IPv6 for Developers used to IPv4

Thiago Macieira

Embedded Linux Conference / OpenIoT Summit – Berlin, October 2016

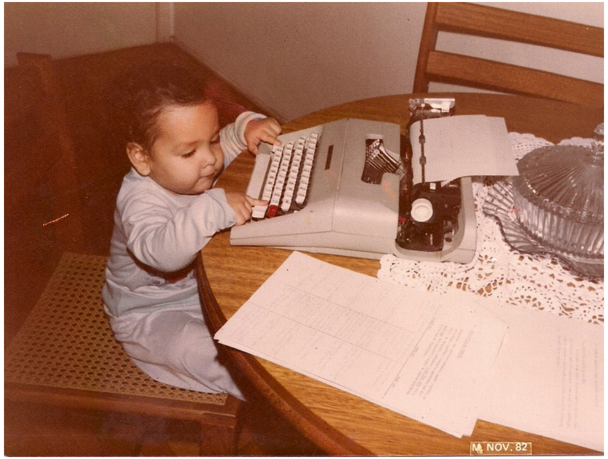
Timeline

1993

IPng formed

1995

First IPv6 RFC



1999/2000

Thiago begins contributing to OSS (an IPv6-capable browser)

?

IANA IPv4 exhaustion

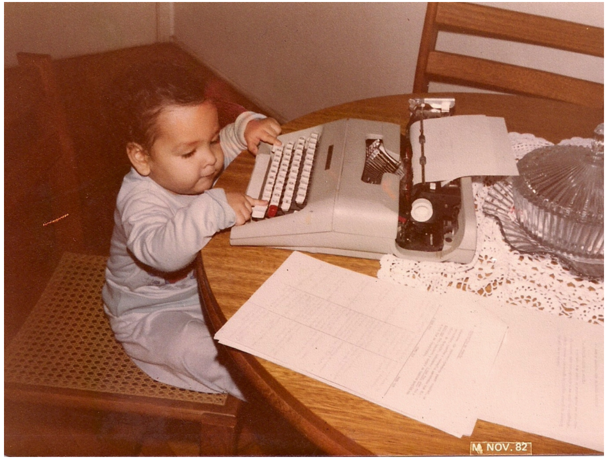
Timeline

1993

IPng formed

1995

First IPv6 RFC



1999/2000

Thiago begins contributing to OSS (an IPv6-capable browser)

2011-01-31

IANA IPv4 exhaustion

Overview of IPv6

Programming with IPv6

Things you can do with IPv6

Comparison to IPv4

	IPv4	IPv6
Address size	32 bits	128 bits
Multicasting	Optional	Mandatory
Minimum MTU	68 octets	1280 octets
Maximum packet size	65,535 octets	4,294,967,295 octets
Fragmentation	By routers	At origin
Privacy extensions	No	Yes
LL address resolution protocol	ARP	IPv6 (ICMPv6)

An IPv6 address

- **IPv4:**

198.51.100.1

- **IPv6:**

2001:0DB8:AC10:FE01:0000:0000:0000:0000

2001:db8:ac10:fe01::

Localhost and anyhost

- **IPv4:**

0.0.0.0/8
127.0.0.1/8

- **IPv6:**

0000:0000:0000:0000:0000:0000:0000:0000/128 → **::/128**

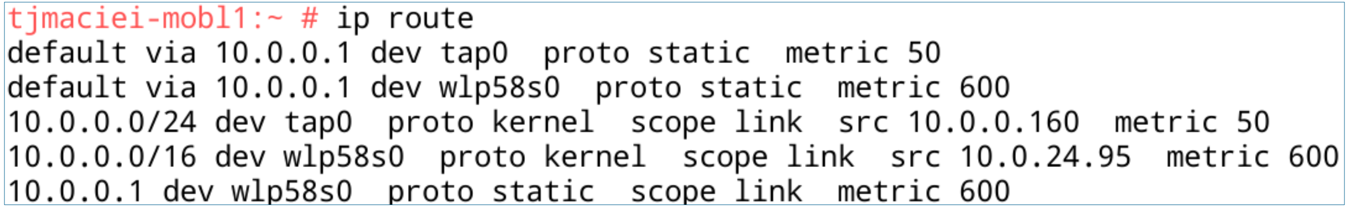
0000:0000:0000:0000:0000:0000:0000:0001/128 → **::1/128**

No NAT, no RFC 1918

- **All connected devices receive global, unique addresses**

  Addressable from the world ↛ Reachable from the world

- **There are Unique Local Addresses**
  - Not globally routable
  - 40 bits of randomness in prefix

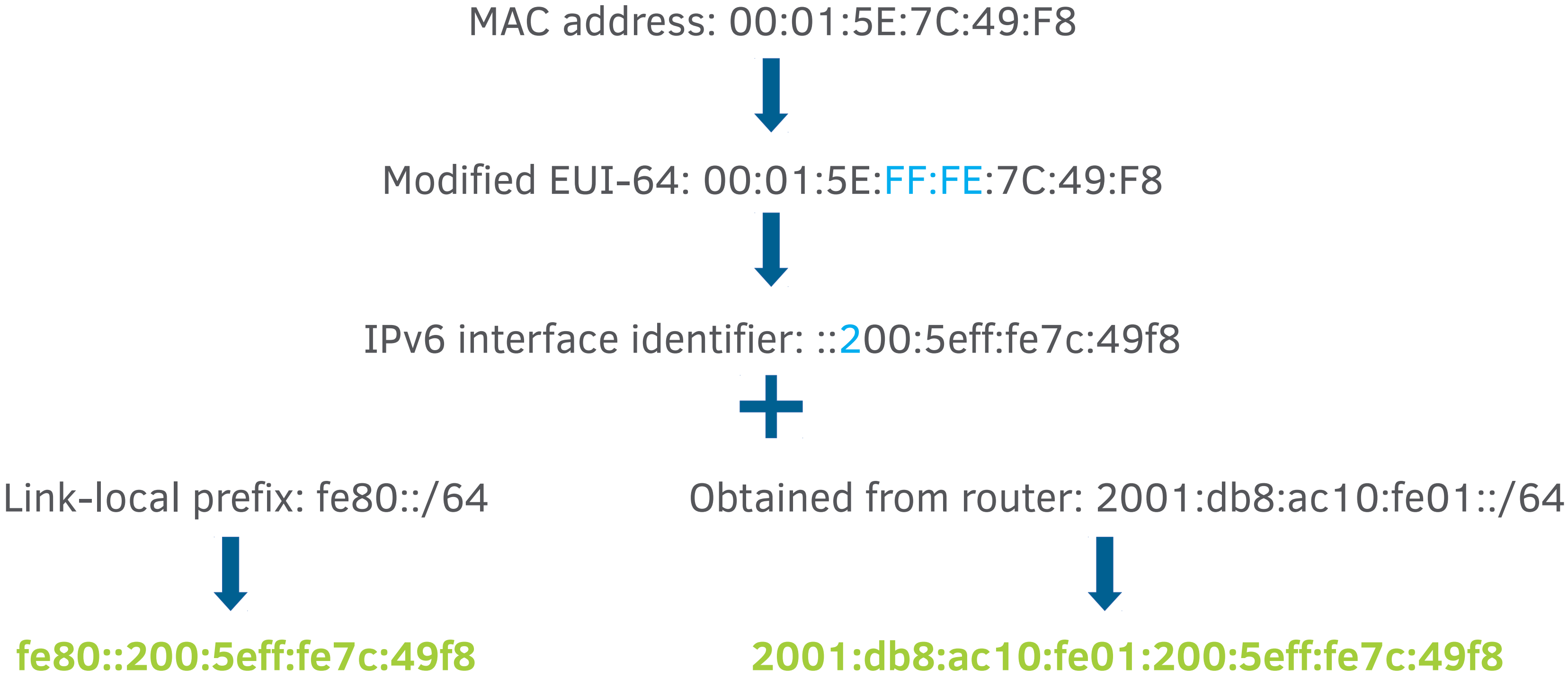


```
tjmaciei-mobl1:~ # ip route
default via 10.0.0.1 dev tap0  proto static  metric 50
default via 10.0.0.1 dev wlp58s0  proto static  metric 600
10.0.0.0/24 dev tap0  proto kernel  scope link  src 10.0.0.160  metric 50
10.0.0.0/16 dev wlp58s0  proto kernel  scope link  src 10.0.24.95  metric 600
10.0.0.1 dev wlp58s0  proto static  scope link  metric 600
```

Stateless address auto-configuration (SLAAC)

- **Enables hosts to communicate without DHCP servers**
- **If a router is present:**
  - Can configure global addresses statelessly
  - Can query DHCPv6 server for extra information (DNS servers, NTP servers, etc.) or more IPv6 addresses

SLAAC Overview



MAC address: 00:01:5E:7C:49:F8

Modified EUI-64: 00:01:5E:FF:FE:7C:49:F8

IPv6 interface identifier: ::200:5eff:fe7c:49f8

Link-local prefix: fe80::/64

Obtained from router: 2001:db8:ac10:fe01::/64

fe80::200:5eff:fe7c:49f8

2001:db8:ac10:fe01:200:5eff:fe7c:49f8

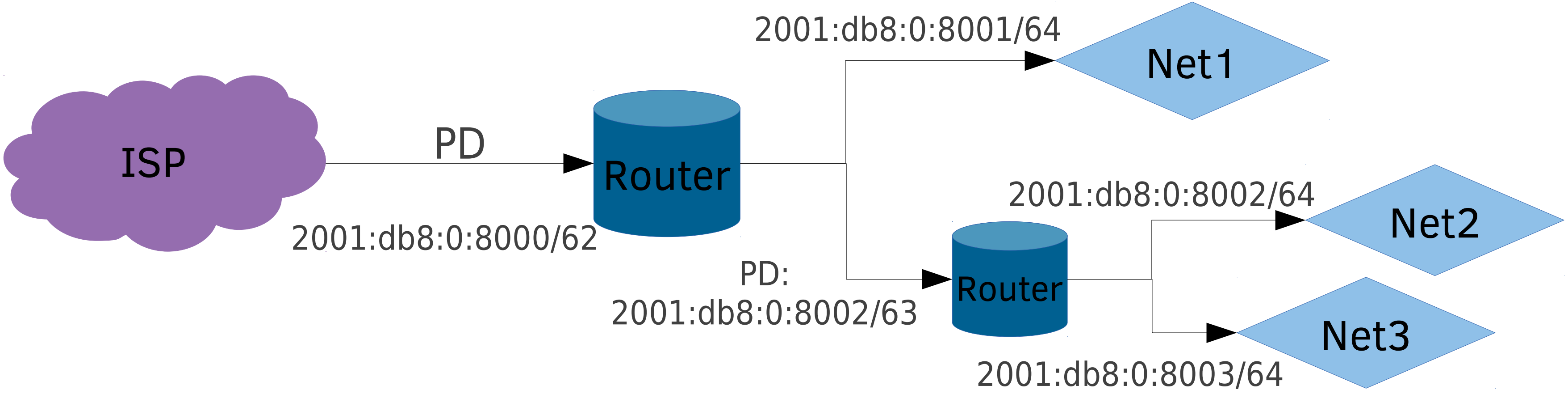
What about my privacy?

- **Temporary addresses**
  - RFC 4941
  - Randomly generated
  - Rotated after a time
  - On Linux, set value 2 in sysctl `net.ipv6.conf.`*`ifname`*`.use_tempaddr`
  - Also supported by NetworkManager

- **Stable but opaque addresses**
  - RFC 7217
  - Suggestion: Result of a pseudorandom function (e.g., SHA-1)
  - Supported in the Linux kernel since 4.1 (`net.ipv6.conf.`*`ifname`*`.stable_secret`)
  - Supported by dhcpcd 6.4 & NM 1.2

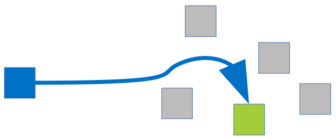
Address assignment in networks

- **DHCP Prefix Delegation**



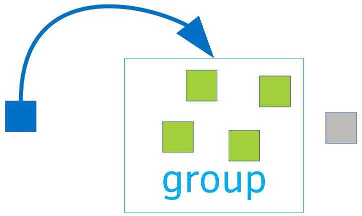
The “casts”

- **Unicast**
  - One to one



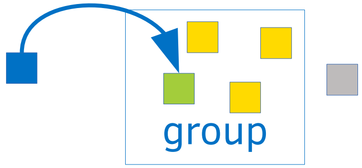
2001:db8:ac10:fe01::1

- **Multicast**
  - One to many (all in a group)



ff02::fb

- **Anycast**
  - One to any (one of a group)



2001:db8:ac10:fe01::

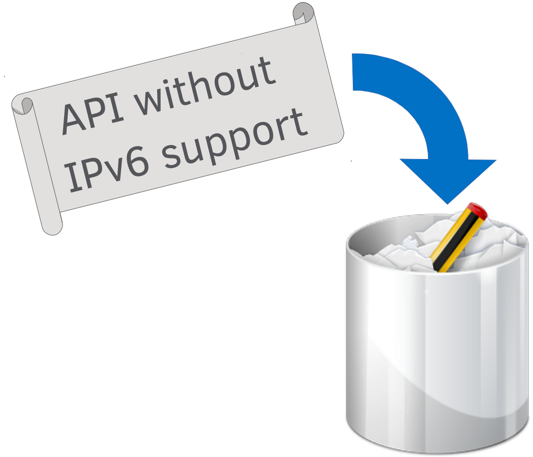
Overview of IPv6

Programming with IPv6

Things you can do with IPv6

What you need to know

- **Don’t assume anything about the address!**
- **Use high-level API that supports IPv6**
  - libcurl, libsoup, Qt; Python libraries, etc.
- **Use the IPv6 API, always**
  - IPv6 sockets can talk to IPv4



Bad assumptions

- **An address is an `uint32_t`**
- **There's only one meaningful address assigned per interface**
  - Or, worse, to the entire device!
- **Addresses don't change while the application is running**
- **The tool to configure addresses is `ifconfig`**

For example, URLs

- **URL is**

scheme://*host*:port/*path*/?*query*#*fragment*

- **Construct the URL for**

```
scheme  http
  host  2001:db8:ac10:fe01:200:5eff:fe7c:49f8
  port  80
  path  /
```

```
http://[2001:db8:ac10:fe01:200:5eff:fe7c:49f8]:80/
```

How to properly really store an address

sockaddr_in

```
struct sockaddr_in
  {
    sa_family_t sin_family;
    in_port_t sin_port;         /* Port number.  */
    struct in_addr sin_addr;    /* Internet address.  */
  };
```

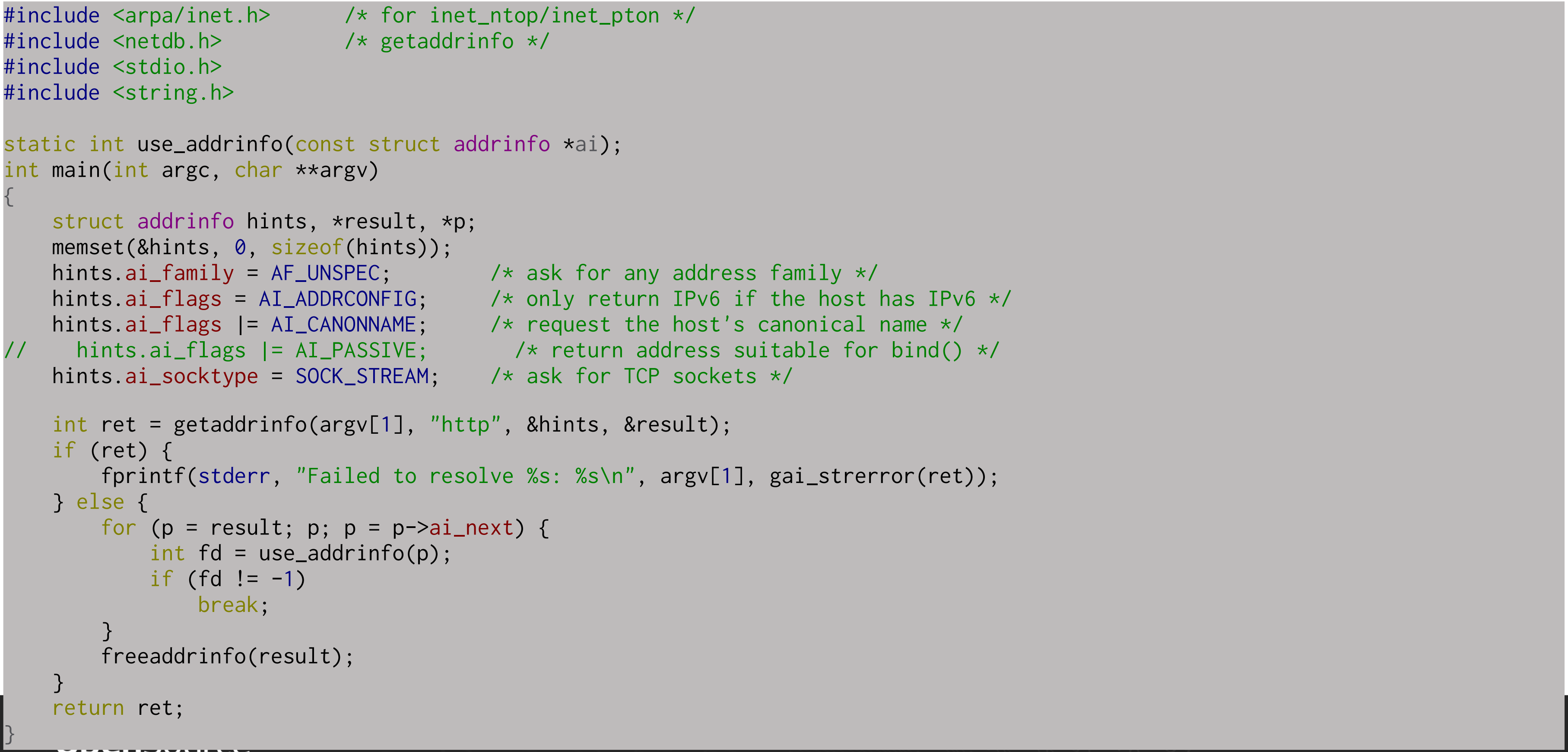
sockaddr_storage

- Big enough for all your addresses

sockaddr_in6

```
struct sockaddr_in6
  {
    sa_family_t sin6_family;
    in_port_t sin6_port;         /* Transport layer port # */
    uint32_t sin6_flowinfo;      /* IPv6 flow information */
    struct in6_addr sin6_addr;   /* IPv6 address */
    uint32_t sin6_scope_id;      /* IPv6 scope-id */
  };
```

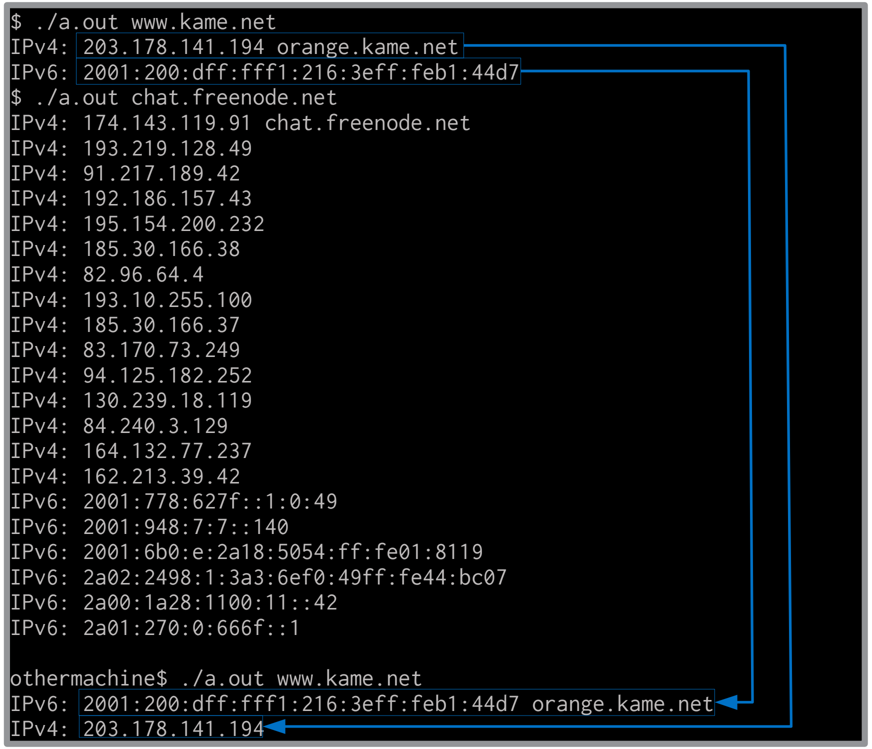
Resolving an address: `getaddrinfo()`



```c
#include <arpa/inet.h>      /* for inet_ntop/inet_pton */
#include <netdb.h>          /* getaddrinfo */
#include <stdio.h>
#include <string.h>

static int use_addrinfo(const struct addrinfo *ai);
int main(int argc, char **argv)
{
    struct addrinfo hints, *result, *p;
    memset(&hints, 0, sizeof(hints));
    hints.ai_family = AF_UNSPEC;        /* ask for any address family */
    hints.ai_flags = AI_ADDRCONFIG;     /* only return IPv6 if the host has IPv6 */
    hints.ai_flags |= AI_CANONNAME;     /* request the host's canonical name */
//    hints.ai_flags |= AI_PASSIVE;       /* return address suitable for bind() */
    hints.ai_socktype = SOCK_STREAM;    /* ask for TCP sockets */

    int ret = getaddrinfo(argv[1], "http", &hints, &result);
    if (ret) {
        fprintf(stderr, "Failed to resolve %s: %s\n", argv[1], gai_strerror(ret));
    } else {
        for (p = result; p; p = p->ai_next) {
            int fd = use_addrinfo(p);
            if (fd != -1)
                break;
        }
        freeaddrinfo(result);
    }
    return ret;
}
```

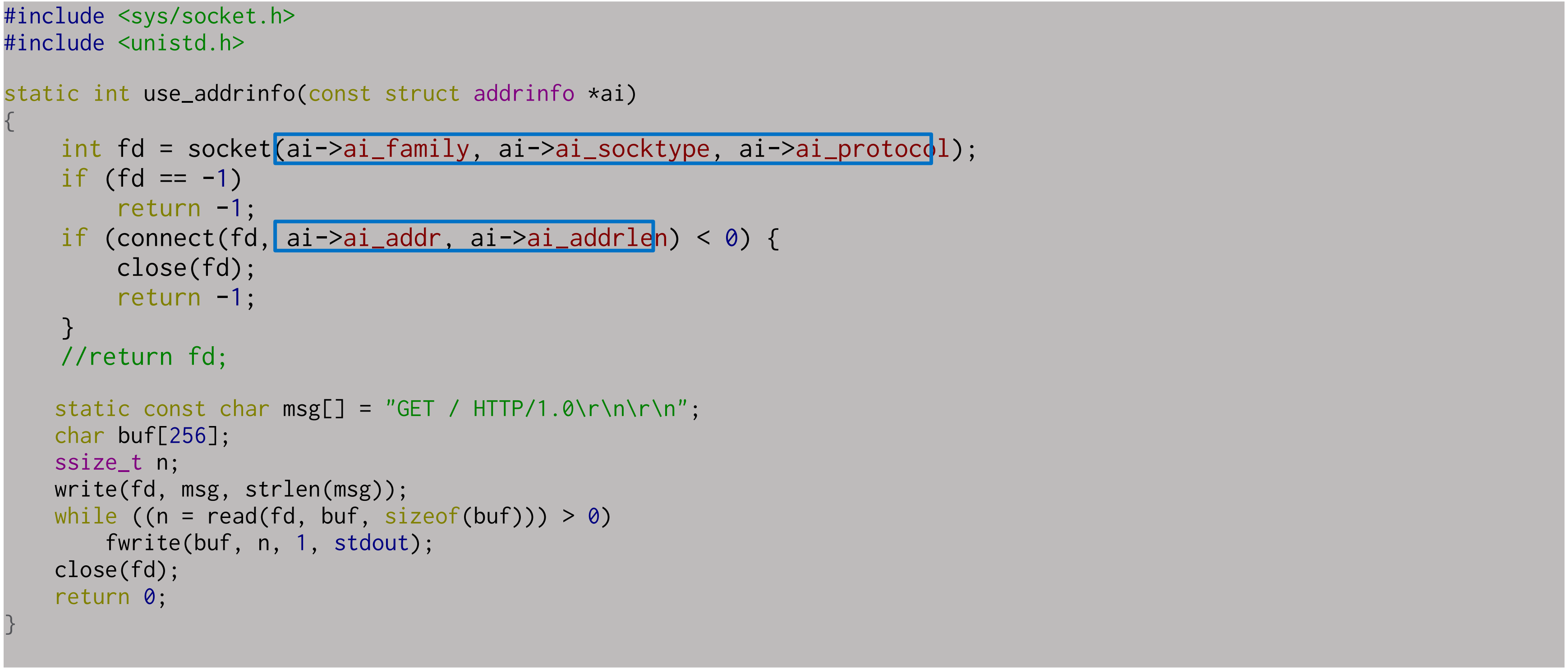
Reversing the resolution: getnameinfo()

```
static int use_addrinfo(const struct addrinfo *ai)
{
    char buf[NI_MAXHOST];
    getnameinfo(ai->ai_addr, ai->ai_addrlen,
                buf, sizeof(buf),
                NULL, 0,                // no port number
                NI_NUMERICHOST);

    printf("%s: %s %s\n",
           ai->ai_family == AF_INET6 ? "IPv6" : "IPv4",
           buf,
           ai->ai_canonname ? ai->ai_canonname : "");

    return -1;
}
```



```
$ ./a.out www.kame.net
IPv4: 203.178.141.194 orange.kame.net
IPv6: 2001:200:dff:fff1:216:3eff:feb1:44d7
$ ./a.out chat.freenode.net
IPv4: 174.143.119.91 chat.freenode.net
IPv4: 193.219.128.49
IPv4: 91.217.189.42
IPv4: 192.186.157.43
IPv4: 195.154.200.232
IPv4: 185.30.166.38
IPv4: 82.96.64.4
IPv4: 193.10.255.100
IPv4: 185.30.166.37
IPv4: 83.170.73.249
IPv4: 94.125.182.252
IPv4: 130.239.18.119
IPv4: 84.240.3.129
IPv4: 164.132.77.237
IPv4: 162.213.39.42
IPv6: 2001:778:627f::1:0:49
IPv6: 2001:948:7:7::140
IPv6: 2001:6b0:e:2a18:5054:ff:fe01:8119
IPv6: 2a02:2498:1:3a3:6ef0:49ff:fe44:bc07
IPv6: 2a00:1a28:1100:11::42
IPv6: 2a01:270:0:666f::1

othermachine$ ./a.out www.kame.net
IPv6: 2001:200:dff:fff1:216:3eff:feb1:44d7 orange.kame.net
IPv4: 203.178.141.194
```

Connecting to the host



```
#include <sys/socket.h>
#include <unistd.h>

static int use_addrinfo(const struct addrinfo *ai)
{
    int fd = socket(ai->ai_family, ai->ai_socktype, ai->ai_protocol);
    if (fd == -1)
        return -1;
    if (connect(fd, ai->ai_addr, ai->ai_addrlen) < 0) {
        close(fd);
        return -1;
    }
    //return fd;

    static const char msg[] = "GET / HTTP/1.0\r\n\r\n";
    char buf[256];
    ssize_t n;
    write(fd, msg, strlen(msg));
    while ((n = read(fd, buf, sizeof(buf))) > 0)
        fwrite(buf, n, 1, stdout);
    close(fd);
    return 0;
}
```

Servers: IPv6 ⊃ IPv4

- **Listen on dual-stack**
  - IPv4 clients can connect just fine
  - Default on Linux
  - Can be changed

```c
#include <sys/socket.h>
#include <unistd.h>

static int use_addrinfo(const struct addrinfo *ai)
{
    int fd = socket(ai->ai_family, ai->ai_socktype, ai->ai_protocol);
    if (fd == -1)
        return fd;

    if (ai->ai_family == AF_INET6) {
        /* Make sure we're getting dual-stack */
        int on = 1;
        setsockopt(fd, SOL_IPV6, IPV6_V6ONLY, &on, sizeof(on));
    }

    if (bind(fd, ai->ai_addr, ai->ai_addrlen) < 0 ||
            listen(fd, 256) < 0) {
        close(fd);
        return -1;
    }
    return fd;
}
```

Be careful with ACLs on dual-stack

- **A dual-stack IPv6 socket can receive IPv4**
- **`getpeername()`, `recvfrom()`, `recvmsg()`, etc. return a “v4-mapped” IPv6 address**

```
::ffff:192.51.100.1
```

Overview of IPv6

Programming with IPv6

Things you can do with IPv6

Use “real” addresses for your entire network

- **No need to use RFC 1918 reserved addresses**
  - Including for routing elements
- **For all your home devices and all your cloud containers**
- **Just don’t forget your firewall rules!**

Replace all your broadcast with multicast

- **Broadcast is “one-to-everyone”**
- **Can create your group without registering with IANA**
- **Variable scopes**

Scope	Meaning
0	Reserved
1	Node-local or interface-local
2	**Link-local**
3	**Realm-local**
4	Admin-local
5	Site-local
8	Organisation-local
e	Global
f	Reserved

More control over packet

- **Advanced Socket API interface (RFC 3542)**
  - Ancillary data in recvmsg and sendmsg
  - IPV6_RECVPKTINFO (setsockopt) / IPV6_PKTINFO (control message)
- **Use-case examples:**

  What IP address was this UDP datagram addressed to? Was it unicast or was it multicast?

  Need to send this UDP datagram on a specific network interface.

6LoWPAN

- **IPv6 over Low-power Wireless Personal Area Network**
  - For IEEE 802.15.4 and Bluetooth networks
  - IPv6 API maps 1:1 with radio packets
- **Adopted by the Thread Group and Bluetooth SIG**

Thiago Macieira

thiago.macieira@intel.com

http://google.com/+ThiagoMacieira