

# Local MAC Addresses in the Overview and Architecture based on IEEE Std 802c

IEEE 802 Tutorial  
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## Abstract

IEEE Std 802c was approved by the IEEE-SA Standards Board on 15 June 2017, amending the IEEE 802 Overview and Architecture to specify Local Medium Access Control (MAC) Address Usage. This tutorial summarizes the changes and implications. It also addresses the perspective of the IEEE Registration Authority and summarizes a recent revision of the relevant tutorial of the IEEE Registration Authority (IEEE RA). The tutorial also reviews the P802.1CQ project on Multicast and Local Address Assignment, providing an illustrative example drawn from an existing standard.

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- Roger Marks

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- Examples of Local Address Assignment protocols from Fibre Channel over Ethernet (FCoE)
- Pat Thaler

## The View from *Silicon Valley*

Dinesh: *What are those devices? Those aren't phones.*

Gilfoyle: *Look at that OUI prefix in these MAC addresses.*

Richard: *OK, so what are those?*

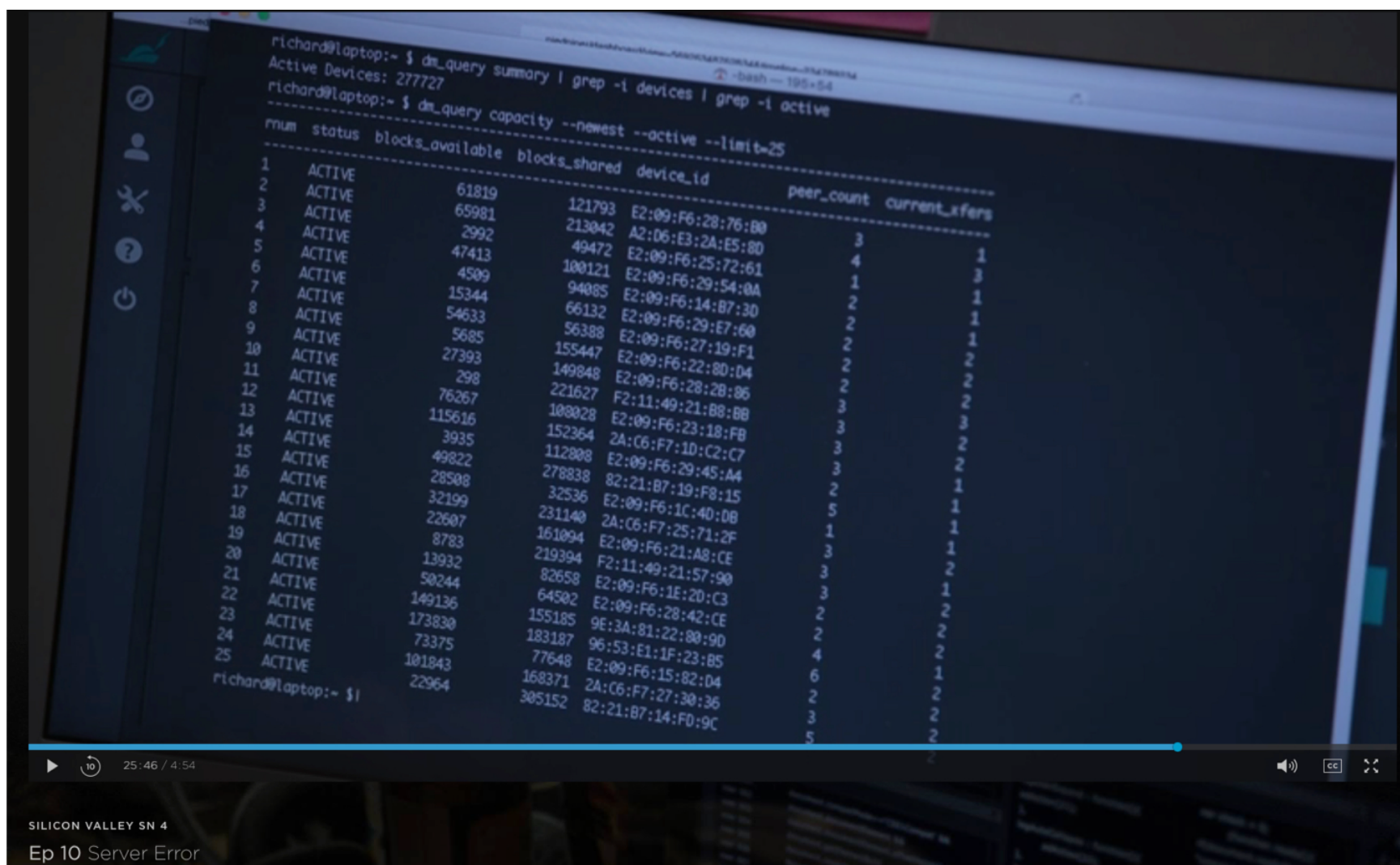
Gilfoyle: *Smart fridges. About 30,000 of them.*

- *Silicon Valley* (a fictional television comedy)

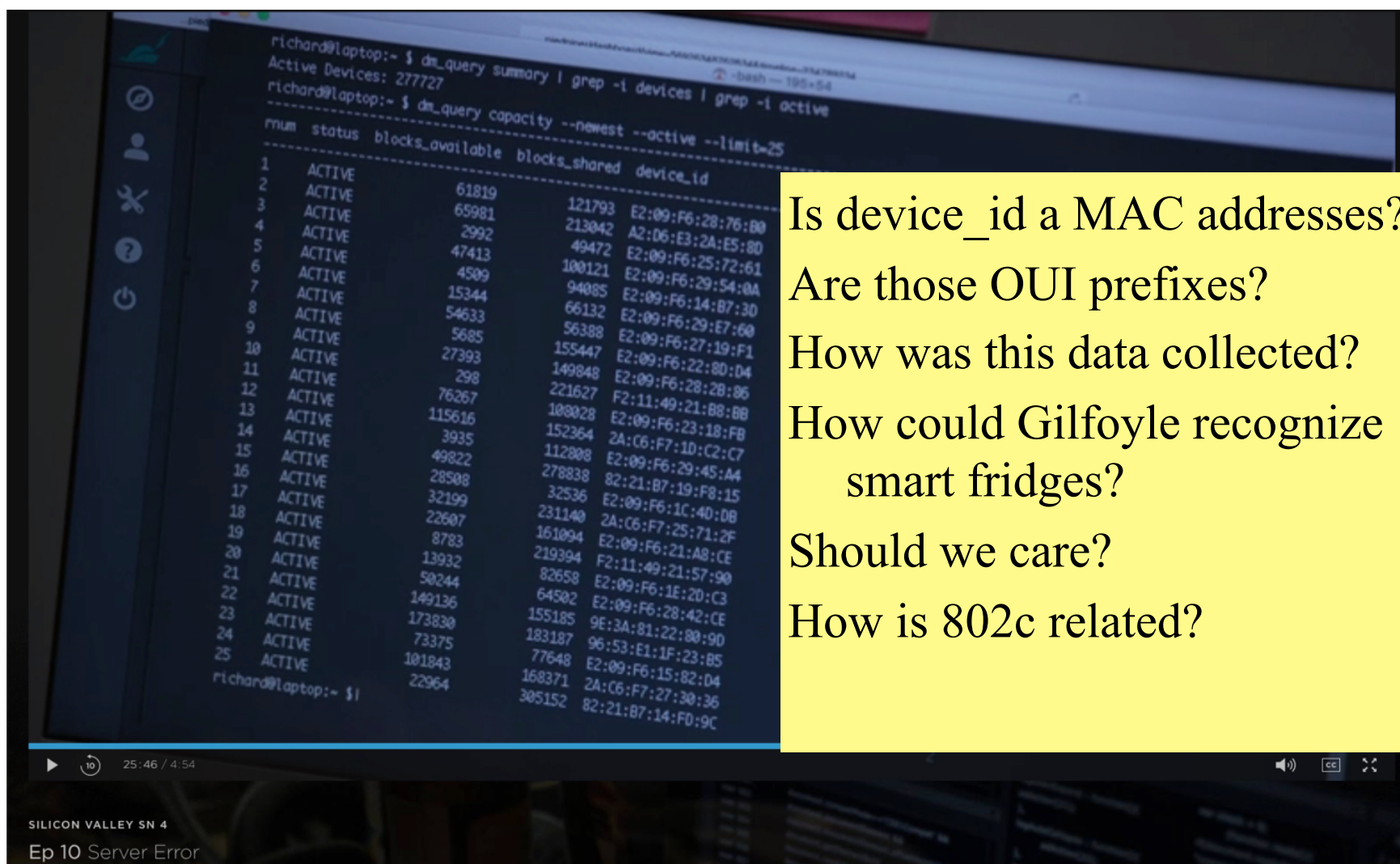
Season 4, Episode 10 (“Server Error”)

First aired on HBO, 2017-06-25

# What Gilfoyle saw



## What Gilfoyle saw



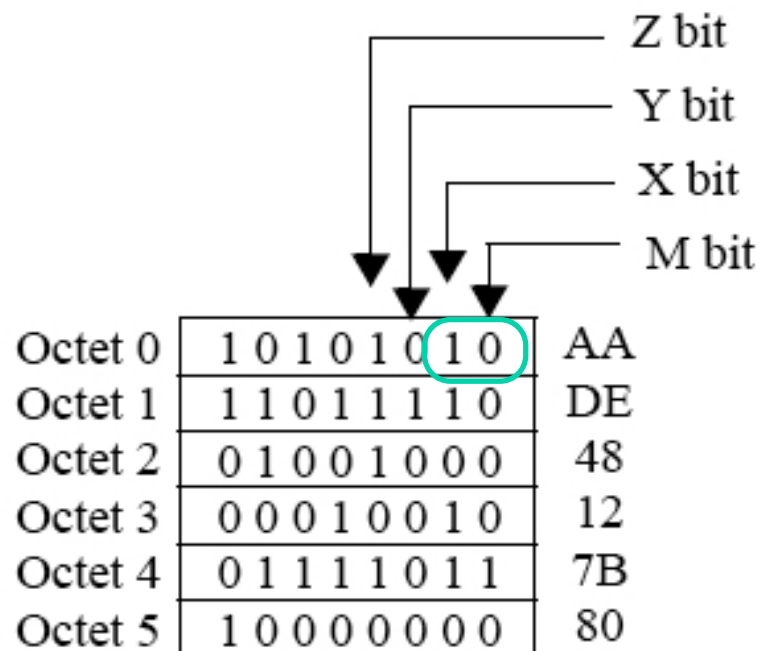
```
richard@laptop:~$ dm_query summary | grep -i devices | grep -i active
Active Devices: 277727
richard@laptop:~$ dm_query capacity --newest --active --limit=25
-----
num status blocks_available blocks_shared device_id
-----
1 ACTIVE 61819 121793 E2:09:F6:28:76:80
2 ACTIVE 65981 213042 A2:06:E3:2A:E5:80
3 ACTIVE 2992 49472 E2:09:F6:25:72:61
4 ACTIVE 47413 100121 E2:09:F6:29:54:0A
5 ACTIVE 4509 94085 E2:09:F6:14:87:30
6 ACTIVE 15344 66132 E2:09:F6:29:E7:60
7 ACTIVE 54633 56388 E2:09:F6:27:19:F1
8 ACTIVE 5685 155447 E2:09:F6:22:80:D4
9 ACTIVE 27393 149848 E2:09:F6:28:28:86
10 ACTIVE 298 221627 F2:11:49:21:88:88
11 ACTIVE 76267 108028 E2:09:F6:23:18:F8
12 ACTIVE 115616 152364 2A:C6:F7:1D:C2:C7
13 ACTIVE 3935 112888 E2:09:F6:29:45:A4
14 ACTIVE 49822 278838 82:21:87:19:F8:15
15 ACTIVE 28508 32536 E2:09:F6:1C:40:08
16 ACTIVE 32199 231140 2A:C6:F7:25:71:2F
17 ACTIVE 22607 161094 E2:09:F6:21:A8:CE
18 ACTIVE 8783 219394 F2:11:49:21:57:90
19 ACTIVE 13932 82658 E2:09:F6:1E:20:C3
20 ACTIVE 50244 64502 E2:09:F6:28:42:CE
21 ACTIVE 149136 155185 9E:3A:81:22:80:90
22 ACTIVE 173830 183187 96:53:E1:1F:23:85
23 ACTIVE 73375 77648 E2:09:F6:15:82:D4
24 ACTIVE 101843 168371 2A:C6:F7:27:30:36
25 ACTIVE 22964 305152 82:21:87:14:F0:9C
richard@laptop:~$
```

Is device\_id a MAC addresses?  
Are those OUI prefixes?  
How was this data collected?  
How could Gilfoyle recognize smart fridges?  
Should we care?  
How is 802c related?

## IEEE Std 802c: Key Facts

- IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture – Amendment 2: Local Medium Access Control (MAC) Address Usage
- Standard approved: 2017-06-15; published 2017-08-25
  - 802 [pseudo-tutorial](#), 2014-11-03
  - 802.1 [Local Address Study Group](#), Nov 2014 - July 2015
  - PAR Authorized: 2015-06-11
  - [PAR](#) Revised: 2016-12-07 (to add maintenance issues)
- Scope in brief:
  - *provide an optional local MAC address space structure to allow multiple administrations to coexist*
  - *designate a range of local MAC addresses for protocols using a Company ID (CID) assigned by the IEEE Registration Authority*
  - *range of local MAC addresses will be designated for assignment by local administrators*
  - *a range of local MAC addresses for use by IEEE 802 protocols*

## Local Address: Example



- M bit (I/G bit): as before, 1 for multicast
- X bit (U/L) bit: as before, 1 for local
  - Y and Z bits: new designations



## SLAP

- *Structured Local Address Plan (SLAP): An optional standardized specification for the use of local medium access control (MAC) address space entailing the use of*
  - *Extended Local Identifier (ELI),*
  - *Standard Assigned Identifier (SAI), and*
  - *Administratively Assigned Identifier (AAI)**addresses in specific disjoint ranges.*

## Assignment Protocols

- *An address assignment protocol assigning local MAC addresses to devices on a LAN should ensure uniqueness of those addresses.*
- *When multiple address assignment protocols operate on a LAN without centralized administration, address duplication is possible, even if each protocol alone is designed to avoid duplication, unless such protocols assign addresses from disjoint address pools.*
- *Administrators who deploy multiple protocols on a LAN in accordance with the SLAP will enable the unique assignment of local MAC addresses within the LAN as long as each protocol maintains unique assignments within its own address subspace.*

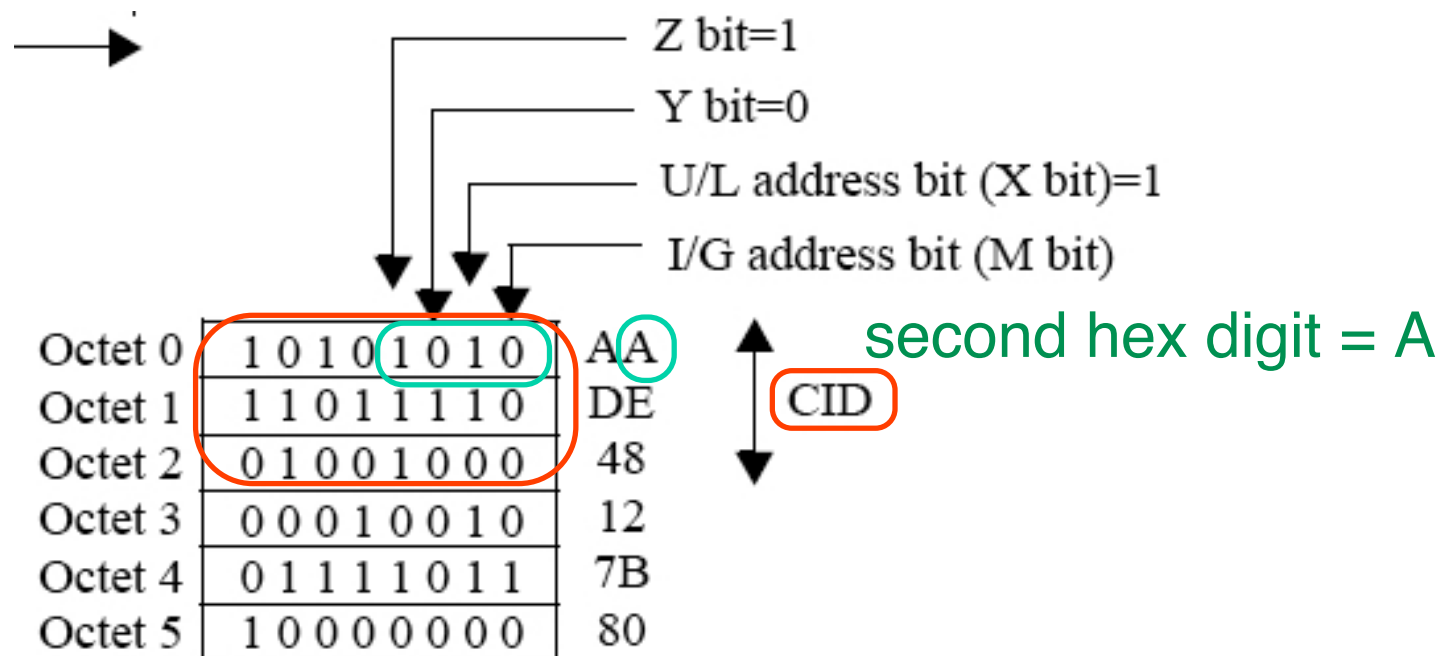
## SLAP Quadrants

| SLAP quadrant | Y bit | Z bit | ZYXM | second hex digit | SLAP local identifier type | SLAP local identifier |
|---------------|-------|-------|------|------------------|----------------------------|-----------------------|
| 01            | 0     | 1     | 1010 | A                | Extended Local             | ELI                   |
| 11            | 1     | 1     | 1110 | E                | Standard Assigned          | SAI                   |
| 00            | 0     | 0     | 0010 | 2                | Administratively Assigned  | AAI                   |
| 10            | 1     | 0     | 0110 | 6                | <i>Reserved</i>            | <i>Reserved</i>       |

“A” for AAI and “E” for ELI would have been nice, but prior IEEE RA assignments put ELI in the “A” quadrant.

|       | Y = 0 | Y = 1           |
|-------|-------|-----------------|
| Z = 0 | AAI   | <i>Reserved</i> |
| Z = 1 | ELI   | SAI             |

## ELI: Extended Local Identifier



- like an EUI, but with a Company ID (CID) instead of an OUI
  - CID has X = 1 (local space).
- IEEE Registration Authority (RA) assigns CIDs, all in SLAP 01
  - CID predates 802c
- 802c reserves 4 CIDs for the local administrator

## AAI: Administratively Assigned Identifier

- AAI: Administratively Assigned Identifier
  - second hex digit = 2
  - *Administrators who wish to assign local MAC addresses in an arbitrary fashion (for example, randomly) and yet maintain compatibility with other assignment protocols operating under the SLAP on the same LAN may assign a local MAC address as AAI.*
- Reserved quadrant can be used like AAI, with reservations:
  - second hex digit = 6
  - *may be administratively used and assigned in accordance with the considerations specified for AAI usage, without effect on SLAP assignments. However, administrators should be cognizant of possible future specifications... that would render administrative assignment incompatible with the SLAP.*

## SAI: Standard Assigned Identifier

- second hex digit = E
- *Specification of the use of the SAI quadrant for SLAP address assignments is reserved for the standard forthcoming from IEEE P802.1CQ.*
- *An SAI is assigned by a protocol specified in an IEEE 802 standard.*
- *Multiple protocols for assigning SAI may be specified within various IEEE 802 standards. Coexistence of such protocols may be supported by restricting each to assignments within a subspace of SAI space.*
- *In some cases, an SAI assignment protocol may assign the SAI to convey specific information. Such information may be interpreted by receivers and bridges that recognize the specific SAI assignment protocol, as identified by the subspace of the SAI. The functionality of receivers and bridges that do not recognize the protocol is not affected.*

## P802.1CQ

- IEEE Standard for Local and Metropolitan Area Networks: Multicast and Local Address Assignment
- PAR authorized: 2016-02-05
- Scope: *This standard specifies protocols, procedures, and management objects for locally-unique assignment of 48-bit and 64-bit addresses in IEEE 802 networks. Peer-to-peer address claiming and address server capabilities are specified.*
- Need: *Currently, global addresses are assigned to most IEEE 802 end station and bridge ports. Increasing use of virtual machines and Internet of Things (IoT) devices could exhaust the global address space. To provide a usable alternative to global addresses for such devices, this project will define a set of protocols that will allow ports to automatically obtain a locally-unique address in a range from a portion of the local address space. Multicast flows also need addresses to identify the flows. They will benefit from a set of protocols to distribute multicast addresses. Peer-to-peer address claiming and address server capabilities will be included to serve the needs of smaller (e.g. home) and larger (e.g. industrial plants and building control) networks.*
- Progress so far: little

## Address Block Sizes (48-bit addresses)

| second hex digit | address type      | Admin    | Block Size                         | Subdivision | Subdivision Block Size          |
|------------------|-------------------|----------|------------------------------------|-------------|---------------------------------|
| ..00 (0,4,8,C)   | EUI-48            | IEEE RA  | $2^{46} \approx 7.0 \cdot 10^{13}$ | MA-L (OUI)  | $2^{24} \approx 1.7 \cdot 10^7$ |
|                  |                   |          |                                    | MA-M        | $2^{20} \approx 1.0 \cdot 10^6$ |
|                  |                   |          |                                    | MA-S        | $2^{12} \approx 4.1 \cdot 10^3$ |
| ..01 (2,6,A,E)   | all local unicast |          | $2^{46} \approx 7.0 \cdot 10^{13}$ |             |                                 |
| 1010 (A)         | ELI               | IEEE RA  | $2^{44} \approx 1.8 \cdot 10^{13}$ | CID         | $2^{24} \approx 1.7 \cdot 10^7$ |
| 1110 (E)         | SAI               | IEEE 802 | $2^{44} \approx 1.8 \cdot 10^{13}$ |             |                                 |
| 0010 (2)         | AAI               |          | $2^{44} \approx 1.8 \cdot 10^{13}$ |             |                                 |
| 0110 (6)         | <i>Reserved</i>   |          | $2^{44} \approx 1.8 \cdot 10^{13}$ |             |                                 |

- How many is  $2^{46}$ ?
  - IEEE manages EUI-48 space to support unique identification of hardware anywhere in the world for 100 years.
  - The SLAP gives IEEE 802 a space one quarter of that size to exploit for a LAN!



# Did Gilfoyle see OUIs?

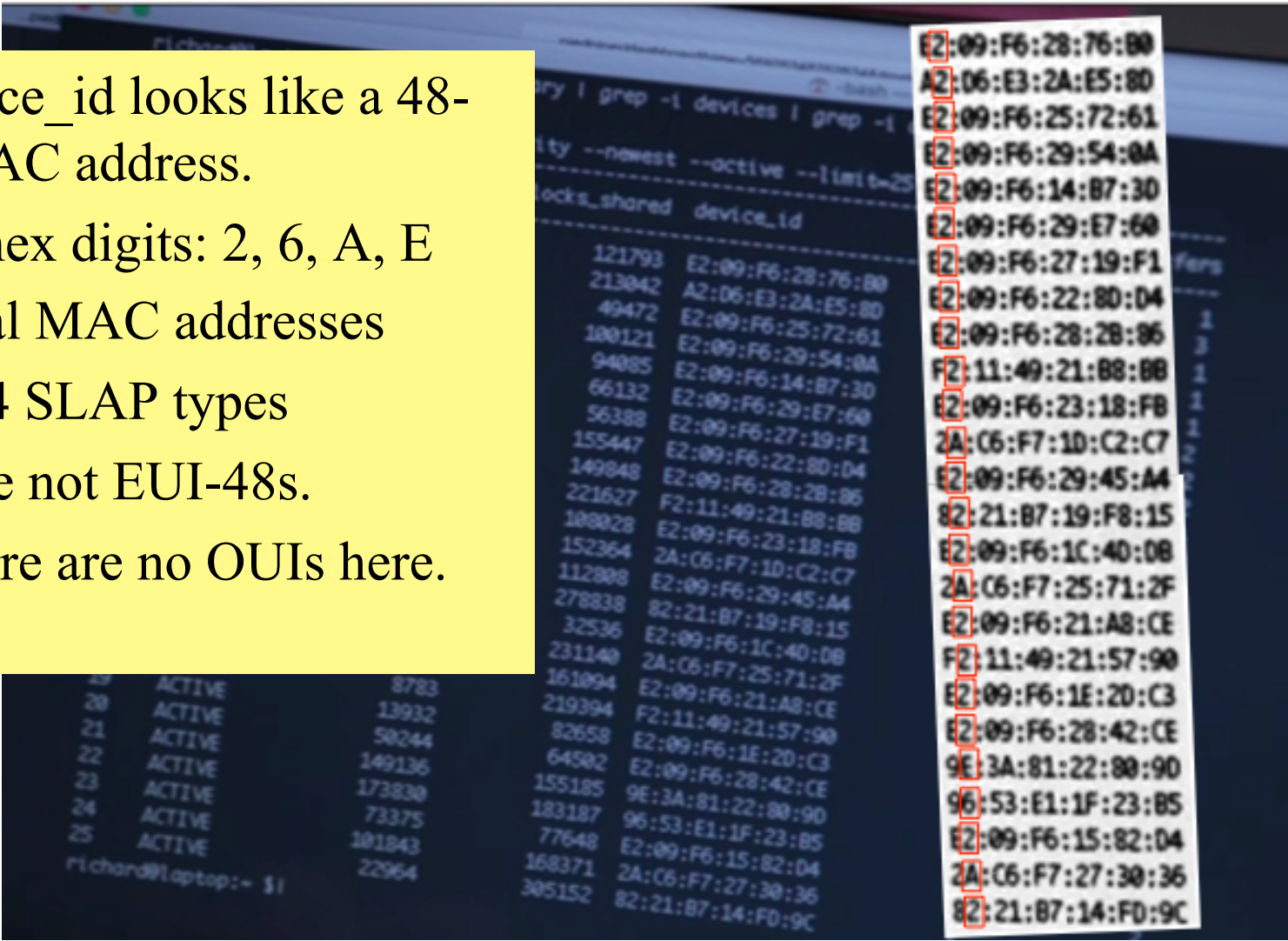
The device\_id looks like a 48-bit MAC address.

Second hex digits: 2, 6, A, E

- local MAC addresses
- all 4 SLAP types

These are not EUI-48s.

- There are no OUIs here.



## Did Gilfoyle see CIDs?

Six-digit prefixes are apparent.

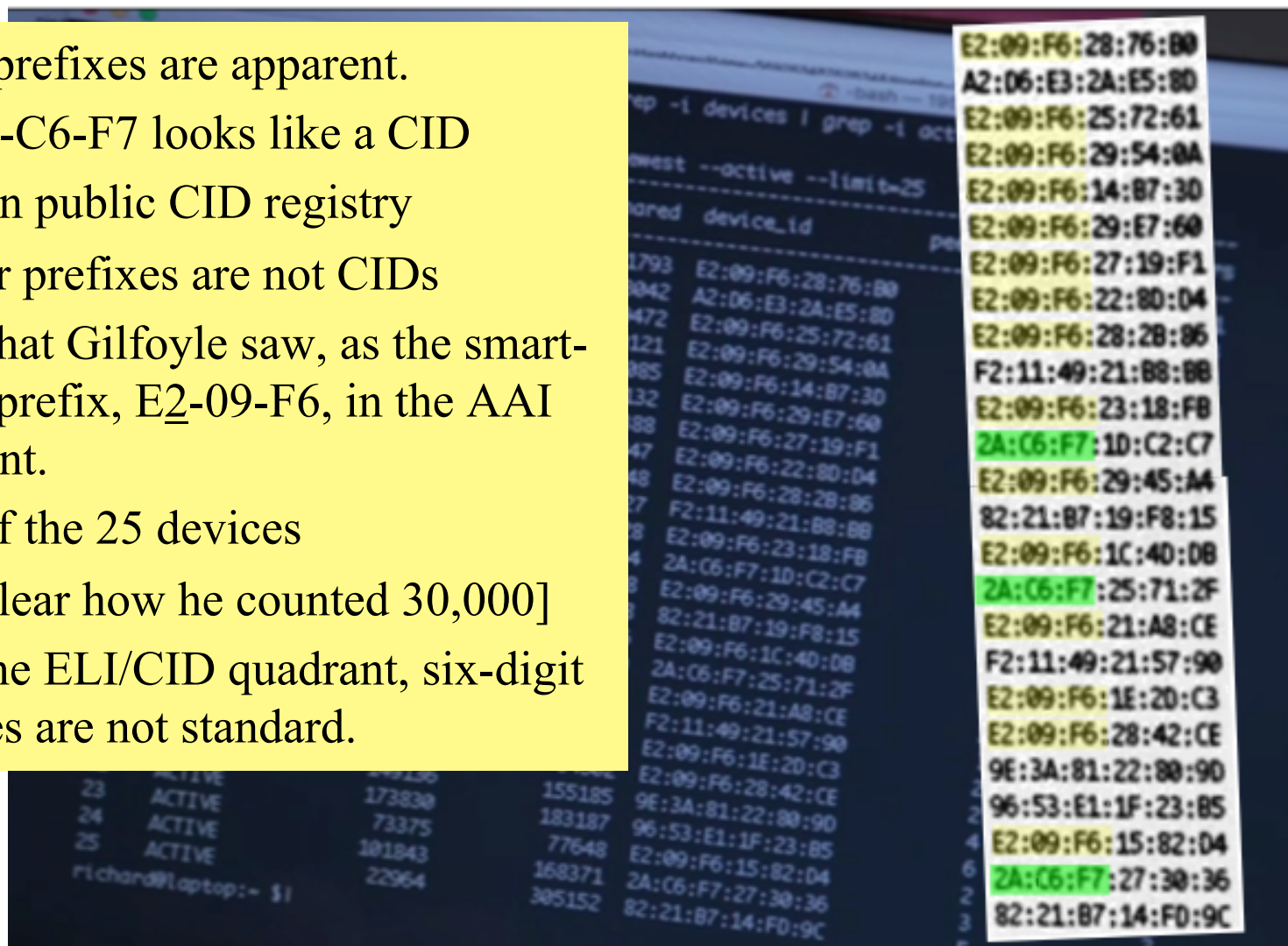
Prefix 2A-C6-F7 looks like a CID

- not in public CID registry
- other prefixes are not CIDs

It seems that Gilfoyle saw, as the smart-fridge prefix, E2-09-F6, in the AAI quadrant.

- 15 of the 25 devices
- [unclear how he counted 30,000]

Outside the ELI/CID quadrant, six-digit prefixes are not standard.



## Could Gilfoyle detect smart fridges?

- In general, the MAC address is not forwarded past an IP router.
  - However, it could be tracked and passed by a device on the LAN, and then be entered into a database.
  - Devices could be programmed to send their addresses.
- Smart-fridge could potentially be identified by OUI, if the EUI was assigned under a specific smart-fridge OUI.
- Local addresses are not global and not normally permanent.
- Smart-fridge addresses would typically not be identified by CID.
  - CID is not definitively tied to the host hardware.
  - For example, CID may identify an assignment protocol.
  - It's feasible for the manufacturer to assign an address to a device as an ELI using a manufacturer's registered CID
    - extension bits could be static or dynamic

## Would a fridge maker use an ELI?

- Fridge manufacturer could obtain a CID assignment and assign MAC address as an ELI
  - could specify informative subfields
  - e.g. could encode model number or serial number
- This might be useful.
  - for example, a smart home hub might be able to discover the fridge solely from its address
- But it may also be dangerous
  - fridge may be susceptible to attack based on characteristics inferred from its address

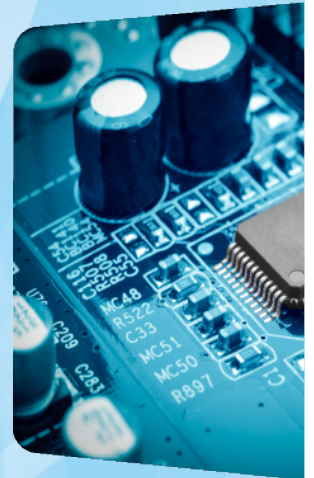
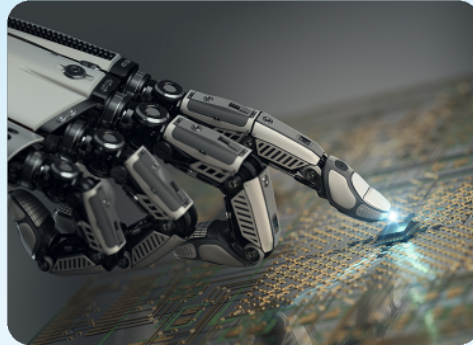
## Is fridge detection a good idea?

- MAC addresses are visible on the LAN, and could be tracked outside the LAN.
  - This could lead to a privacy violation.
  - But it could offer opportunities
    - Gilfoyle took advantage of a property of an address
    - Other addresses can have other special properties
    - Network management takes advantage of known addresses
- If we keep informative addresses separate from flat (e.g. random) addresses, then we can support both types on the LAN.
- If we don't keep them separate, then we may see collisions.

## SLAP Happy

- The SLAP offers:
  - organizations a CID block of ~17M addresses for innovative ELI uses
  - standards developers a block of  $\sim 1.8 \times 10^{13}$  addresses for innovative SAI uses
  - administrators a block of  $\sim 1.8 \times 10^{13}$  addresses to do what they want while avoiding collision with ELI and SAI users
- The SAI block is a huge opportunity!
- Let's use it!





# IEEE Registration Authority Committee and IEEE Std 802c-2017

*Robert Grow, RAC Chair*

*30 Oct 2017*

# Overview of the Registration Authority Committee (RAC)

- ▶ The RAC is a standing committee of the IEEE-SA Board of Governors
- ▶ The RAC provides oversight of all registration activities defined or referenced in approved and proposed IEEE standards, or non-IEEE standards relevant to IEEE interests
  - The RAC recommends if registries defined in IEEE standards should be administered by the IEEE Registration Authority (IEEE RA)
  - Some standards or standards committees are the de facto registration authority
  - A referenced registry may be administered by a non-IEEE registration authority (e.g., Internet Assigned Numbers Authority)
  - Perform mandatory coordination on proposed IEEE standards with registry activity
- ▶ Provide oversight of the IEEE Registration Authority (IEEE RA)
  - Define and refine usage policies for IEEE RA administered registries (currently, 13 registries)
  - Provide guidance where IEEE RA policies don't cover issues that might arise



# IEEE Std 802 and the RAC

- ▶ IEEE Std 802 is the primary standard for multiple IEEE RA administered registries
  - IEEE RA administered universally unique MAC address registries (MA-L, MA-M and MA-S)
  - Specifications for use of Organizationally Unique Identifier (OUI) contained in MA-L, and Company ID (CID)
  - Hierarchical registries (e.g., oid and urn)
- ▶ IEEE Std 802c-2017 includes specifications for use of the CID in local MAC address space and includes specifications for use of CID previously described in registry tutorials
- ▶ IEEE Std 802 revisions and amendments are carefully coordinated with the RAC

## RAC related concerns addressed by 802c

- ▶ Industry trends such as virtualization were dramatically increasing consumption of OUIs
- ▶ Standards increasingly specified OUIs for non-MAC address uses
- ▶ Other trends highlighted the possibilities for use of the local MAC address space to mitigate problems and extend the longevity of the OUI-based MAC address registries
- ▶ IEEE Std 802c carefully considered incumbent use by standards of the local address space (e.g., IETF standards, Fibre Channel, etc.)
- ▶ IEEE Std 802c defines the use of CID for hierarchical administration of local MAC addresses

# IEEE RA Tutorial

## *Guidelines for Use of EUI, OUI, CID*

- ▶ IEEE Registration Authority assigns OUIs, CIDs, etc.
- ▶ Provides tutorials on identifiers and policies:
  - <http://standards.ieee.org/develop/regauth/tut>
- ▶ Tutorial on EUI (referenced in IEEE Std 802):
- ▶ *Guidelines for Use of Extended Unique Identifier (EUI), Organizationally Unique Identifier (OUI), and Company ID (CID)*
  - Published August 2017, in coordination with 802c
  - Supersedes:
    - *Guidelines for Use Organizationally Unique Identifier (OUI) and Company ID (CID)*
    - *Guidelines for 48-Bit Global Identifier (EUI-48)*
    - *Guidelines for 64-bit Global Identifier (EUI-64)*

# Guidelines for Use of EUI, OUI, CID

*more details*

- ▶ Published August 2017
  - <http://standards.ieee.org/develop/regauth/tut/eui.pdf>
- ▶ Covers local addresses, SLAP, CID, and ELI
- ▶ Clarifies other policies; notably (unrelated to local addressing) regarding the multicast bit:
  - *The assignee of an OUI or OUI-36 is exclusively authorized to assign group MAC addresses, with I/G=1, by extending a modified version of the assigned OUI or OUI-36 in which the M bit is set to 1. Such addresses are not EUIs and do not globally identify hardware instances, even though U/L=0.*
  - *The assignee of a CID may assign local group MAC addresses by extending a modified version of the assigned CID by setting the M bit to 1 (so that I/G=1).*

**IEEE Project P802.1CQ:  
Multicast and Local Address Assignment**

## Non-permanent Addresses

- IEEE 802 is most familiar with permanent addresses
- Local addresses are typically not permanent
  - they may be assigned during use
- Need to consider the ramifications

## Some Address Features

- Uniqueness
  - most fundamental property
  - local (on the LAN), or universal
  - relevant to identity
- Permanence/Longevity
  - relevant to trackability
  - relevant to management
- Structure and Information content
  - Does the address convey information beyond identity?
  - Can address convey location (e.g., IP)
  - other possibilities

## Some Examples of Assignment Protocols

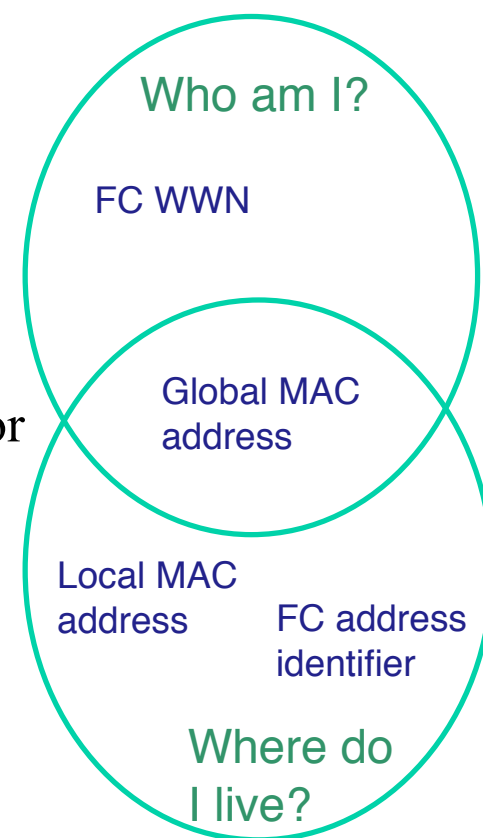
- Server-based
    - DHCP – currently for IP addresses as well as other network info, a draft is being prepared for DHCP MAC address assignment
    - Fibre Channel – see following slides
  - Stateless (per IETF)
    - IPv6 “Stateless Address Autoconfiguration” (SLAAC)
      - could be based on IEEE EUI
      - requires Duplicate Address Detection (DAD)
    - Claiming, FCoE PT2PT and IEEE P1722
      - device claims an address by announcement, but
        - may probe first for addresses in use
        - may check afterwards for collisions
- \*P802.1CQ PAR mentions “peer-to-peer address claiming and address server capabilities”



**Example:**  
**MAC address assignment protocols in  
Fibre Channel over Ethernet (FCoE)**

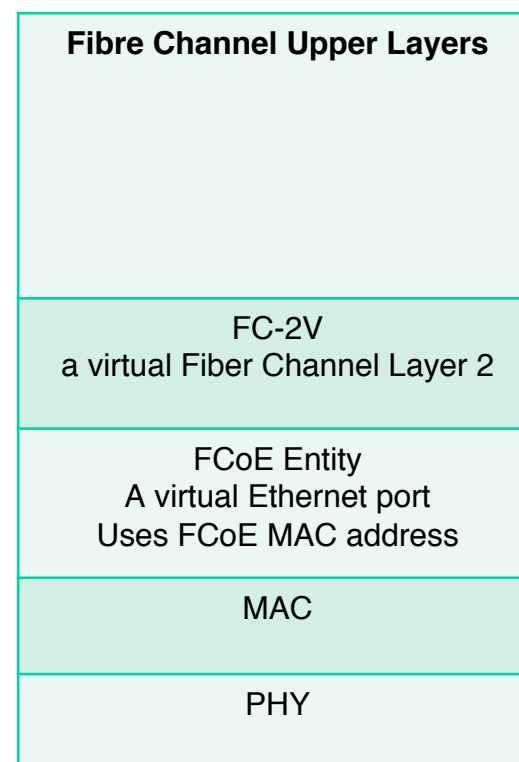
## Addressing and Identity

- IEEE 802 global MAC addresses serve as both Layer 2 address and identifier of the port.
- In Fibre Channel, these are separate.
- World Wide Name (WWN) – 64-bit (or 128-bit)
  - Identifies a system or a port
  - Multiple formats defined, including based on an EUI-48 or EUI-64
  - Appears in packets only as needed, e.g. to identify the entity when making a packet.
  - Not used as an address; not used in packet headers to identify source and destination
- Address identifier – 24-bit
  - Source ID and Destination ID in packets to identify the end points



## Fibre Channel over Ethernet (FCoE) Addresses

- Fibre Channel networks use a 24-bit Layer 2 “address identifier”
- For FCoE ports
  - From the Ethernet perspective, FC-2V acts like a Layer 3 similar to an IP layer
  - Wanted to use the FC address identifier as part of the FCoE MAC addresses
  - Avoids needing mapping tables between FC address identifier and MAC address



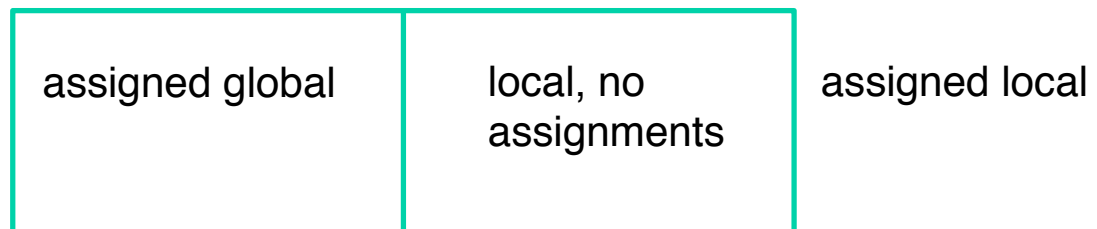
FCoE stack

## Making space for FCoE MAC addresses

T11 faced a problem of where to put the FCoE MAC addresses.

- They aren't global addresses so shouldn't go in that space
- They wanted them to always be in the same address "range" but there was no way to get an assignment
- They decided to just pick part of the local address space
  - Cases such as this were part of the impetus for creating IEEE 802c
- Since IEEE 802c and CID assignments didn't exist yet, they just picked some address ranges

Before IEEE Std 802c



## Two kinds of FCoE networks

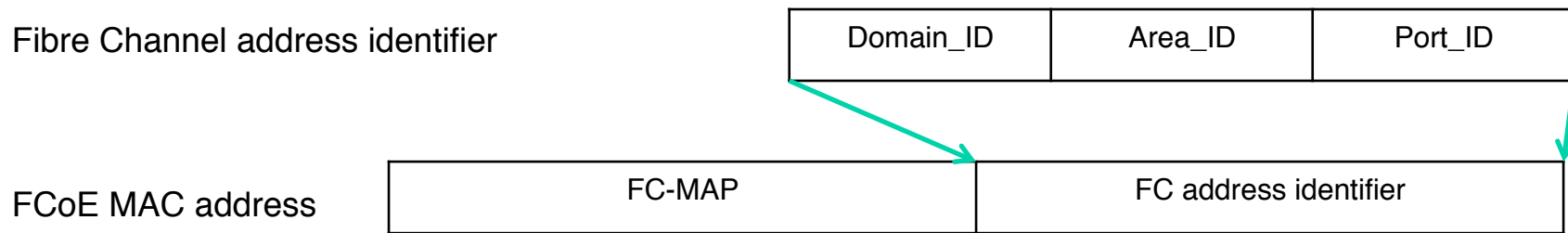
VN2VN (virtual node to virtual node)

- FC switches operate an FC fabric
- The fabric can be a mix of native FC and partly over Ethernet
- FC switches assign FC address identifiers to the end nodes that connect to them.
  - For FCoE, the FC address identifier assignment also produces a MAC address.

PT2PT (point-to-point)

- There are no FC switches or fabric
- Only applies to FCoE
- End nodes generate MAC addresses through a claiming process and establish point-to-point connections to other FCoE nodes

## FCoE VN2VN address assignment



- FC switches also serve as FC address servers
  - Protocol between the switches chooses one to control the fabric (Principle Switch) and distribute 8-bit Domain\_IDs to switches.
- FC switches assign the remaining 16 bits of FC address id to end-node ports.
  - End node gets an address when it connects.
  - Area\_ID can identify one or more ports of the FC switch
- There are 16 FC-MAP values
  - Allows for multiple FC fabrics to coexist on an Ethernet network
  - 0E-FC-00 is the default value
  - 0E-FC-00 to 0E-FC-FF are allowed.

## Potential Applicability to IEEE 802 Address Assignment Protocols

- Principle address servers might not be in bridges.
  - Should allow for a set of principle address servers
  - At least allow for fail-over to a passive server or allow cooperating active servers with fail-over
- Allow a bridge, access point or hypervisor to lease a block of addresses from a principle address server and distribute the addresses to end nodes on connection
  - Faster address acquisition by end nodes
  - For mobile devices, do they change that address as they move or could keep it for at least a lease time?
- Would we ever want a heirarchical address where a subset of the address identified position in the network for forwarding decisions?

## Getting a MAC address from the network without a MAC address

- Virtual nodes have an address to use during address acquisition, so no problem for them
- Could define a Null source address value to use when no address
  - Replies can be sent to a well-known multicast and filtered based on identifier in the packet (e.g. EUI-64, IP address, longer random number)
  - Bridge or Access point could proxy by inserting its source address to reduce the multicast load (similar to IPv6 protocol) for the network
- If the adjacent bridge or access point provides the address, it may not matter much what address the end point uses
  - Could use an address generated in a range with some random bits during connection until the address is assigned.
  - Potential conflicts are only those on the shared medium.

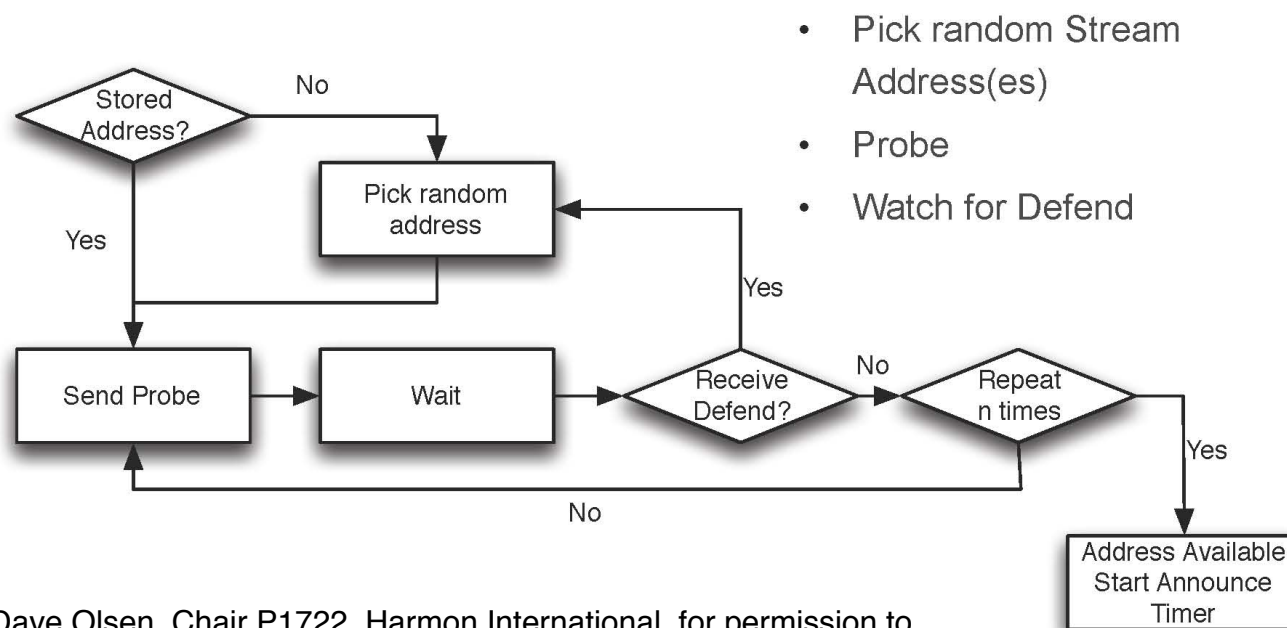


## FCoE PT2PT address assignment

- End nodes acquire addresses without any central authority
- Fixed value for FC-MAP: 0E-FD-00
- Remaining 24-bits randomly chosen by node
  - Can try last used value if re-connecting
- Checks for uniqueness and generates another address if conflict.
- 3-phases to the acquisition of an address
  - Probing: checks to see if anyone else is using the address
  - Claiming: announces that it is going to use the address
  - Usage: periodically sends a beacon announcing its address to check for conflicts, e.g. due to a network join.
  - P1722 uses a similar 3 phase process: probe, announce, defend

# IEEE P1722 Probe and Announce

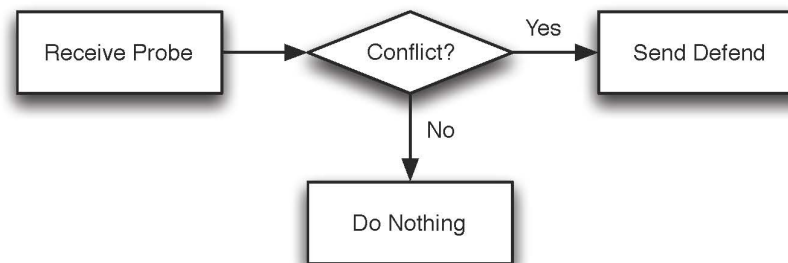
## Address Acquisition Algorithm



With thanks to Dave Olsen, Chair P1722, Harmon International, for permission to borrow content on this and the following slide from him.

# IEEE P1722 Defense

## Address Defense Algorithm



- Watch for Probe packets
- If a conflict, send a Defend

- P1722 nodes also send Announce every 20 seconds
- Discard and return to acquisition if there is a conflict.

## Probing and Claiming

- FCoE nodes have a MAC with an address to use as the source address in probe and claim packets
- Destination address is a multicast identifying PT2PT FCoE ports
- Candidate FCoE address appears only in the packet payload.
- Probe and claim packets are sent multiple times (at least 2) to allow for packet loss
- All PT2PT FCoE ports listen for Probe, Claim and Beacon packets
- Probing ports try another address if another node responds that it's already claimed
- Tie breaker (based on whether the ports are reusing a prior address and WWN of the two ports) decides which one keeps the address if both are claiming or if both are probing.

## Potential applicability to IEEE 802 address assignment protocols

Comments about MAC address to use before one has an address on the earlier slide apply

- For Ethernet networks, much of the protocol could be adapted with little change
- For a general solution, need to deal with situations including
  - Nodes that sleep to conserve power
  - Nodes that move in and out of connectivity
  - Possibly higher BER over wireless
- An access point acting as proxy for its attached nodes could help.

## Claiming vs Server-based protocol

- Claiming seems more complex, but the server-based description doesn't include protocols running between servers.
- Claiming allows for operation without server infrastructure
- Server protocol allows for faster address acquisition. Claiming protocol has to have waits to allow responses to arrive.
- Not necessarily either/or
  - A node could use a server if present or claim
  - For example, a server could watch for probes and offer to provide an address.

## Summary

- The local address space is huge and valuable.
- The IEEE RA's CID give companies a chance to innovate
  - SLAP supports ELIs based on CID
  - standards should not step on any company's ELIs
- SLAP specifies a reserved quadrant
  - standards should not step on it
- SLAP specifies an AAI quadrant
  - standards should use the AAI quadrant in any way
- SLAP offers a 44 bit SAI quadrant to IEEE 802 to exploit.
  - standards should put SAI to use in an orderly fashion.
- Let's ensure protocol coexistence for best success.
- Please participate in development of P802.1CQ.

## **Further Information:**



# **Other examples of address distribution protocols**

## Example: IPv4

- IPv4 address can be globally routable
- IPv4 address can be local
- IPv4 address is hierarchical, with two components:
  - prefix: identifies network or subnet
  - host identifier: identifies interface
  - hierarchy provides for routing by network, not by address
  - 802 local addressing could support this approach

## View from IETF: IPv6

For ideas on possible protocols, consider IETF.

- IPv6 unicast address (128 bits) includes:
  - subnet prefix ( $n$  bits, typically 64)
  - interface ID (IID) (128- $n$  bits, typically 64)
    - used to identify interfaces on a link
    - formerly encouraged creation from IEEE EUI (e.g. RFC 4291)
  - RFC 7136: *various new forms of IIDs have been defined: including temporary addresses [RFC4941], Cryptographically Generated Addresses (CGAs) [RFC3972] [RFC4982], Hash-Based Addresses (HBAs) [RFC5535] ...*

## IETF: Temporary Addresses

- SLAAC = “Stateless Address Autoconfiguration”
- RFC 4941: Privacy Extensions for SLAAC in IPv6
  - Sept. 2007
  - *...for interfaces whose interface identifier is derived from an IEEE identifier. Use of the extension causes nodes to generate global scope addresses from interface identifiers that change over time, even in cases where the interface contains an embedded IEEE identifier. Changing the interface identifier (and the global scope addresses generated from it) over time makes it more difficult for eavesdroppers and other information collectors to identify when different addresses used in different transactions actually correspond to the same node.*

## Semantically Opaque Interface Identifiers

- RFC 7217
  - Apr. 2014
  - *temporary addresses can be challenging.... from a network-management point of view, they tend to increase the complexity of event logging, troubleshooting, enforcement of access controls, and quality of service.... some organizations disable the use of temporary addresses even at the expense of reduced privacy... may also result in increased implementation complexity*
  - *...Interface Identifier changes when the host moves from one network to another. This method is meant to be an alternative to generating Interface Identifiers based on hardware addresses (e.g., IEEE LAN Media Access Control (MAC) addresses), such that the benefits of stable addresses can be achieved without sacrificing the security and privacy of users.*

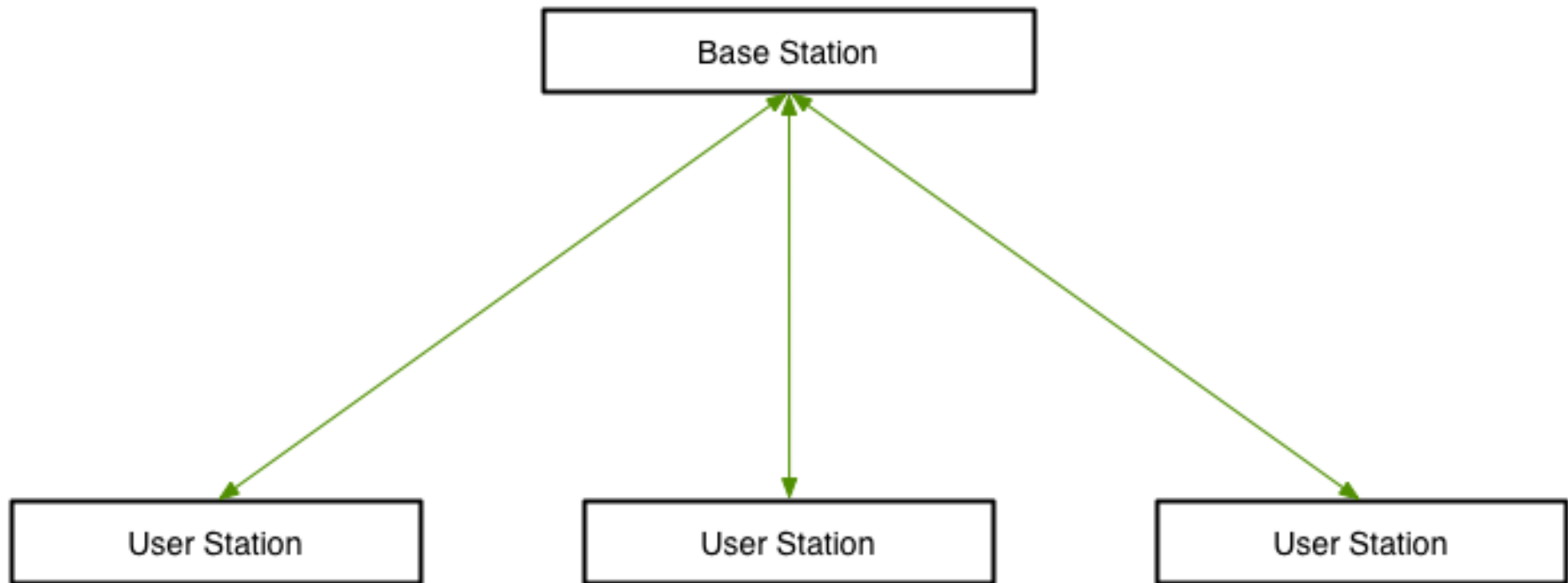
## IETF CGA

- CGA = “Cryptographically Generated Address”
- RFC 3972
  - March 2005
  - *interface identifier is generated by computing a cryptographic one-way hash function from a public key and auxiliary parameters. The binding between the public key and the address can be verified by re-computing the hash value and by comparing the hash with the interface identifier. Messages sent from an IPv6 address can be protected by attaching the public key and auxiliary parameters and by signing the message with the corresponding private key. The protection works without a certification authority or any security infrastructure.*
  - includes collision count field based on duplicate address detection

## Example: CGA and Privacy can coexist

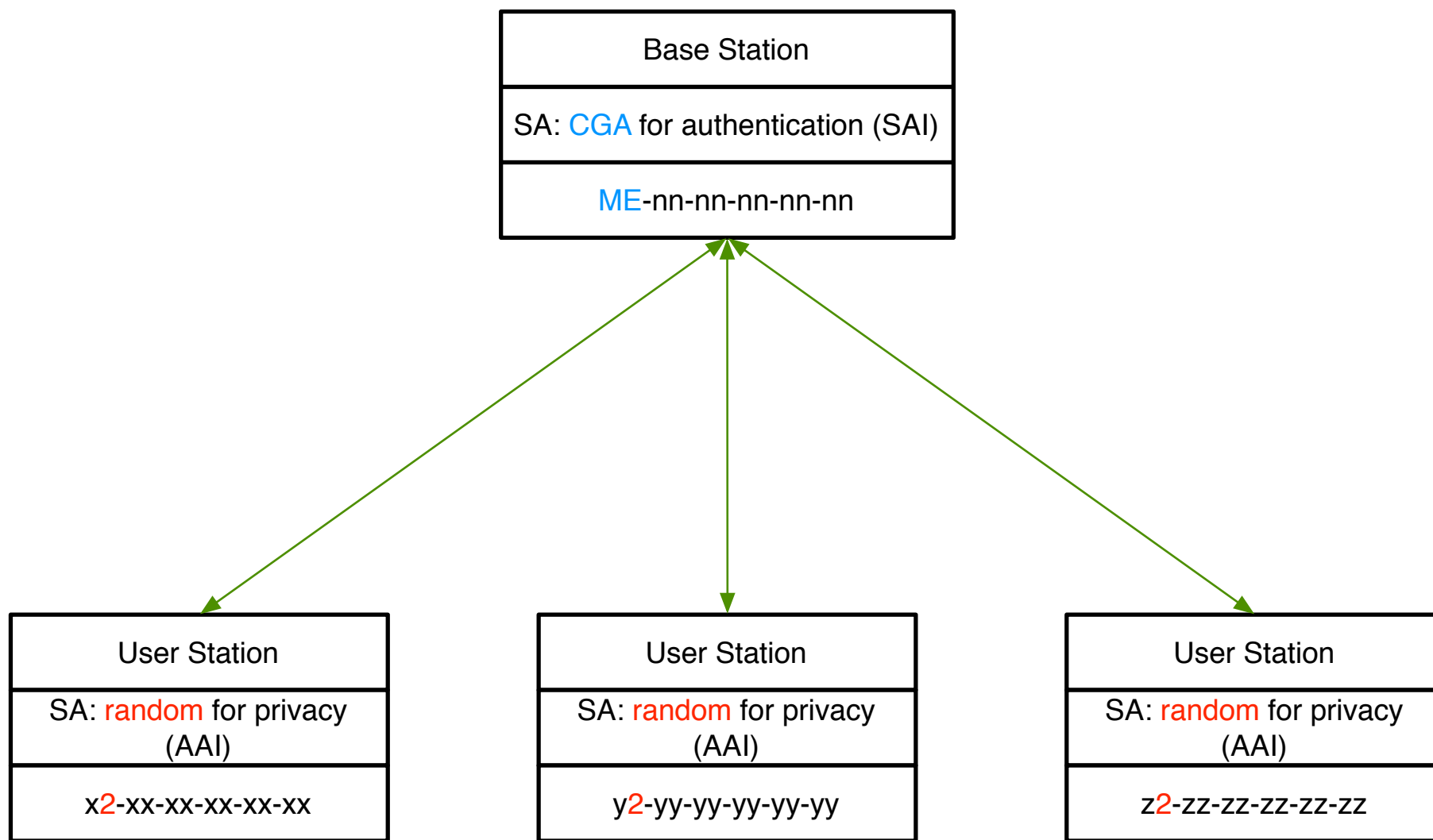
- On a LAN, some devices strive for privacy
  - may use a randomized address
- On a LAN, some devices may not value privacy but put value on other features, such as verification
  - example: access points should be easily found
  - address may be structured for meaning
- Both types of devices should be able to coexist
  - random addresses should stay out of assigned space
  - receiver can then determine the type of address and respond accordingly

# CGA/Privacy Coexistence

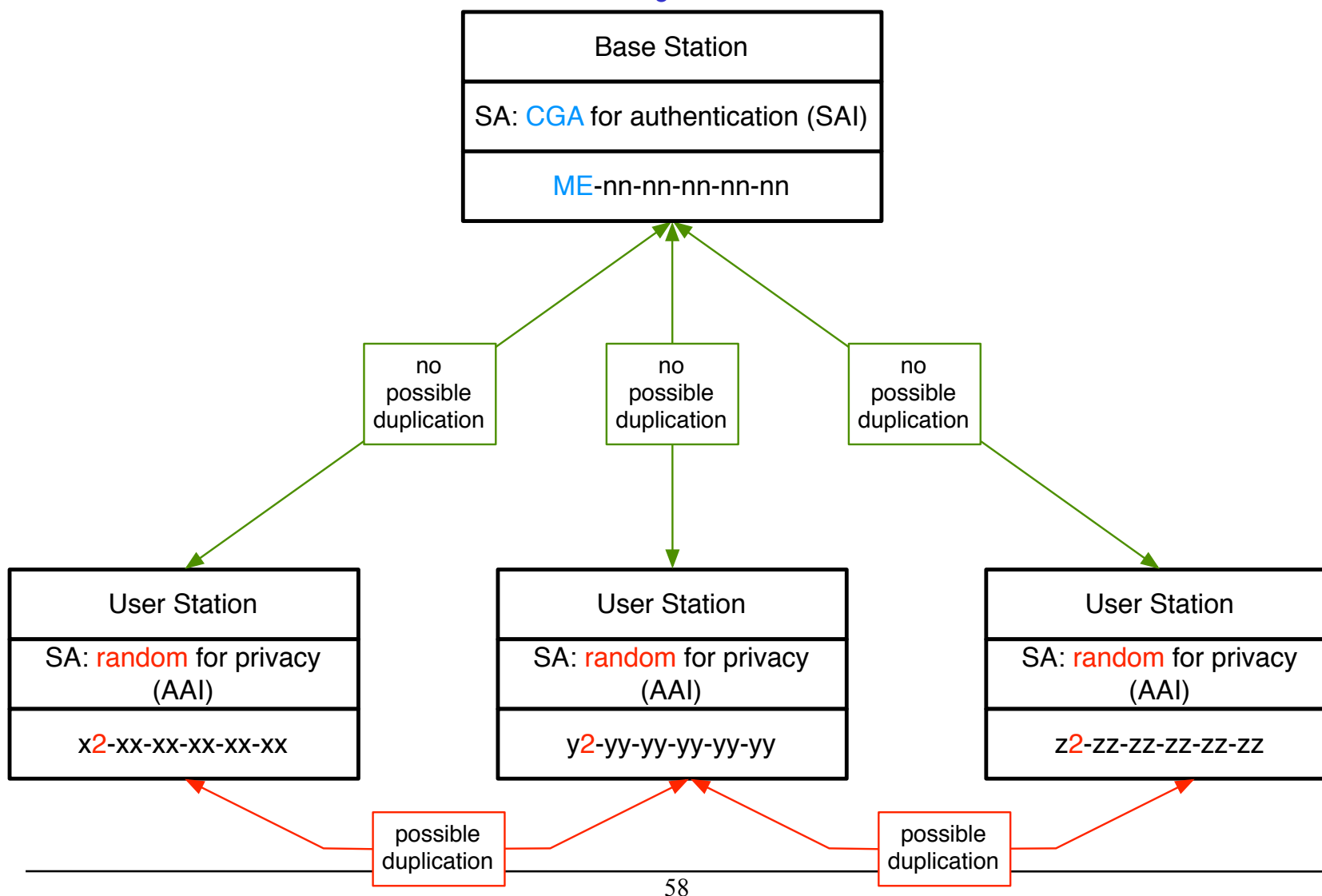




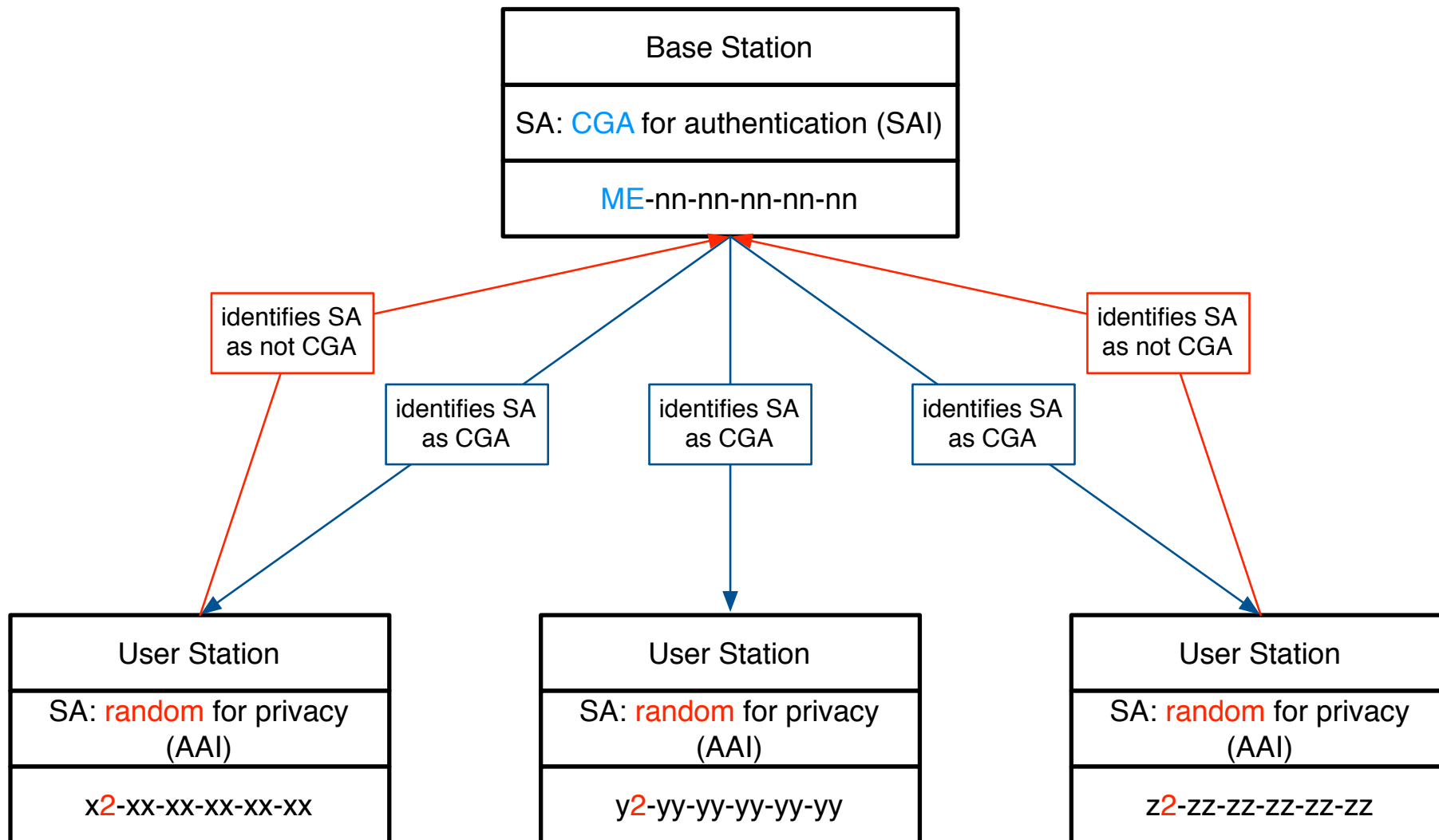
# CGA/Privacy Coexistence



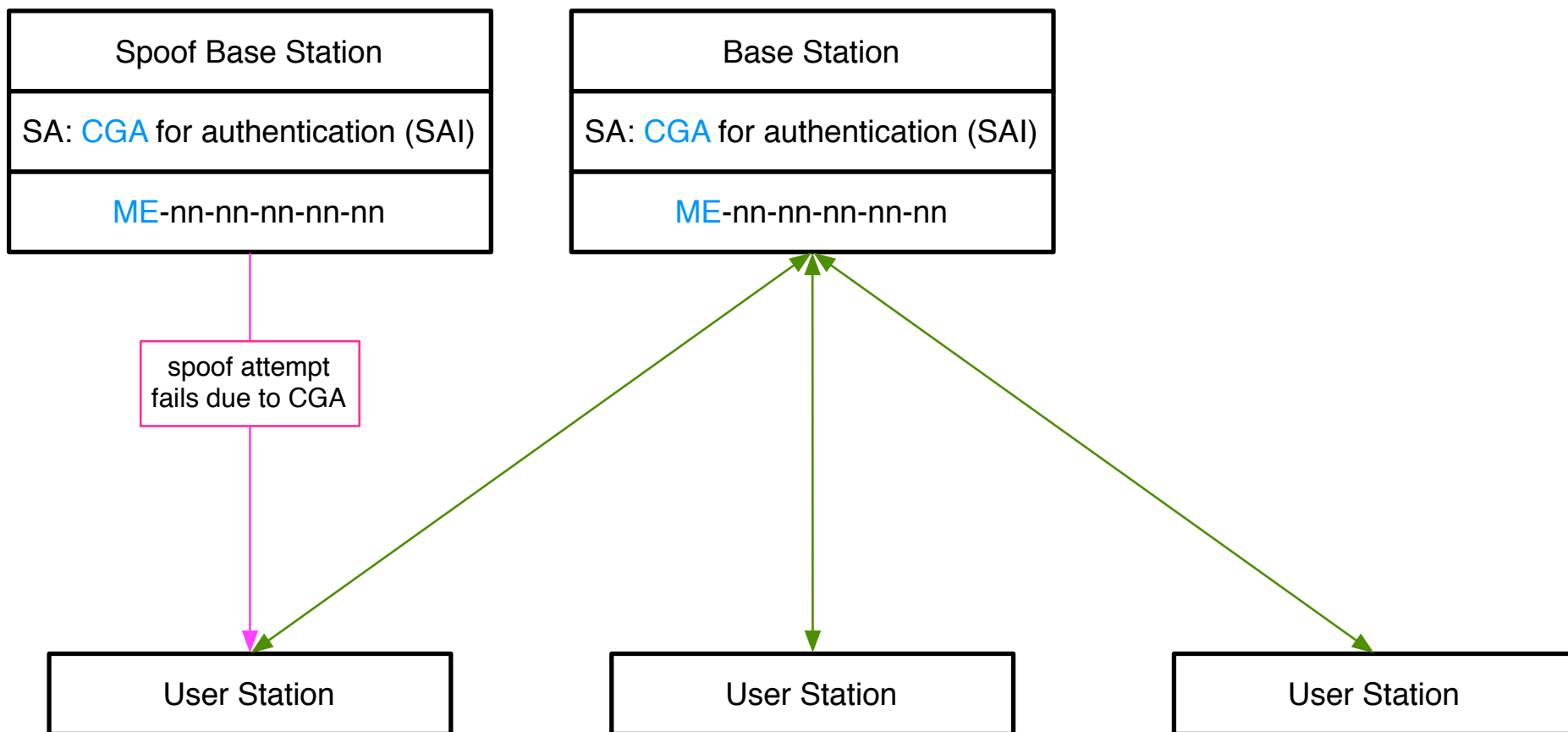
# CGA/Privacy Coexistence



# CGA/Privacy Coexistence



# CGA/Privacy Coexistence



# CGA/Privacy Coexistence

