Securing Privacy in MQTT-Based Systems

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Project Overview

Objective:

- Design/Analyze a secure MQTT-based communication system in the context of disaster relief

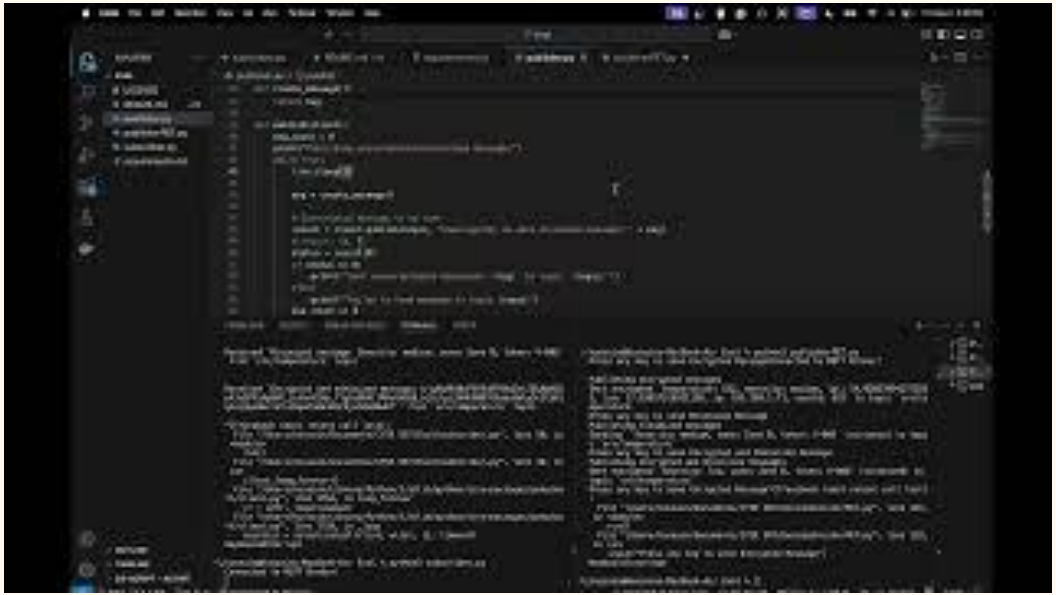
Challenge:

- Plain MQTT messages expose personal data (GPS, IPS, etc) leading to major privacy threats

Solutions:

- Apply Privacy-Enhancing Techniques (PETs) to protect users

Current Configuration



LINDDUN Privacy Threat Analysis 1

- Linkability
  - Threat: An attacker can link multiple MQTT messages to the same user
  - Justification: Messages share the
- Identifiability
  - Threat: An attacker can identify someone based on the message content
  - Justification: Messages could contain unique tokens or even account names
- Non-repudiation
  - Threat: Users cannot deny sending a message
  - MQTT logs do not contain any signatures/hashes

LINDDUN Privacy Threat Analysis 2

- Detectability
  - Threat: An attacker can detect that someone is communicating, even without knowing what messages are being sent.
  - Justification: MQTT topics are visible unless configured differently.
- Disclosure of Information
  - Threat: Sensitive content can be exposed during MQTT transmissions
  - Justification: MQTT messages are not TLS encrypted by default

LINDDUN Privacy Threat Analysis 3

- Unawareness
  - Threat: Victims may not know what is being collected or who receives it. Might be automatic collection
  - Justification: No interface is present to warn/confirm what is being shared
- Non-compliance
  - Threat: System may be violating privacy laws
  - Justification: Due to it being un-encrypted by default, the engineers are not complying to privacy policies

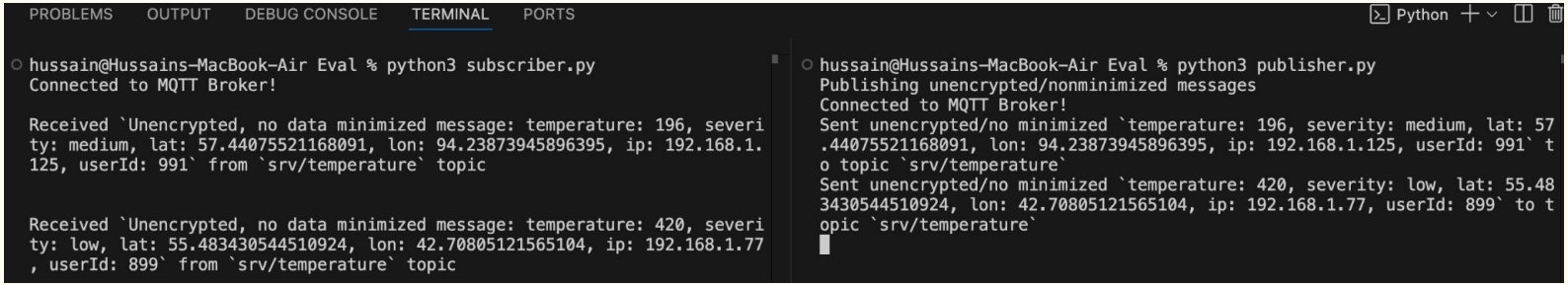
PETs to be implemented

- Encrypted Payloads
  - How it's implemented
    - Uses fernet symmetric encryption (from the cryptography library)
    - Publisher encrypts the payload before sending
    - Subscriber decrypts using the same secret key
  - Why
    - Prevents Disclosure of Information
- Pseudonymization
  - How it's implemented
    - Victim IDs become "VIC-XXX" instead of username.
    - GPS coordinates are assigned to zones
  - Why it matters
    - Prevents identifiability and Linkability

PET configurations

Improved Config with PETs

Before:



After:

Privacy Metric

- Before PETs: 5 fields exposed (Victim ID, GPS, IP, Temperature, Severity)
- After PETs: 1 field exposed
  - Other fields got tokenized
- 80% reduction in exposed sensitive data

- To access messages without encryption:
  - Requires 3.4 x 10 ^ 38 possible keys
  - Brute force requirements: 1.7 x 10 ^14 years (too long!)

Effectiveness, Overhead, Trade offs

- Effectiveness:
  - Tokenizatio hides real identities and exact locations
  - Encryption protects the entire message payload from eavesdroppers
- Overhead:
  - Increased message size due to encryption
  - Have to convert zones into locations
  - Key maintenance
- Trade offs:
  - More secure but harder debugging for encryption
  - Increased processing power requirement for encrypting/decrypting
  - Rotation of keys

Privacy Impact on System Behaviour

- Encrypted messages are no longer human readable which hinders eavesdropping
- Randomized victim tokens prevent cross-session tracking
- System design uses pseudonyms
- Business objectives not affected
- Aligns system with privacy regulations