial configuration dialog, the IP address management suite shows an overview over all existing DNS zones and DHCP scopes of the Microsoft server added to the management of the solution. Furthermore, an IP Address Range is shown which will be described later in this chapter. Figure 21 displays all the DNS Zones as listed from the Windows Server including IPv6 reverse and forward lookup zones.



| Zone Name | Authority | Type |
|-------------------------------------------|--------------------------------|--------|
| _msdcs.ipam-lab.com. | [AD Integrated - ipam-lab.com] | Master |
| ipam-lab.com. | [AD Integrated - ipam-lab.com] | Master |
| ipam. | [AD Integrated - ipam-lab.com] | Master |
| 8.26.172.in-addr.arpa. | [AD Integrated - ipam-lab.com] | Master |
| 6.8.9.1.0.0.d.a.b.b.a.d.2.0.0.2.ip6.arpa. | [AD Integrated - ipam-lab.com] | Master |
| 9.7.6.5.4.3.2.1.8.b.d.0.1.0.0.2.ip6.arpa. | [AD Integrated - ipam-lab.com] | Master |

Figure 21 Overview of DNS Zones, as displayed by Men&Mice

In the Graphical User Interface displayed in the above figure, DNS zones can be expanded showing all A and AAAA records in the zone from hosts registered in a DNS zone with the according timestamp. This allows IPv6 addresses to be tracked implicitly, as long as they have been assigned a DNS entry. The corresponding MAC addresses to in Figure 22 displayed addresses are not listed. Moreover, no temporary IPv6 addresses are displayed. Hence, the tracking of them is not possible.

| Name | TTL | Type | Data | Timestamp |
|-----------------------------|------|------|----------------------------------------|--------------------|
| _ldap_tcp.Default-First-S | 600 | SRV | 0 100 389 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _gc_tcp.ipam-lab.com. | 600 | SRV | 0 100 3268 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _kerberos_tcp.ipam-lab.com. | 600 | SRV | 0 100 88 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _kpasswd_tcp.ipam-lab.com. | 600 | SRV | 0 100 464 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _ldap_tcp.ipam-lab.com. | 600 | SRV | 0 100 389 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _kerberos_udp.ipam-lab.com. | 600 | SRV | 0 100 88 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _kpasswd_udp.ipam-lab.com. | 600 | SRV | 0 100 464 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| DomainDnsZones.ipam-l. | 600 | A | 192.168.2.107 | Aug 5, 2014 16:00 |
| DomainDnsZones.ipam-l. | 600 | AAAA | 2001:db8:1986:1234::1 | Aug 5, 2014 12:00 |
| _ldap_tcp.Default-First-S | 600 | SRV | 0 100 389 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _ldap_tcp.DomainDnsZ | 600 | SRV | 0 100 389 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| ForestDnsZones.ipam-lal | 600 | A | 192.168.2.107 | Aug 5, 2014 16:00 |
| ForestDnsZones.ipam-lal | 600 | AAAA | 2001:db8:1986:1234::1 | Aug 5, 2014 12:00 |
| _ldap_tcp.Default-First-S | 600 | SRV | 0 100 389 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| _ldap_tcp.ForestDnsZor | 600 | SRV | 0 100 389 win2012r2vm.ipam-lab.com. | Aug 5, 2014 12:00 |
| win2012r2vm.ipam-lab.c | 1200 | A | 192.168.2.107 | |
| WIN7VM.ipam-lab.com. | 1200 | A | 192.168.2.119 | Aug 10, 2014 15:00 |
| WIN8VM.ipam-lab.com. | 1200 | A | 192.168.2.121 | Aug 10, 2014 15:00 |
| ipam-lab.com. | 600 | AAAA | 2001:db8:1986:1235::1 | Aug 10, 2014 15:00 |
| ipam-lab.com. | 600 | AAAA | 2001:db8:1986:1235:8445:db47:b0c4:ebfe | Aug 10, 2014 15:00 |
| DomainDnsZones.ipam-l | 600 | AAAA | 2001:db8:1986:1235::1 | Aug 10, 2014 15:00 |
| DomainDnsZones.ipam-l | 600 | AAAA | 2001:db8:1986:1235:8445:db47:b0c4:ebfe | Aug 10, 2014 15:00 |
| ForestDnsZones.ipam-lal | 600 | AAAA | 2001:db8:1986:1235::1 | Aug 10, 2014 15:00 |
| ForestDnsZones.ipam-lal | 600 | AAAA | 2001:db8:1986:1235:8445:db47:b0c4:ebfe | Aug 10, 2014 15:00 |
| win2012r2vm.ipam-lab.c | 1200 | AAAA | 2001:db8:1986:1235::1 | |
| win2012r2vm.ipam-lab.c | 1200 | AAAA | 2001:db8:1986:1235:8445:db47:b0c4:ebfe | |
| WIN7VM | 1200 | AAAA | 2001:db8:1986:1235:8e6b:a388:32cc:c3e0 | Aug 10, 2014 15:00 |
| WIN8VM.ipam-lab.com. | 1200 | AAAA | 2001:db8:1986:1235:2a29:315d:fed4:b9c4 | Aug 10, 2014 15:00 |

34 records AD integrated

Figure 22 DNS records of DHCPv6 clients

Additionally, Men&Mice provides several DNS options including Round Robin records and finding orphaned PTR records. Figure 23 shows all Round Robin records in a DNS zone, while Figure 24 shows all orphaned records listed with no matching A or AAAA record.

Round Robin Records

Click the Start button to search for Round Robin records. When the search is complete, you can delete individual records from the list below

Name

- Win2012R2IPAM
- Win2012R2IPAM
- testdevice
- testdevice
- win2012r2
- win2012r2

Figure 23 Round Robin records

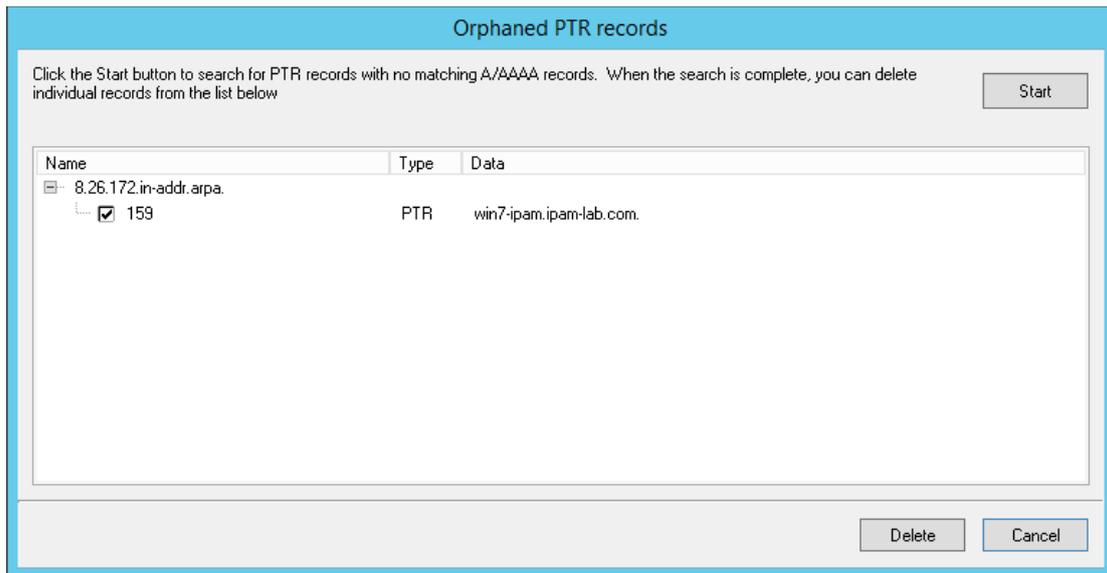


Figure 24 Orphaned PTR records

In the "DHCP Scopes" section, only IPv4 scopes are listed. DHCPv6 is not supported in the latest version. Therefore, all IPv6 scopes configured on the Windows DHCP server are not listed in the management interface. Figure 25 shows an IPv4 scope created to exemplify, that only IPv4 scopes are displayed.



Figure 25 DHCP scope list

In the "IP Address Ranges" tab, static IPv6 ranges can be created in an existing container. As there is no support for DHCPv6 in the used version, a static IPv6 range with a prefix length of 64 has been created in order to evaluate additional functionalities of the IP address management solution. The context menu from the created range allows splitting the range into sub ranges, viewing the address utilization as well as generating IPv6 reverse zones with *Active Directory (AD)* zone replication. Generated IPv6 reverse zones are listed in the DNS Zones section after the zone has been created. Figure 26 show the creation of an IPv6 reverse zone with active directory replication.

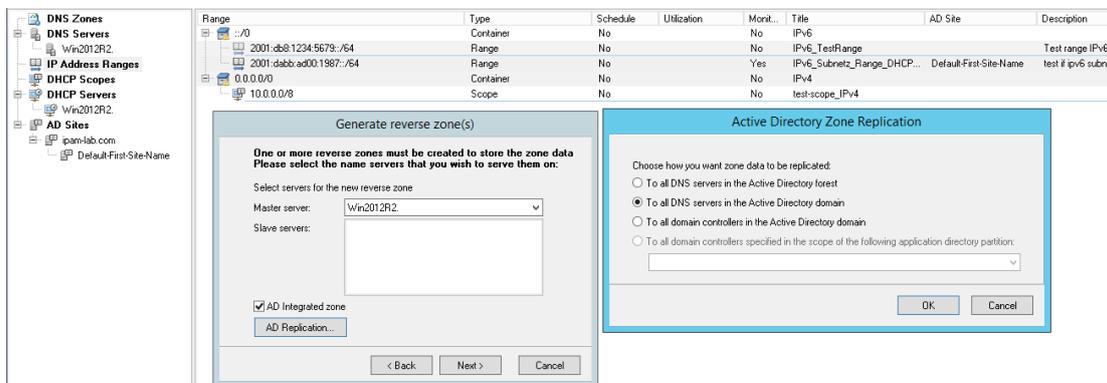


Figure 26 Creation of an IPv6 reverse zone with AD replication

Furthermore, inside IPv6 address ranges, static available IPv6 addresses can be assigned. Options in the context menu of the assigned addresses allow modifying the address, pinging the address as well as linking the address to a device. As no DHCPv6 leases can be displayed in the absence of DHCPv6 support, a non-allocated IPv6 address has been assigned and linked to a device. If no device has been created yet, another option allows creating a new device and associating the address. Entering a name as well as the hardware's (MAC) address of the device is required for this step. Figure 27 shows the addition of a host to the management interface.

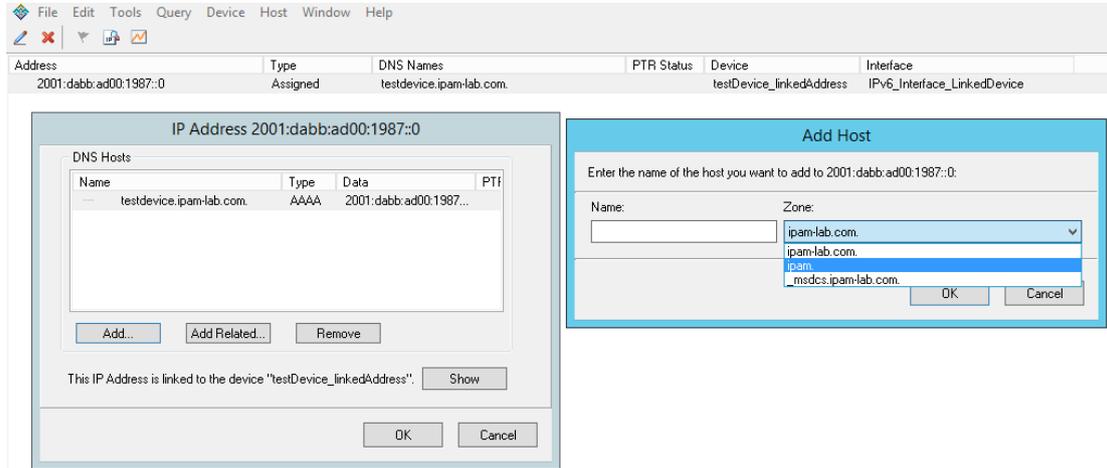


Figure 27 Adding a static IPv6 host

All IPv6 addresses of added and existing hosts, as well as devices in the management interface are displayed in lowercase characters. Based on the several options, the management interface allows searching for a host or a device. In order to evaluate the support of RFC 5952, the following host has been added to the management interface:

- 2001:0DB8:0000:0000:0000:0000:0102

Figure 28 shows the added device with the configured address following all rules specified in RFC 5952.

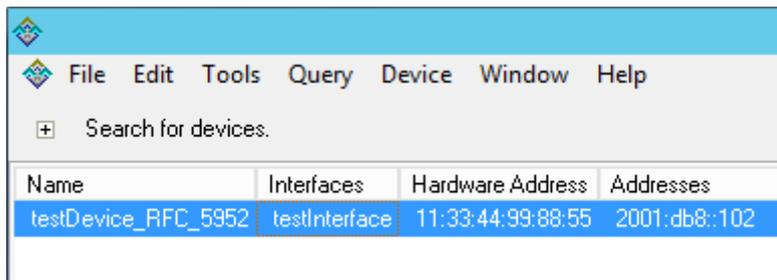
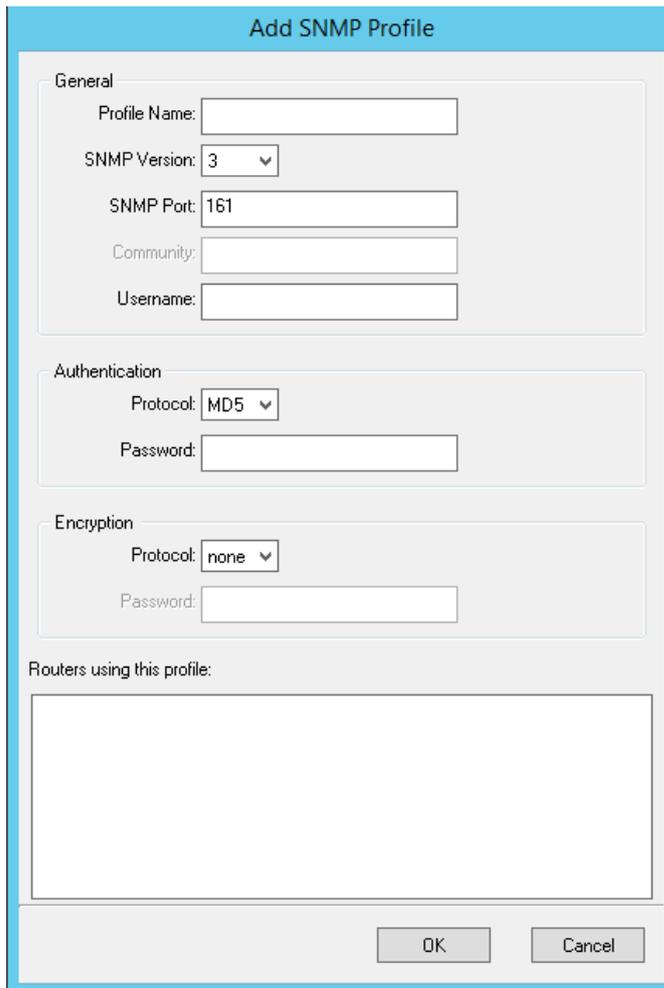


Figure 28 Device Address RFC5952 compliant

The System settings of the solution allow creating SNMP profiles. These profiles are used to poll the ARP caches from IPv4 network devices and hosts. As Figure 29 shows, SNMPv3 is also supported.



Add SNMP Profile

General

Profile Name:

SNMP Version: 3

SNMP Port:

Community:

Username:

Authentication

Protocol: MD5

Password:

Encryption

Protocol: none

Password:

Routers using this profile:

Figure 29 Support of SNMPv3

However, since polling IPv6 addresses from network devices' caches is not supported, SNMP is not going to be further examined in this solution. Men&Mice also provides the feature to export all data as for examples DNS zones as .txt files. Figure 30 shows an exported DNS zone as a .txt file.

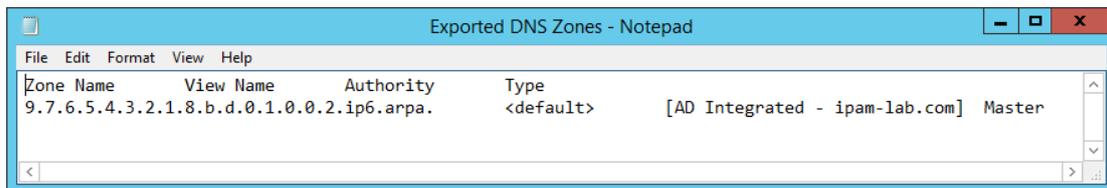


Figure 30 Exported DNS zone

Moreover, the maintenance menu of this solution allows exporting the address utilization from IP address ranges. Data from the last 24 hours, last week and last month can be exported as CSV files. Figure 31 shows an excerpt from an exported IPv6 range as a CSV file.


```

ca. Administrator: Command Prompt

C:\Users\elsaesser>ipconfig

Windows IP Configuration

Ethernet adapter Local Area Connection 3:

    Connection-specific DNS Suffix  . : test.example.com
    IPv6 Address. . . . . : 2001:db8:c001:cafe::9e6d
    Link-local IPv6 Address . . . . . : fe80::98f5:ad83:3b31:88ff%18
    IPv4 Address. . . . . : 192.168.2.119
    Subnet Mask . . . . . : 255.255.255.0
    Default Gateway . . . . . : fe80::a00:27ff:fe24:22e%18
                                192.168.2.1

Tunnel adapter isatap.{514797D8-03F1-4E28-A685-7520696D4ACF}:

    Media State . . . . . : Media disconnected
    Connection-specific DNS Suffix  . : test.example.com

Tunnel adapter Local Area Connection* 11:

    Media State . . . . . : Media disconnected
    Connection-specific DNS Suffix  . :

C:\Users\elsaesser>
  
```

Figure 33 Windows 7 Terminal with ISC DHCPv6 assigned address

Figure 34 also indicates the deployed and active lease.

```

root@ubuntuVM: /var/lib/dhcp
root@ubuntuVM:/var/lib/dhcp# cat dhcpd6.leases
# The format of this file is documented in the dhcpd.leases(5) manual page.
# This lease file was written by isc-dhcp-4.2.4

server-uid "\000\001\000\001\033\213\276k\010\000'$\002.";

ia-na "\000\010\025\000\001\000\001\030\222W0\000\034B\177\331\005" {
  cltt 6 2014/08/23 23:05:34;
  iaaddr 2001:db8:c001:cafe::9e6d {
    binding state active;
    preferred-life 604800;
    max-life 2592000;
    ends 1 2014/09/22 23:05:34;
  }
}
root@ubuntuVM:/var/lib/dhcp#
  
```

Figure 34 ISC DHCPv6 leases

After the Ubuntu virtual machine has been added to the management of the Men&Mice IPAM solution, it is listed as DHCP server in the interface. As Figure 35 indicates, the configured DHCPv6 scope on the Ubuntu VM is not listed.

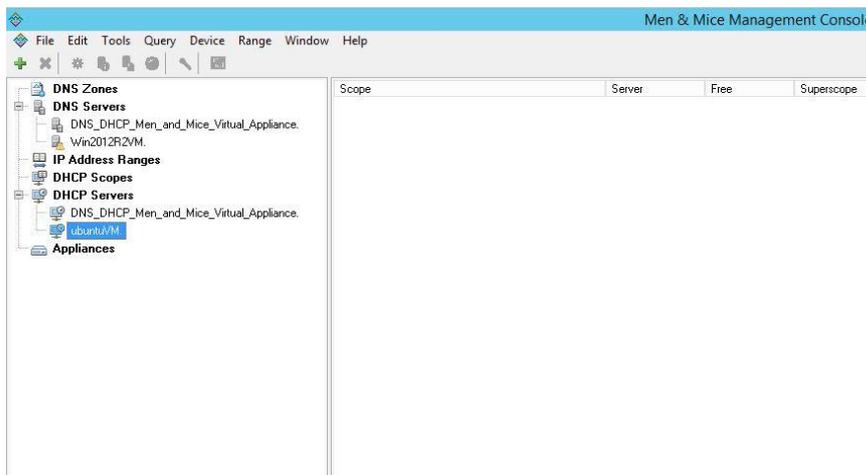


Figure 35 Missing ISC DHCPv6 scope

Figure 36 also shows the missing option to create a DHCPv6 scope with the ISC DHCP server.

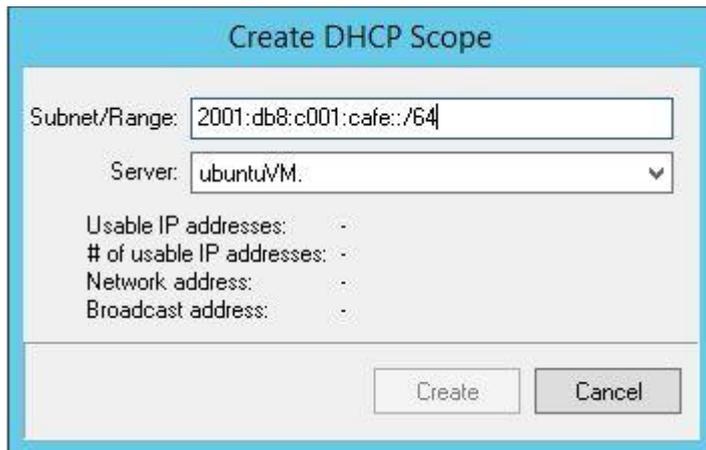


Figure 36 Missing option to create DHCPv6 scope ISC DHCP server Men&Mice

4.5.5 Stateless Address Auto-configuration

The only difference in comparison to the first testing scenario with stateful address auto-configuration is the tracking of SLAAC addresses in DNS zones. Figure 37 displays all records of hosts with SLAAC addresses registered in DNS zones. Windows clients are only listed with their IPv6 address while temporary addresses are not shown. Furthermore, clients using EUI-64 addresses including MacOS X and Debian clients are not listed either.

| Name | TTL | Type | Data | Timestamp |
|---------------------------------------------------|------|------|-----------------------------------------|--------------------|
| _gc_tcp.ipam-lab.com. | 600 | SRV | 0 100 3268 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| _kerberos_tcp.ipam-lab.com. | 600 | SRV | 0 100 88 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| _kpasswd_tcp.ipam-lab.com. | 600 | SRV | 0 100 464 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| _ldap_tcp.ipam-lab.com. | 600 | SRV | 0 100 389 win2012r2.ipam-lab.com. | Aug 2, 2014 11:00 |
| _kerberos_udp.ipam-lab.com. | 600 | SRV | 0 100 88 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| _kpasswd_udp.ipam-lab.com. | 600 | SRV | 0 100 464 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| DomainDnsZones.ipam-lab.com. | 600 | A | 172.26.8.151 | Jul 24, 2014 01:00 |
| _ldap_tcp.Default-First-Site-Name_s.ipam-lab.com. | 600 | SRV | 0 100 389 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| _ldap_tcp.DomainDnsZones.ipam-lab.com. | 600 | SRV | 0 100 389 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| ForestDnsZones.ipam-lab.com. | 600 | A | 172.26.8.151 | Jul 24, 2014 01:00 |
| _ldap_tcp.Default-First-Site-Name_s.ipam-lab.com. | 600 | SRV | 0 100 389 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| _ldap_tcp.ForestDnsZones.ipam-lab.com. | 600 | SRV | 0 100 389 win2012r2.ipam-lab.com. | Jul 24, 2014 01:00 |
| test-host.ipam-lab.com. | 3600 | AAAA | 2001:db8:1986:1234::1 | |
| Test_IPv6.ipam-lab.com. | 3600 | AAAA | 2001:db8:c001:cafe:dabb:ad00:0:0 | |
| Win2012R2IPAM.ipam-lab.com. | 1200 | A | 172.26.8.150 | Aug 8, 2014 23:00 |
| Win2012R2IPAM.ipam-lab.com. | 1200 | AAAA | 2001:dabb:ad00:1986:2c5a:ef95:691b:f080 | Aug 8, 2014 23:00 |
| Win7-IPAM.ipam-lab.com. | 1200 | A | 172.26.8.156 | Aug 8, 2014 15:00 |
| Win8-ipam.ipam-lab.com. | 1200 | A | 172.26.8.158 | Aug 8, 2014 15:00 |
| Win8-ipam.ipam-lab.com. | 1200 | AAAA | 2001:dabb:ad00:1986:a566:5eef:e821:1b4c | Aug 8, 2014 15:00 |
| WinServer2012IPAM.ipam-lab.com. | 1200 | A | 172.26.8.150 | Jul 28, 2014 21:00 |
| WinServer2012IPAM.ipam-lab.com. | 1200 | AAAA | 2001:dabb:ad00:1986:51a6:55ee:95f8:1101 | Jul 28, 2014 21:00 |
| WinServerIPAM.ipam-lab.com. | 1200 | A | 172.26.8.150 | Jul 28, 2014 23:00 |
| WinServerIPAM.ipam-lab.com. | 1200 | AAAA | 2001:dabb:ad00:1986:c082:cc15:5de9:2502 | Jul 28, 2014 23:00 |
| testdevice.ipam-lab.com. | 3600 | AAAA | 2001:dabb:ad00:1986:1234:5678:8765:4321 | |
| testdevice.ipam-lab.com. | 3600 | AAAA | 2001:dabb:ad00:1987::0 | |
| testHost_RFC_5952.ipam-lab.com. | 3600 | AAAA | 2001:db8::102 | |
| ipam-lab.com. | 3600 | NS | win2012r2vm.ipam-lab.com. | |
| win2012r2vm.ipam-lab.com. | 3600 | A | 192.168.2.107 | |
| win2012r2.ipam-lab.com. | 3600 | AAAA | 2001:dabb:ad00:1986:39ed:f096:c4c7:8b0c | |
| Win7-IPAM.ipam-lab.com. | 1200 | AAAA | 2001:dabb:ad00:1986:95e7:1521:6be9:16ad | Aug 8, 2014 15:00 |
| win2012r2.ipam-lab.com. | 3600 | A | 172.26.8.151 | |
| win2012r2.ipam-lab.com. | 3600 | AAAA | 2001:dabb:ad00:1986:1c3b:c660:19df:5908 | |
| win2012r2.ipam-lab.com. | 3600 | AAAA | 2001:dabb:ad00:1986::5 | |

Figure 37 DNS records stateless IPv6 addresses

4.5.6 Summary

The overlaying software – based IP address management solution provided by Men&Mice easily integrates into existing network infrastructures, but allows the management of an IPv4 network only. The monitoring of DNS zones

allows the tracking of dynamic assigned IPv6 addresses of hosts that joined the Windows server 2012R2 domain. Clients that have not joined the domain are not listed. Also by using stateless auto-configuration, clients using EUI-64 to create an IPv6 interface identifier are not listed. Polling the neighbor cache from network devices is also not supported by Men&Mice. The suite furthermore provides a function that allows exporting addresses in a CSV format. IPv6 addresses are displayed in a RFC 5952 compliant format.

4.6 IP Address Management Windows Server 2012R2

Microsoft Windows Server 2012R2 provides a built-in IP address management solution, which can either be configured with PowerShell scripts, or with the *Graphical User Interface (GUI)*. This section covers results achieved by using the GUI to configure and evaluate the MS Windows Server 2012R2 built-in IP address management. A detailed description of the results is now given below.

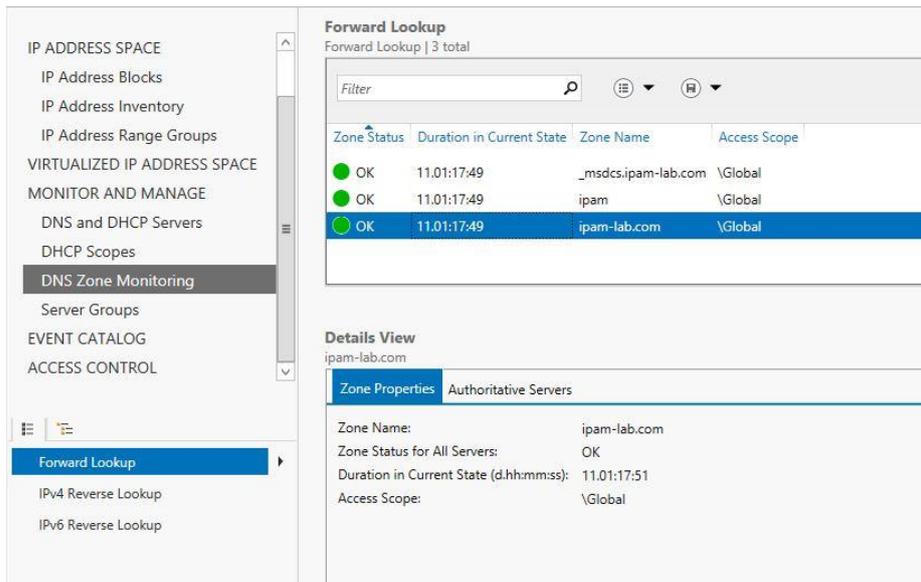
4.6.1 Stateful Address Auto-Configuration

The Windows IPAM solution only provides the possibility to manage DNS and DHCP services deployed by other Microsoft servers in the environment. The required IPAM role may not be installed on the same server deploying the above-mentioned services. Therefore, a second Windows server was set up. After the installation and configuration of the IPAM role, the IPAM management lists all existing DNS zones and DHCP scopes, including DHCPv6 scopes from added server. These can be modified, new zones and scopes can be created. Although the solution provides full support for stateful auto-configuration, only the number of active leases is given, the corresponding IPv6 addresses are not listed. Figure 38 indicates a detailed view of an existing DHCPv6 scope, displaying a count of stateful-utilized addresses.

| Details View | | | |
|---------------------------|----------------------------------------|------------------------------------|------------------------|
| 2001:db8:c001:cafe::/64 | | | |
| Configuration Details | | Event Catalog | |
| Network: | 2001:db8:c001:cafe::/64 | Overlapping: | Yes |
| Subnet Mask: | ffff:ffff:ffff:ffff:: | Access Scope: | \Global |
| Start IP Address: | 2001:db8:c001:cafe::1 | Is Inherited Access Scope: | Yes |
| End IP Address: | 2001:db8:c001:cafe:ffff:ffff:ffff:ffff | Virtualized: | No |
| IP Address Type: | Global | Used for Utilization Calculations: | No |
| Assignment Type: | Dynamic | Dhcp Server Name: | win2012r2.ipam-lab.com |
| Network Type: | | Dhcp Scope Name: | IPv6_DHCP_Scope |
| Percentage Utilized: | 0.00 | Exclusion Ranges: | |
| Utilization: | Under | Owner: | |
| Utilization Calculation: | Automatic | Assignment Date: | |
| Assigned Addresses: | 1,84467440737096E+19 | Last Reclaim Run Time: | |
| Utilized Addresses: | 5 | DHCP Stateful Addresses: | 5 |
| DHCP Stateless Addresses: | 0 | Connection-specific DNS Suffix: | |
| Gateway Addresses: | | DNS Suffixes: | |
| Reserved IP Addresses: | | DNS Servers: | |
| Virtual IP Addresses: | | | |
| Managed by Service: | MS DHCP | | |
| Service Instance: | win2012r2.ipam-lab.com | | |

Figure 38 Utilized addresses Microsoft DHCPv6

The solution also provides a "DNS Zone Monitoring" function showing the status of each zone. But as the name already indicates, the interface only lists existing zones including forward – as well as reverse lookup zones. Corresponding records inside these zones are not displayed. Figure 39 shows monitored DNS zones by the Windows IPAM interface.

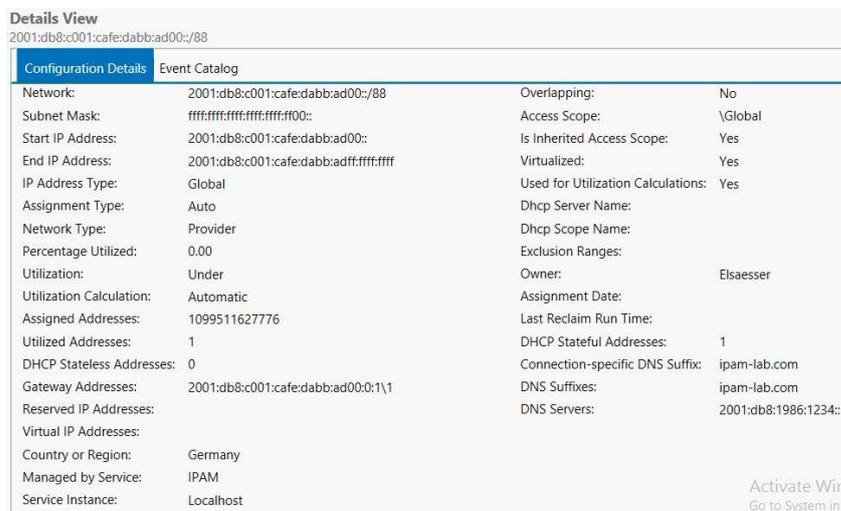


| Zone Status | Duration in Current State | Zone Name | Access Scope |
|-------------|---------------------------|---------------------|--------------|
| OK | 11.01:17:49 | _msdcs.ipam-lab.com | \Global |
| OK | 11.01:17:49 | ipam | \Global |
| OK | 11.01:17:49 | ipam-lab.com | \Global |

| Zone Properties | |
|-----------------------------------------|--------------|
| Zone Name: | ipam-lab.com |
| Zone Status for All Servers: | OK |
| Duration in Current State (d.hh:mm:ss): | 11.01:17:51 |
| Access Scope: | \Global |

Figure 39 DNS zones monitoring

The IP address management solution from Microsoft also provides the possibility to allocate private and public address space managed by the solution itself or with other Windows Server instances added to the management. Figure 40 shows the allocation of a global IPv6 address space.



| Configuration Details | Event Catalog |
|------------------------------------|----------------------------------------|
| Network: | 2001:db8:c001:cafe:dabb:ad00::/88 |
| Subnet Mask: | ffff:ffff:ffff:ffff:ff00:: |
| Start IP Address: | 2001:db8:c001:cafe:dabb:ad00:: |
| End IP Address: | 2001:db8:c001:cafe:dabb:adff:ffff:ffff |
| IP Address Type: | Global |
| Assignment Type: | Auto |
| Network Type: | Provider |
| Percentage Utilized: | 0.00 |
| Utilization: | Under |
| Utilization Calculation: | Automatic |
| Assigned Addresses: | 1099511627776 |
| Utilized Addresses: | 1 |
| DHCP Stateless Addresses: | 0 |
| Gateway Addresses: | 2001:db8:c001:cafe:dabb:ad00:0:1 |
| Reserved IP Addresses: | |
| Virtual IP Addresses: | |
| Country or Region: | Germany |
| Managed by Service: | IPAM |
| Service Instance: | Localhost |
| Overlapping: | No |
| Access Scope: | \Global |
| Is Inherited Access Scope: | Yes |
| Virtualized: | Yes |
| Used for Utilization Calculations: | Yes |
| Dhcp Server Name: | |
| Dhcp Scope Name: | |
| Exclusion Ranges: | |
| Owner: | Elsaesser |
| Assignment Date: | |
| Last Reclaim Run Time: | |
| DHCP Stateful Addresses: | 1 |
| Connection-specific DNS Suffix: | ipam-lab.com |
| DNS Suffixes: | ipam-lab.com |
| DNS Servers: | 2001:db8:1986:1234::1 |

Figure 40 Allocated global IPv6 address block

4.6.2 Stateless Address Auto-configuration

As the IP address management solution does not support any tracking of IPv6 addresses, all results achieved with stateless auto-configuration only differ from the results in section 4.6.1 in one case. The detailed view of the IP address range groups now displays the count of addresses, utilized through stateless auto-configuration. Figure 41 indicates a detailed view of the IP address range groups displaying the count of DHCPv6 stateless utilized addresses.

Details View
2001:dabb:ad00:1986::/64

| Configuration Details | | Event Catalog | |
|---------------------------|-----------------------------------------|------------------------------------|------------------------|
| DHCPv6 Scope | | | |
| Network: | 2001:dabb:ad00:1986::/64 | Overlapping: | No |
| Subnet Mask: | ffff:ffff:ffff:ffff:: | Access Scope: | \Global |
| Start IP Address: | 2001:dabb:ad00:1986::1 | Is Inherited Access Scope: | Yes |
| End IP Address: | 2001:dabb:ad00:1986:ffff:ffff:ffff:ffff | Virtualized: | No |
| IP Address Type: | Global | Used for Utilization Calculations: | Yes |
| Assignment Type: | Dynamic | Dhcp Server Name: | win2012r2.ipam-lab.com |
| Network Type: | | Dhcp Scope Name: | IPv6_Scope |
| Percentage Utilized: | 0.00 | Exclusion Ranges: | |
| Utilization: | Under | Owner: | |
| Utilization Calculation: | Automatic | Assignment Date: | |
| Assigned Addresses: | 1.84467440737096E+19 | Last Reclaim Run Time: | |
| Utilized Addresses: | 3 | DHCP Stateful Addresses: | 0 |
| DHCP Stateless Addresses: | 3 | Connection-specific DNS Suffix: | |
| Gateway Addresses: | | DNS Suffixes: | |
| Reserved IP Addresses: | | DNS Servers: | |
| Virtual IP Addresses: | | | |
| Managed by Service: | MS DHCP | | |
| Service Instance: | win2012r2.ipam-lab.com | | |

Activate Windows
Go to System in Control Panel

Figure 41 Microsoft DHCPv6 stateless utilized addresses

4.6.3 Summary

The built-in IP address managed solution in Windows Server 2012R2 provides mainly monitoring functionalities. Although the solution provides support for stateful auto-configuration, active leases deployed with a managed MS DHCP server cannot be displayed. This also applies to all DNS zones displayed in the interface. Corresponding records are not listed. The management allows allocating global IPv6 address blocks as well as DHCPv6 ranges inside these blocks. All data can be exported as CSV files. All IPv6 addresses are displayed in RFC 5952 – compliant manner.

4.7 Overview Results

The following Table 1 provides an itemized statement about the fulfillment of all requirements of all IP Address Management solutions.

| Requirement | Alcatel | BlueCat Networks | BT Diamond | Infoblox | Men&Mice | Windows 2012R2 IPAM |
|------------------------------------------------------------------------|---------|------------------|------------|----------|----------|---------------------|
| Tracking of all dynamic address assignments | ⊘ | ✓ | ⊘ | ✓ | ⊘ | ⊘ |
| Support SNMPv3 | ⊘ | ✓ | ✓ | ✓ | ✓ | ⊘ |
| Display connected switch port | ⊘ | ✓ | ⊘ | ✓ | ⊘ | ⊘ |
| Sort addresses according to their categories | ⊘ | ✓ | ⊘ | ✓ | ⊘ | ⊘ |
| Full support for RFC 5952 | ✓ | ⊘ | ✓ | ✓ | ✓ | ✓ |
| Management of IP inventory | ✓ | ✓ | ⊘ | ✓ | ✓ | ✓ |
| Integration in existing IPv6 network infrastructure (Windows or Linux) | ⊘ | ⊘ | ⊘ | ✓ | ✓ | ✓ |
| Other methods than SNMP to poll neighbor cache from Network device | ⊘ | ⊘ | ⊘ | ✓ | ⊘ | ⊘ |
| Identify system with various address types (e.g. static + SLAAC) | ⊘ | ⊘ | ⊘ | ✓ | ⊘ | ⊘ |
| Reporting / exporting addresses in CSV or other formats | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Table 1 Itemized Statement Fulfillment Requirements

It has to be noted that some of the above listed features were not tested with the Infoblox appliances, not least given that some capabilities are not part of their core IPAM offering. The results above are partly based on the documentation of the corresponding Infoblox components.

4.8 Conclusion

The results described in Chapter 4 show, that almost no IP address management solution fulfills all the mandatory information security requirements which were specified based on the information needed by administrators to manage their IPv6 space as well as the security needs of the network forensics examiners.

Because of the missing option to configure a domain controller in the Alcatel Lucent QIP solution, dynamic addresses could not be deployed. Hence, the solution could not be properly examined.

With their Proteus and Adonis appliance, BlueCat Networks allows the tracking of all dynamic IPv6 address assignments, whether stateful by using their own DNS / DHCPv6 server from the Adonis appliance, or stateless by configuring the reconciliation policy and polling the neighbor cache from Layer-3 and Layer-2 network devices. Corresponding data is displayed in the management interface, including for instance the DUID, the MAC address, or the connected switch port.

The IPAM solution offered by BT Diamond neither implements any services to assign dynamic IPv6 addresses, nor provides any features to poll neighbor caches from network devices. Dynamic assigned IPv6 addresses can hence not be tracked. Although the IP address management software is an overlaying solution, no features are implemented to monitor any services deployed on the server.

Infoblox provides an IPAM solution that allows deploying DNS and DHCP services as well as offers an IP address management in a single appliance. Dynamic addresses can be assigned through DHCPv6, active leases can be displayed with the corresponding DUID. Services deployed by Microsoft instances can also be monitored and managed.

With their Network Insight appliance, it is possible discovering all kind of IPv6 nodes on the network and load the data in the IPAM database of the DDI appliance. SNMPv3 is also supported for this task. Furthermore, the appliance offers the possibility to login to discovered devices via telnet and ssh.

With the overlaying IP address management from Men&Mice, DNS and DHCP services deployed by Microsoft servers, by ISC DHCP servers or by its own appliance can be managed for IPv4 networks. Dynamic IPv6 addresses cannot be assigned, but can be tracked through DNS entries. DNS zones deployed by Microsoft servers can be monitored and corresponding entries can be listed in the management interface of the Men&Mice suite. EUI-64 addresses as well as well as temporary addresses are not listed and hence, cannot be tracked. Polling any IPv6 neighbor cache is not supported either. The main focus of the built-in IP address management solution from Windows Server 2012R2 is on managing IPv4 networks. Although DNS zones and DHCPv6 services deployed by other Microsoft server can be displayed and managed, neither any active leases are listed nor can any DNS entries be displayed. Dynamic IPv6 addresses can also not be tracked.

Although each IPAM solution provides certain functionalities that might be supportive in administrative tasks, each solution has also room for improvements regarding information security requirements in IPv6 networks.

After several support inquiries to the vendors providing an IPAM solution lacking some features they all announced that they will offer a solution with native IPv6 support within the next years. Overall as of end of 2014 only the solutions of BlueCat and Infoblox seem to have a sufficient maturity as for a large scale IPv6 deployment. For the latter (Infoblox) this only applies once extra components (next to their core IPAM offering) are added.

5 APPENDIX

5.1 References

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<http://www.infoblox.com>
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<http://tools.ietf.org/html/rfc6355>

5.2 Disclaimer

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