Implementation Report on the use of EAP and RADIUS for US eduroam

saag Meeting
IETF 115: London, UK
November 2022

Background

- We worked with Internet2 to implement and deploy new AWS-based US eduroam infrastructure that went live in November 2021
  - FreeRADIUS-based, geographically-redundant, load-balanced deployment
- We have worked with Internet2 to operate, monitor and maintain the US eduroam infrastructure for the past year

The goal of this presentation is to **share our EAP and RADIUS implementation and operation experiences** with the IETF. Although much of this presentation focuses on **need for improvement**, our overall experience has been **positive and highly successful.**

Outline

- Quick review: What is eduroam?
  - Underlying technologies
  - eduroam proxy hierarchy
- Overview of the US eduroam deployment
  - Deployed infrastructure
  - Facts & figures
- Request “routing” in eduroam
- Security challenges
- Operational challenges

What is eduroam?

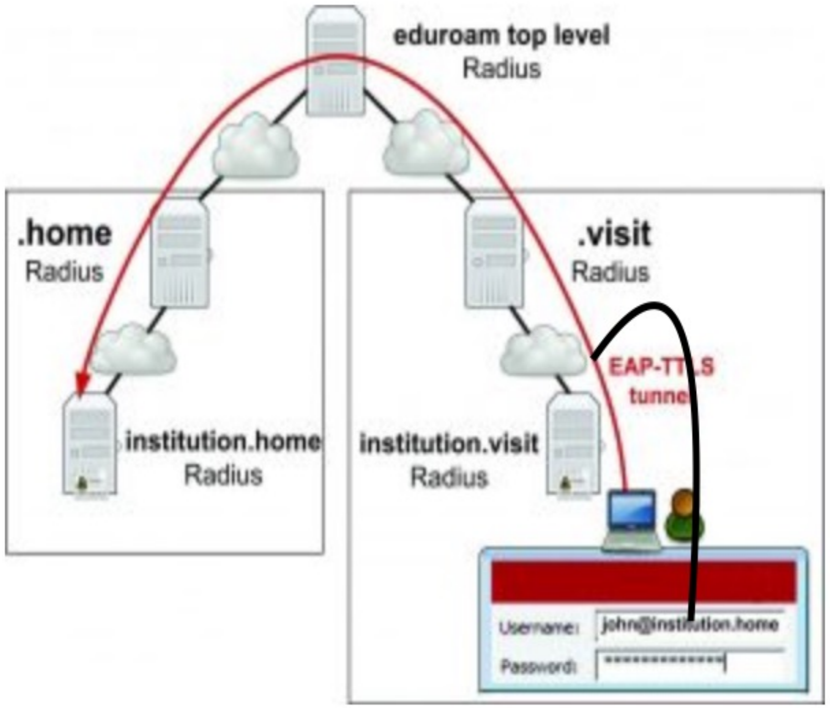
- A widely-used, international roaming service for higher education and research
    - Now being expanded to K-12, libraries, museums, etc.
- Allows students & staff from education or research institutions to access the Internet at remote eduroam service locations
    - Uses a common SSID: “eduroam”
    - Free, seamless access -- no need for captive portals or new configuration
    - May provide more privileges or better performance than public guest access
- A home institution (IdP) verifies a user’s identity and provides credentials
- eduroam service locations (RPs) proxy authentication requests to the eduroam infrastructure for authentication by the user’s home institution
- Millions of students and staff from thousands of home institutions access eduroam at tens of thousands of service locations throughout the world
- See https://eduroam.org for more information

eduroam authentication overview

A user from “institution.home” uses his Supplicant to access the ”eduroam” SSID at “institution.visit”

User: john@institution.home
IdP: institution.home
RP: institution.visit

The request runs through an eduroam Roaming Operator that is peered with both institutions

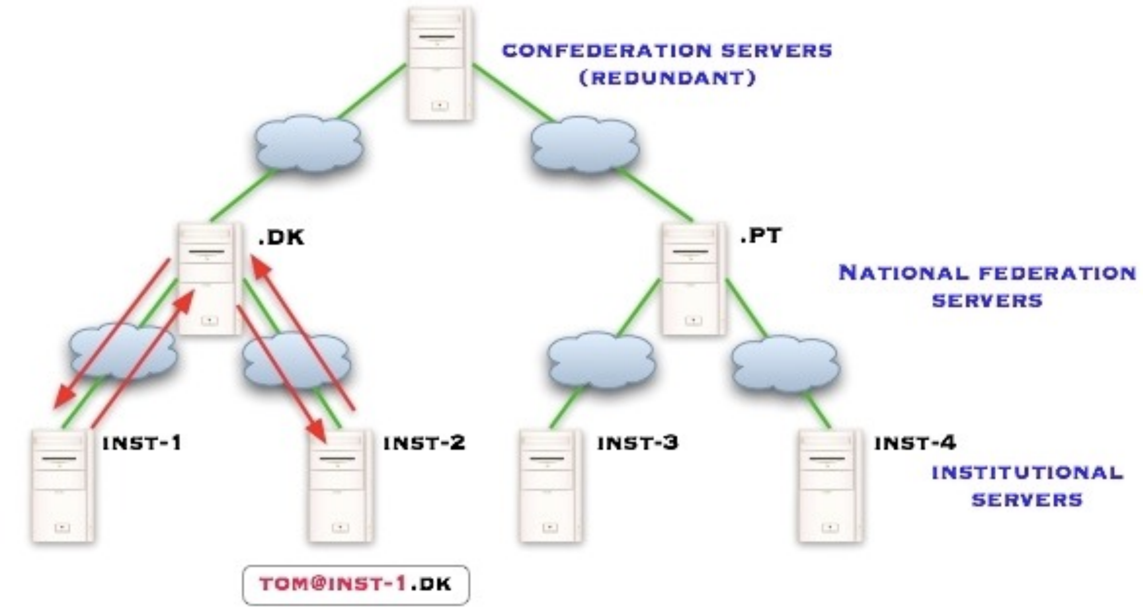


Underlying technologies

- RFC 2865: Remote Dial In User Service (RADIUS)
- RFC 3748: Extensible Authentication Protocol (EAP)
- RFC 3579: RADIUS Support for EAP
- Various EAP authentication methods, such as:
  - RFC 5216: EAP Transport Layer Security (EAP-TLS)
  - RFC 5281: EAP Tunneled Transport Layer Security (EAP-TTLS)
  - RFC 8940: Protected EAP Protocol
- IEEE 802.11 & IEEE 802.1x

eduroam proxy hierarchy

- Three-tier proxy hierarchy
  - Individual eduroam institutions
  - National-level proxies
  - Top-level eduroam proxies
    - Europe and Asia
- At each level, requests for authentication for unknown realms are forwarded upward



Overview of the US eduroam deployment

- US eduroam is operated by Internet2 InCommon
- US eduroam consists of
  - > 1000 home institutions
  - > 3000 service access points
  - ~2M eligible students and staff members

- See https://incommon.org/eduroam/ for more information

US eduroam System Architecture

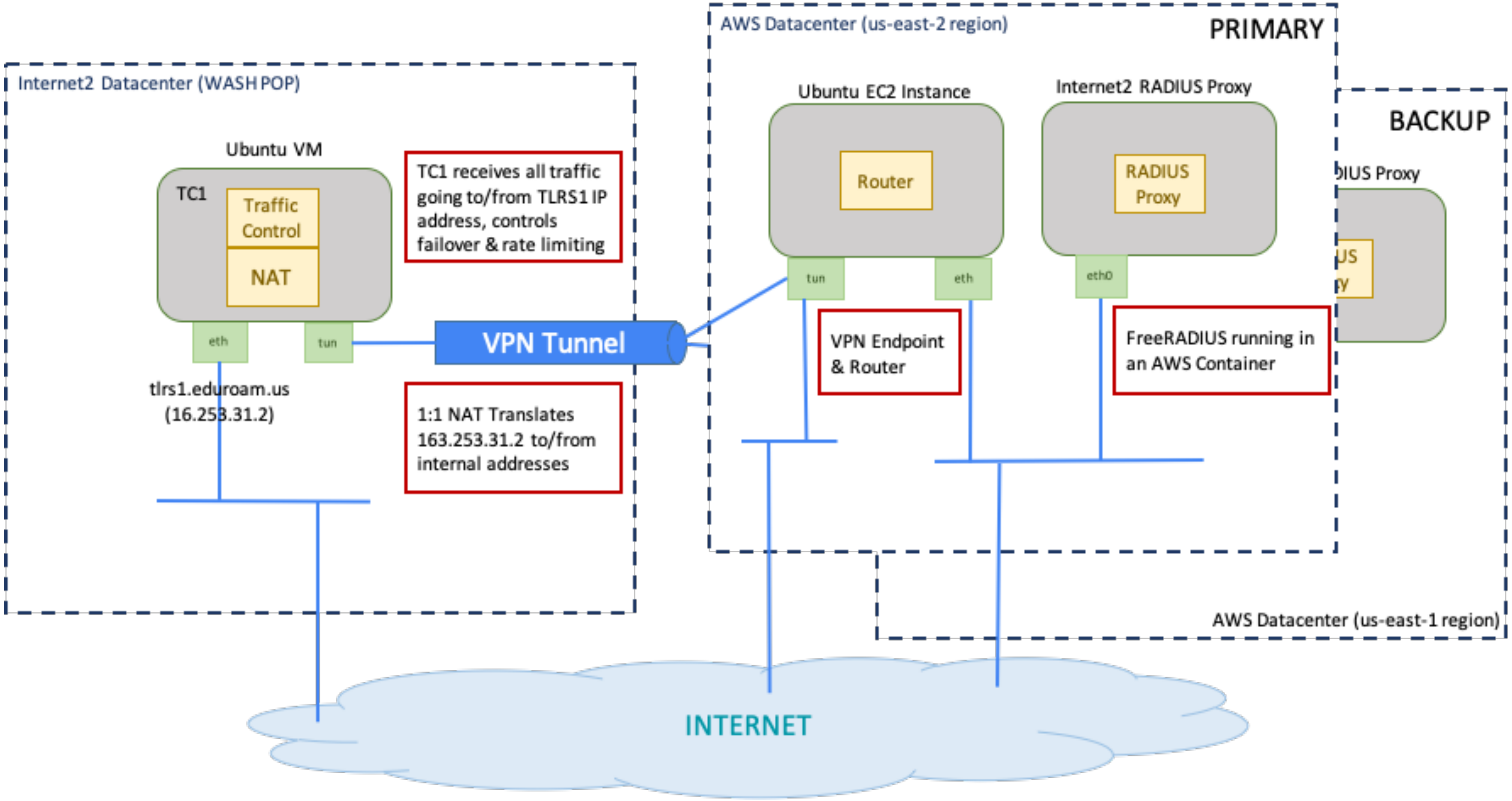


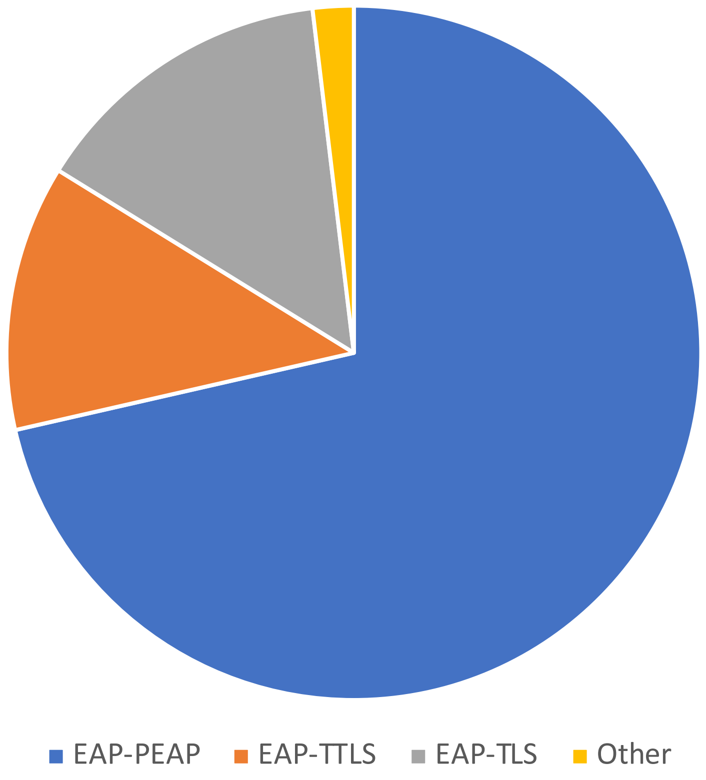
Diagram shows East Coast deployment, duplicated for West Coast

US eduroam facts & figures

- During a typical peak period:
  - Up to 100,000 RADIUS messages received per minute
  - > 12,000 unique authentication requests completed per minute
    - ~65% Access-Accept
    - ~35% Access-Reject
  - ~18% of incoming requests rejected or discarded by our proxy
    - Looping
    - Missing or malformed username or realm
    - Unknown client
    - Invalid authenticator
    - Malformed EAP message

EAP method distribution

- ~75% PEAP
- ~15% EAP-TLS
- ~12% EAP-TTLS



From a report compiled in Q1 2022

Request “routing” in eduroam

- There are two sets of top-level eduroam operators, one in Europe and one in Asia
- There is a National Roaming Operator (NRO) in each country who is responsible for enrolling eduroam institutions and proxying requests between eduroam institutions within their country
- Each NRO provides a JSON-formatted list of their enrolled institutions to their top-level provider (for example, US eduroam provides their list to GEANT in Europe)

- If an institution RADIUS server receives a non-local eduroam request, the request is forwarded to their NRO RADIUS proxy
- If an NRO proxy does not have a matching IDP realm registered, the request will be forwarded to a top-level server
  - If a country code is included in the realm name, the request will be forwarded accordingly
  - Otherwise, a top-level server will be picked in a round robin fashion.
- If the top-level operator does not have a registration entry for the realm, it will be forwarded to the other top-level operator.

An inefficient (but realistic) example

A user from example.com (a Canadian institution) visits a US eduroam service location and attempts to join the ”eduroam” SSID.

- The service location RADIUS server (1) determines that example.com is not a local realm, and forwards the request to one of the US eduroam proxies.
- The US eduroam proxy (2) determines that example.com is not a realm registered in the US, finds no country code in the realm, and forwards the request to an Asian top-level RADIUS proxy
- The Asian proxy (3) determines that the IDP ream, example.com, is not registered by one of its NROs, so it forwards the request to one of the European top-level servers
- The European top-level server 4) determines that example.com was registed by the Canadian NRO and forwards the request to one of the Canadian RADIUS proxies.
- The Canadian proxy (5)forwards the request to one of example.com’s RADIUS servers (6).

Cost of “routing” inefficiency

- Successful eduroam authentication requests may traverse up to 6 RADIUS proxies
- Each eduroam authentication requires several request/response exchanges which will follow the same path as the first message
  - Typically 3 to 7 request/response exchanges, depending on the chosen EAP method and credential size
- Crytographic message authentication is performed for every RADIUS message at every hop, so efficient routing would be highly desirable

- No dynamic routing, and no equivalent of ICMP redirects
- No standard mechanism for loop detection or prevention

Lack of testing/debugging tools

- When a remote EAP/RADIUS request is dropped or rejected, it can be very difficult to figure out *why* it didn't work.
  - Many errors result in proxies silently discarding packets
  - Access-Reject messages do not typically contain a useful error code

- Although Status-Server messages provide a way to query the health of a directly-connected server, there is no way to query the health of a more remote server (i.e. no multi-hop ping)
- There is no way to trace the path that a request will take across the proxy fabric (i.e. no traceroute)

Security challenges

- RADIUS message protection is antiquated by today's standards
- It consists of pairwise shared secrets and and MD5 hash for message authentication
  - The keys are often typed by the administrator into a UI or a plain text file
  - There is no consistently enforced minimum length for the keys, nor is there any requirement for cryptographic generation
  - There is no algorithm agility

Privacy vs. secondary credentials

- User privacy is essential in eduroam, because the risk is exposing the physical location of an end-user
- Secondary credentials (such as certificates) can be valuable to allow password-less authentication, or to protect primary credentials from potential exposure

- PEAP and TTLS allow the use of an anonymous username in the outer method, so that the username is only transmitted over an encrypted tunnel
- EAP-TLS supports secondary credentials, but the username is exposed in plaintext in the unencrypted client certificate

- Support for TLS 1.3 in EAP-TLS and/or wider user of RadSec would meet both requirements if they were fully available and easily deployed
- It would also be desirable to have a non-PKI solution that would support both the privacy and secondary credential requirements.

Operational challenges

- Looping is the most frequent cause of dropped requests
  - Looping is typically caused by misconfiguration of an institution server
  - No standard method for RADIUS loop detection/prevention (we use a vendor attribute)
- Many clients will retry a failed authentication request immediately, with the same credentials
  - No back-off, no apparent limit on the number of retries
  - One example involved 37,000 requests every 5 minutes until manual intervention at the service location
- Long-expired or obsolete credentials often remain configured on user devices
  - There is no way for the IDP to signal the device that the credentials should be invalidated
- Supplicants will try to use obviously bogus credentials
  - Spaces or special characters in usernames or realms, missing realms, expired certs, etc.
- We receive many requests per second with realms of the form wlan.mncNNN.mccNNN.3gppnetwork.org
  - Are we being mistaken for a 3gpp carrier network? How can we make this stop?

Ongoing Progress

- Since I originally offered to make this presentation, work has been proposed in the IETF (in some cases by us) that would address some of the issues we have encountered
  - RADEXT(RA) BOF and rechartering effort
  - EAP-DIE discussion in EMU

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This presentation contains our own observations and opinions only. It does not represent the views or opinions of Internet2, eduroam.org or any other company or organization.

Questions?