Network Access Control and Cloud Security

Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@wustl.edu

Audio/Video recordings of this lecture are available at:
http://www.cse.wustl.edu/~jain/cse571-17/
Overview

1. Network Access Control (NAC)
2. RADIUS
3. Extensible Authentication Protocol (EAP)
4. EAP over LAN (EAPOL)
5. 802.1X
6. Cloud Security

Network Access Control (NAC)

- **AAA:**
  - **Authentication:** Is the user legit?
  - **Authorization:** What is he allowed to do?
  - **Accounting:** Keep track of usage

- **Components:**
  - **Supplicant:** User
  - **Authenticator:** Network edge device
  - **Authentication Server:** Remote Access Server (RAS) or Policy Server. Backend policy and access control
Network Access Enforcement Methods

- IEEE 802.1X used in Ethernet, WiFi
- Firewall
- DHCP Management
- VPN
- VLANs
**RADIUS**

- **Remote Authentication Dial-In User Service**
- Central point for **Authorization, Accounting, and Auditing data** ⇒ **AAA** server
- Network Access servers get authentication info from RADIUS servers
- Allows RADIUS Proxy Servers ⇒ ISP roaming alliances
- Uses UDP: In case of server failure, the request must be re-sent to backup ⇒ Application level retransmission required  
  - TCP takes too long to indicate failure

![RADIUS Diagram]


©2017 Raj Jain
Extensible Authentication Protocol (EAP)

- Old Methods: Password Authentication Protocol (PAP), Challenge Handshake Authentication Protocol (CHAP), Microsoft CHAP (MS-CHAP)
- Each authentication protocols required a new protocol ⇒ Extensible Authentication Protocol
- Allows using many different authentication methods
- Single-Step Protocol ⇒ Only one packet in flight ⇒ Duplicate elimination and retransmission
  Ack/Nack ⇒ Can run over lossy link
- No fragmentation. Individual authentication methods can deal with fragmentation. One frag/round trip ⇒ Many round trips
- Allows using a backend authentication server ⇒ Authenticator does not have to know all the authentication methods
- Can run on any link layer (PPP, 802, ...). Does not require IP.

EAP (Cont)
EAP Terminology

- **Peer**: Entity to be authenticated = Supplicant
- **Authenticator**: Authenticating entity at network boundary
- **Authentication Server**: Has authentication database
- **EAP server** = Authenticator if there is no backend Authentication Server otherwise authentication server
- **Master Session Key (MSK)** = Keying material agreed by the peer and the EAP server. At least 64b. Generally given by the server to authenticator.
EAP Exchange

- EAP Message Format:
  - Code | Identifier | Length | [Type] | Data
  - 8b    | 8b          | 16b    | 8b

- Only four message codes:
  - Request (01)
  - Response (02)
  - Success (03)
  - Failure (04)

- Supplicant -> Authenticator

- Identifier is incremented for each message.
  Identifier in response is set equal to that in request.

- Type field in the request/response indicates the authentication.
  Assigned by Internet Assigned Number Authority (IANA)
EAP Types

1 = Identity
2 = Notification (messages to be displayed to user)
3 = Nack
4 = MD5 Challenge (CHAP)
5 = One time password
6 = Generic Token card (GTC)
254 = Expanded types (allows vendor specific options)
255 = Experimental

Notification requests are responded by notification responses.
Nack type is valid only for responses.
Expanded types include a 3B vendor ID and 4B vendor msg type.
Expanded Nack is used in response to requests of type 254 and may include alternative suggestions for methods.
EAP Multiplexing Model

- EAP Layer demultiplexes using code. Code 1 (request), 3 (success), and 4 (failure) are delivered to the peer layer.
- Code 2 (response) is delivered to the EAP authenticator layer.
- Both ends may need to implement peer layer and authenticator layer for mutual authentication.
- Lower layer may be unreliable but it must provide error detection (CRC).
- Lower layer should provide MTU of 1020B or greater.

Ref: RFC 3748
## EAP Pass through Authenticator

- **EAP Peer/Auth layers demultiplex using “type” field.**

- **Diagram: EAP Method X**
  - **EAP Peer**
  - **EAP Layer**
  - **Lower Layer**

- **EAP Method X**
  - **EAP Auth**
  - **EAP Layer**
  - **AAA/IP**

**Diagram:**

- Peer層、Pass-thru Authenticator層、Authentication Server層の間で、EAP Peer/Auth層は“type”フィールドを使用してデマルチプレックスされます。

**詳細:**

- Peer層:
  - EAP Method X
  - EAP Peer
  - EAP Layer
  - Lower Layer

- Authentication Server層:
  - EAP Method X
  - EAP Auth
  - EAP Layer
  - AAA/IP

- Pass-thru Authenticator層:
  - EAP Method X
  - EAP Peer
  - EAP Auth
  - EAP Layer
  - Lower Layer
  - AAA/IP
EAP Upper Layer Protocols

- **Lightweight EAP (LEAP):** Uses MS-CHAP. Not secure.
- **EAP-TLS:** Transport Level Security. Both sides need certificates.
- **EAP-TTLS:** Tunneled TLS. Only server certificates. Secure tunnel for peer.
- **EAP-FAST:** Flexible Authentication via Secure Tunneling. Certificates optional. Protected tunnels.
- **Protected EAP (PEAP):** Server Certificates. Client password.
- **PEAPv1 or EAP-GTC:** Generic Token Token Cards. Client uses secure tokens.
- **EAP-SIM:** Subscriber Identity Module used in GSM. 64b keys.
- **EAP-AKA:** Authentication and Key Agreement. Used in 3G. 128b keys.
- **EAP-PSK:** Pre-shared key + AES-128 to generate keys.
- **EAP-IKEv2:** Internet Key Exchange. Mutual authentication. Certificate, Password, or Shared secret.


Washington University in St. Louis  http://www.cse.wustl.edu/~jain/cse571-17/ ©2017 Raj Jain
EAP over LAN (EAPOL)

- EAP was designed for Point-to-point line
- IEEE extended it for LANs ⇒ EAPOL
- Added a few more messages and fields
- Five types of EAPOL messages:
  - EAPOL Start: Sent to a multicast address
  - EAPOL Key: Contains encryption and other keys sent by the authenticator to supplicant
  - EAPOL packet: Contains EAP message (Request, Response, Success, Failure)
  - EAPOL Logoff: Disconnect
  - EAPOL Encapsulated-ASF-Alert: Management alert
- Message Format: Version=1, Type=start, key, …

Ref: http://en.wikipedia.org/wiki/Eapol
Washington University in St. Louis http://www.cse.wustl.edu/~jain/cse571-17/ ©2017 Raj Jain
EAPOL (Cont)
802.1X

- Authentication framework for IEEE802 networks
- Supplicant (Client), Authenticator (Access point), Authentication server
- No per packet overhead ⇒ Can run at any speed
- Need to upgrade only driver on NIC and firmware on switches
- User is not allowed to send any data until authenticated

Ref: [http://en.wikipedia.org/wiki/802.1x](http://en.wikipedia.org/wiki/802.1x)
802.1X Authentication

Station
- Can I connect please?
- What’s your user name?
- My user name is john
- What’s your password?
- My password is mary?
- You can connect!

Access Point
- EAP Identity Request
- EAP Identity Response
- EAP Auth Request
- EAP Auth Response
- EAP-Success

Authentication Server
- EAP Identity Response
- EAP Auth Request
- EAP Auth Response
- EAP-Success

- Authentication method can be changed without upgrading switches and access points
- Only the client and authentication server need to implement the authentication method
EAP with RADIUS

EAP Peer

EAP Authenticator

Authentication server (RADIUS)

EAP-Request/Identity

EAP-Response/Identity

EAP-Request/Auth

EAP-Response/Auth

... 

EAP-Request/Auth

EAP-Response/Auth

EAP-Success/Failure
Cloud Computing

- Using remote resources (Processor, Storage, Network, software, services)

- Five **Characteristics**
  1. Shared: Resource Pooling
  2. Ubiquitous: Broad network access
  3. Rapidly Provisioned: Rapid Elasticity
  4. Configurable: Measured Service
  5. On-demand Self-Service

- Three **Service Models**
  1. Infrastructure as a Service (IaaS): CPU
  2. Platform as a Service (PaaS): CPU+OS
  3. Software as a Service (SaaS): Application

- Four **Deployment models**
  1. Public
  2. Private
  3. Hybrid
  4. Community


Washington University in St. Louis [http://www.cse.wustl.edu/~jain/cse571-17/](http://www.cse.wustl.edu/~jain/cse571-17/)

©2017 Raj Jain
Roles

- Cloud Consumer
- Cloud Service Provider (CSP)
- Cloud Broker
- Cloud Auditor
- Cloud Carrier: Internet service Provider (ISP)
Cloud Security Risks and Countermeasures

- 7 Risks and Countermeasures

1. Abuse and Criminal Use:
   - Strict user authentication
   - Intrusion detection
   - Monitoring public blacklists for own network blocks

2. Malicious Insiders:
   - Comprehensive assessment of CSP
   - Human resource requirement as a part of the legal contract
   - Transparency into overall security management
   - Security breach notification process
Risks and Countermeasures (Cont)

3. Insecure Interfaces and API’s:
   - Analyze security models of CSP interface
   - Ensure strong authentication and encryption

4. Shared Technology Issues:
   - Monitor environment for unauthorized changes
   - Strong authentication and access control for administrators
   - SLAs for patching vulnerability remediation
   - Conduct vulnerability scanning and configuration audits
Risks and Countermeasures (Cont)

5. Data Loss or Leakage:
   - Strong API access control
   - Encrypt data in transit
   - Analyze data protection at design and runtime
   - Strong key generation, storage, management, and destruction

6. Account or Service Hijacking:
   - No sharing of credentials between users and services
   - Strong two-factor authentication
   - Intrusion detection
   - Understand CSP security policies and SLAs
7. Unknown Risk Profile:

- Disclosure of applicable logs and data
- Partial/full disclosure of infrastructure details
- Monitoring and alerting on necessary information
NIST Guidelines on Cloud Security

- 9 Guidelines

1. Governance:
   - Extend organizational policies and procedures to cloud
   - Audit mechanisms to ensure that policies are followed

2. Compliance:
   - Understand legal and regulatory obligations
   - Ensure that the contract meets these obligations
   - Ensure that CSP’s discovery capabilities do not compromise security and privacy of data
NIST Guidelines (Cont)

3. Trust:
   - Visibility into the security and privacy controls of CSP
   - Clear exclusive ownership of data
   - Institute a risk management system
   - Continuously monitor the system

4. Architecture:
   - Understand CSP’s provisioning methods and their impact on the security over the entire life cycle

5. Identity and Access Management:
   - Ensure strong authentication, authorization, and identity management
NIST Guidelines (Cont)

6. Software Isolation:
   ➢ Understand the virtualization techniques and their risks

7. Data Protection:
   ➢ Evaluate CSP’s ability to control access to data at rest, in transit, and in use and to sanitize data
   ➢ Access risk of collating data with other organizations with high threat value
   ➢ Understand CSP’s cryptographic key management
NIST Guidelines (Cont)

8. Availability:
   - Assess procedures for data backup, recovery, and disaster recovery
   - Ensure critical operations can be resumed immediately after a disaster and other operations can be eventually resumed

9. Incident Response:
   - Ensure contract provisions for incident response meet your requirements
   - Ensure that CSP has a transparent process to share information during and after an incident
   - Ensure that you can respond to incident in coordination with CSP
Data Protection Risks

Two database service models:

1. **Multi-instance model:**
   - Each subscriber gets a unique DBMS on a VM
   - Subscriber has complete control over role definition, user authorization, and other administrative tasks related to security

2. **Multi-tenant model:**
   - Subscriber shares a predefined environment with other tenants, typically by tagging data with a subscriber identifier
   - CSP needs to establish and maintain a sound secure database environment
Data Protection in the Cloud

- Data must be secured while at rest, in transit, and in use, and access to the data must be controlled
- Use encryption to protect data in transit
  ⇒ Key management responsibilities for the CSP
- Store only encrypted data in the cloud
  ⇒ CSP has no access to the encryption key
  - Encrypt the entire database and not provide the encryption/decryption keys to CSP
  - Can’t access individual data items based on searches or indexing on key parameters
  - Need to download entire tables from the database, decrypt the tables, and work with the results

To provide more flexibility it must be possible to work with the database in its encrypted form
Data Protection (Cont)
Cloud Security as a Service (SecaaS)

- **SecaaS**: Provisioning of security applications and services via the cloud either to cloud-based infrastructure and software or from the cloud to the customers’ on-premise systems.

- **SecaaS Categories of Service**:
  1. Identity and access management
  2. Data loss prevention
  3. Web security
  4. E-mail security
  5. Security assessments
  6. Intrusion management
  7. Security information and event management
  8. Encryption
  9. Business continuity and disaster recovery
  10. Network security
Summary

1. RADIUS allows centralized authentication server and allows roaming
2. EAP allows many different authentication methods to use a common framework ⇒ Authenticators do not need to know about authentication methods
3. Many variations of EAP authentication methods depending upon certificates, shared secrets, passwords
4. 802.1X adds authentication to LAN and uses EAPOL
5. Cloud computing uses a shared pool of resources. Numerous security issues and counter measures.
Homework 16

- Read RFC 3748 on EAP. Is clear text password one of the EAP authentication method? If yes, what is the code for this. If not, why not?
Lab 16: Netcat

- Netcat is an application for creating a backdoor and file transfer. It can be used by attackers to control a victim machine or by administrators to move data out of the victim machines.

- You need two computers: A victim with Windows and an attacker with any operating system.

- You can perform the lab in one of the following ways:
  - Your computer and your classmate’s computer (one of them is windows)
  - Your computer (windows) and any type of virtual machine (Ubuntu, Kali, ..)
  - On the lab computers (CSE571XPS and DL9150) using your accounts

Lab 16: Netcat (Cont)

- Download netcat
  - For Windows: https://joncraton.org/files/nc111nt.zip
  - For Mac: http://macappstore.org/netcat/
  - For Linux: sudo apt-get install netcat-traditional
  - Already installed under c:\program files (or c:\program files (86)) in the lab machines

- Run netcat and explore its various options
  - You need to be in the netcat directory in case of Windows
1. **Use netcat as a messaging system**
   - On the victim machine, use netcat to listen to port 9999
   - From the other machine, use netcat to connect to the victim machine on the same port with –vv option
   - Write anything on one of the machine’s command window (cmd) and notice what happens on the other machine
   - Submit a screenshot along with commands used

2. **Use netcat as a backdoor to implant a file**
   - On the victim machine, use netcat to listen to port 9999 and save the output to a file
   - On the attacker machine, create a text file called hacked.txt and transfer it to the victim
   - Submit the screenshots along with the commands used
Lab 16: Netcat (Cont)

3. **Use netcat for backdoor command access**
   - On the victim machine, use netcat to listen to port 9999 and allow the execution of cmd.exe application (use `netcat -d -e c:\windows\system32\cmd.exe` along with other options to open the port and listen to it. Make sure that cmd is allowed to run by remote users.)
   - On the other machine, use netcat to connect to the port and get access to the command window
   - Submit a screenshot along with commands used
Acronyms

- AAA: Authentication, Authorization, and Accounting
- AES: Advanced Encryption Standard
- AKA: Authentication and Key Agreement
- API: Application Programming Interface
- AR: Access Requester
- ASF: Alerting Standards Forum
- CHAP: Challenge Handshake Protocol
- CP: Cloud Provider = CSP
- CPU: Central Processing Unit
- CRC: Cyclic Redundancy Check
- CSP: Cloud Service Provider
- DCHP: Dynamic Host Control Protocol
- EAP-AKA: EAP with Authentication and Key Agreement
- EAP-FAST: EAP with Flexible Authentication via Secure Tunneling
- EAP-IKEv2: EAP with Internet Key Exchange version 2
- EAP-PSK: EAP with Pre-shared key
Acronyms (Cont)

- **EAP-SIM**: EAP with Subscriber Identity Module
- **EAP-TLS**: EAP with Transport Level Security
- **EAP-TTLS**: EAP with Tunneled Transport Level Security
- **EAP**: Extensible Authentication Protocol
- **EAPOL**: EAP over LAN
- **FAST**: Flexible Authentication via Secure Tunneling
- **GSM**: Global System for Mobile Communications
- **GTC**: Generic Token card
- **IaaS**: Infrastructure as a Service
- **IANA**: Internet Assigned Number Authority
- **ID**: Identifier
- **IEEE**: Institution of Electrical and Electronic Engineers
- **IKEv2**: Internet Key Exchange version 2
- **IP**: Internet Protocol
- **ISP**: Internet Service Provider
- **LAN**: Local Area Network
Acronyms (Cont)

- LEAP: Lightweight Extensible Authentication Protocol
- MD5: Message Digest 5
- MS-CHAP: Microsoft Challenge Handshake Protocol
- MS: Microsoft
- MSK: Master Session Key
- MTU: Maximum Transmission Unit
- NAC: Network Access Control
- NAK: Negative Acknowledgement
- NAS: Network Access Server
- NIC: Network Interface Card
- NIST: National Institute of Science and Technology
- OS: Operating System
- PaaS: Platform as a Service
- PAP: Password Authentication Protocol
- PEAP: Protected Extensible Authentication Protocol
- PEAPv1: PEAP version 1
Acronyms (Cont)

- **PPP**  Point-to-Point Protocol
- **PSK**  Pre-shared key
- **RADIUS**  Remote Access Dial-In Server
- **RAS**  Remote Access Server
- **RFC**  Request for Comments
- **SaaS**  Software as a Service
- **SecaaS**  Security as a Service
- **SIM**  EAP Subscriber Identity Module
- **SLA**  Service Level Agreement
- **TCP**  Transmission Control Protocol
- **TLS**  EAP Transport Level Security
- **TTLS**  Tunneled Transport Level Security
- **UDP**  User Datagram Protocol
- **VLAN**  Virtual Local Area Network
- **VM**  Virtual Machine
- **VPN**  Virtual Private Network
- **WiFi**  Wireless Fidelity
Related Modules

CSE571S: Network Security (Spring 2017),
http://www.cse.wustl.edu/~jain/cse571-17/index.html

CSE473S: Introduction to Computer Networks (Fall 2016),
http://www.cse.wustl.edu/~jain/cse473-16/index.html

Wireless and Mobile Networking (Spring 2016),
http://www.cse.wustl.edu/~jain/cse574-16/index.html

CSE571S: Network Security (Fall 2014),
http://www.cse.wustl.edu/~jain/cse571-14/index.html

Audio/Video Recordings and Podcasts of Professor Raj Jain's Lectures,
https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw