An Analysis of Amazon Echo's Network Behavior

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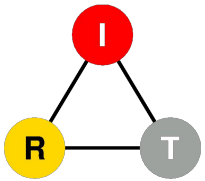

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Talk Outline

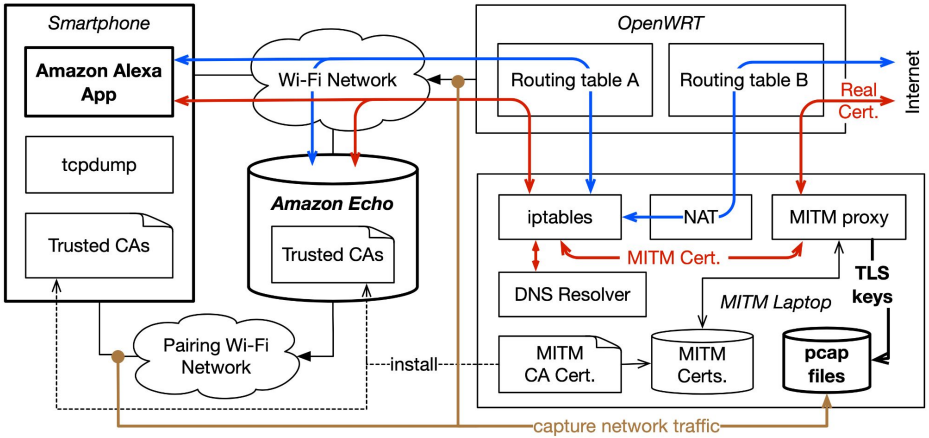
1. Introduction
2. Methodology & Experimental Setup
3. Network Behavior & Protocols
4. Discussion
5. Summary and Q&A

Introduction

- More than 20 million Amazon Echo units sold since 2015
- Deployed in home, school classrooms, some hotels
- What do we know about its network behavior?
  - How secure is the Wi-Fi pairing process?
  - How secure is the connection to Amazon Cloud?
  - Are the calls made from an Amazon Echo encrypted?

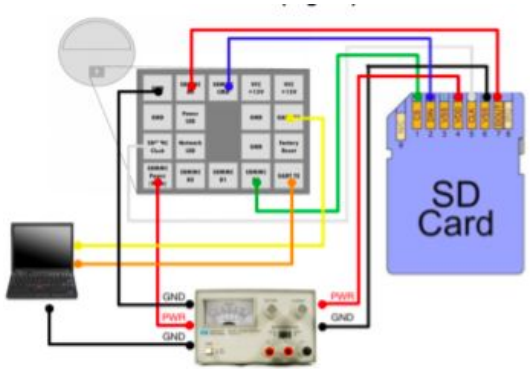
Methodology

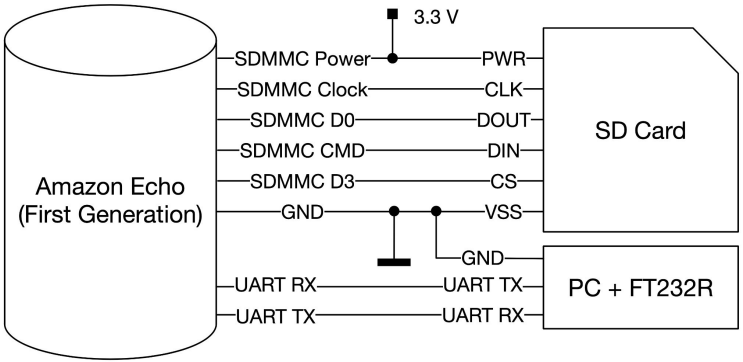
1. Put a man-in-the-middle (MITM) TLS proxy between Echo and internet
2. Make the Echo accept the proxy's CA certificate
3. Record, decrypt, analyze communication between Echo and Amazon cloud
4. Analyze Wi-Fi pairing on rooted Android device

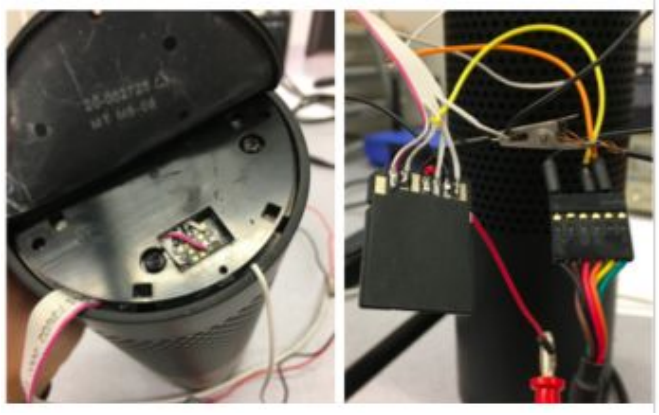


Hardware Setup

- 1st gen. Amazon Echo with exposed pins
- External SD card with Amazon Echo OS image
- Laptop with USB-UART converter
- Laboratory power supply







Out of the Box Experience (OOBE)

Protocol executed between Echo, smartphone/web app, and Amazon cloud

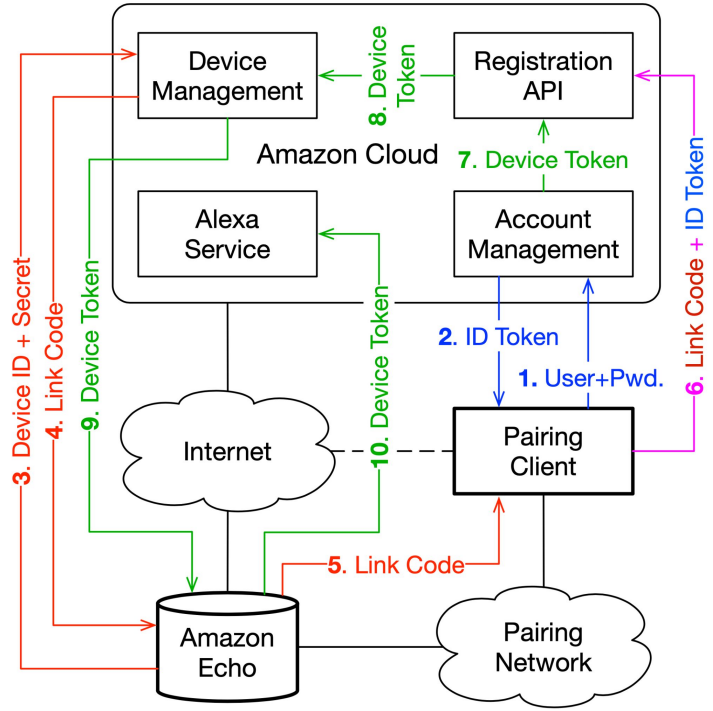
1. Provision Wi-Fi network name and password into the Echo
2. Associate the device with an Amazon user account
3. Performed after factory reset or when Wi-Fi is unusable

Pairing takes place over open temporary Wi-Fi network created by Echo

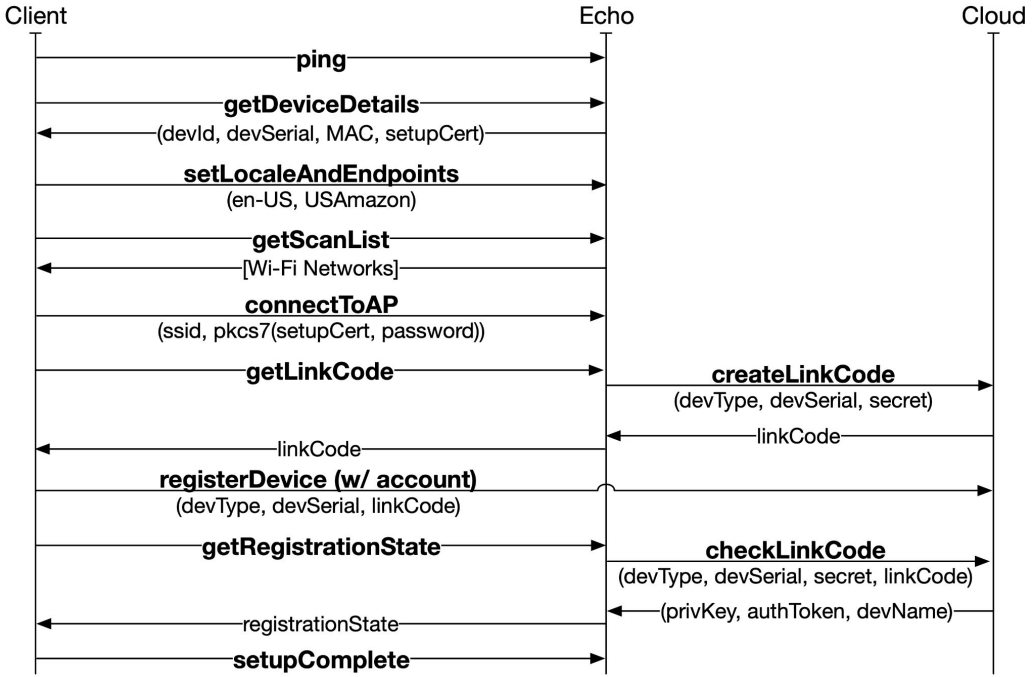
OOBE Key Features

- Echo supports Wi-Fi AP and client roles at the same time
- Echo provides internet connectivity to smartphone during pairing
  - Necessary to associate Echo with user's Amazon user account
- Wi-Fi credential provisioning:
  - Password encrypted (AES-256 in CBC mode) with random secret
  - Random secret encrypted with Echo's public key (from self-signed X.509 certificate)
  - Vulnerable to MITM
- Amazon user account registration:
  - Link code: five alphanumeric characters obtained from Amazon cloud
  - Based on a secret string set during manufacturing
  - Associated with user account via HTTP cookie (must be logged in to Amazon in browser)

OOBE Overview of Operation



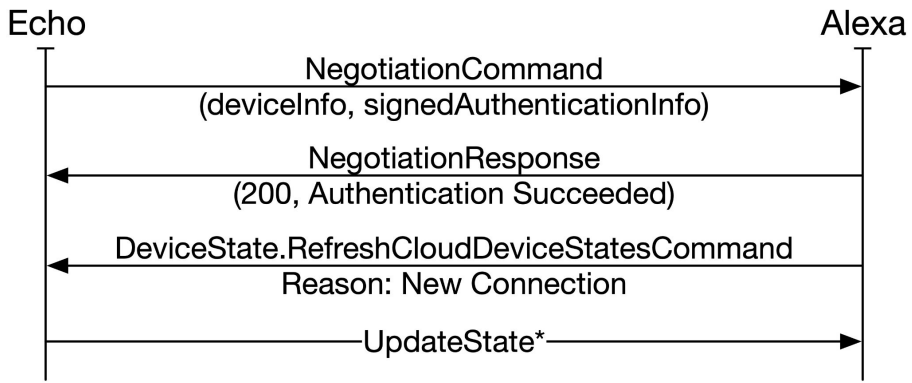
System architecture diagram



OOBE message flow diagram

Alexa Voice Service (AVS)

- Speech recognition, natural language understanding, text to speech
- Public API provided by Amazon cloud (available to third-party developers)
- Echo maintains a persistent SPDY connection to AVS
- **NegotiationCommand** authenticates the device
- Authenticated with a secret key obtained during device pairing
- Rest similar to public AVS

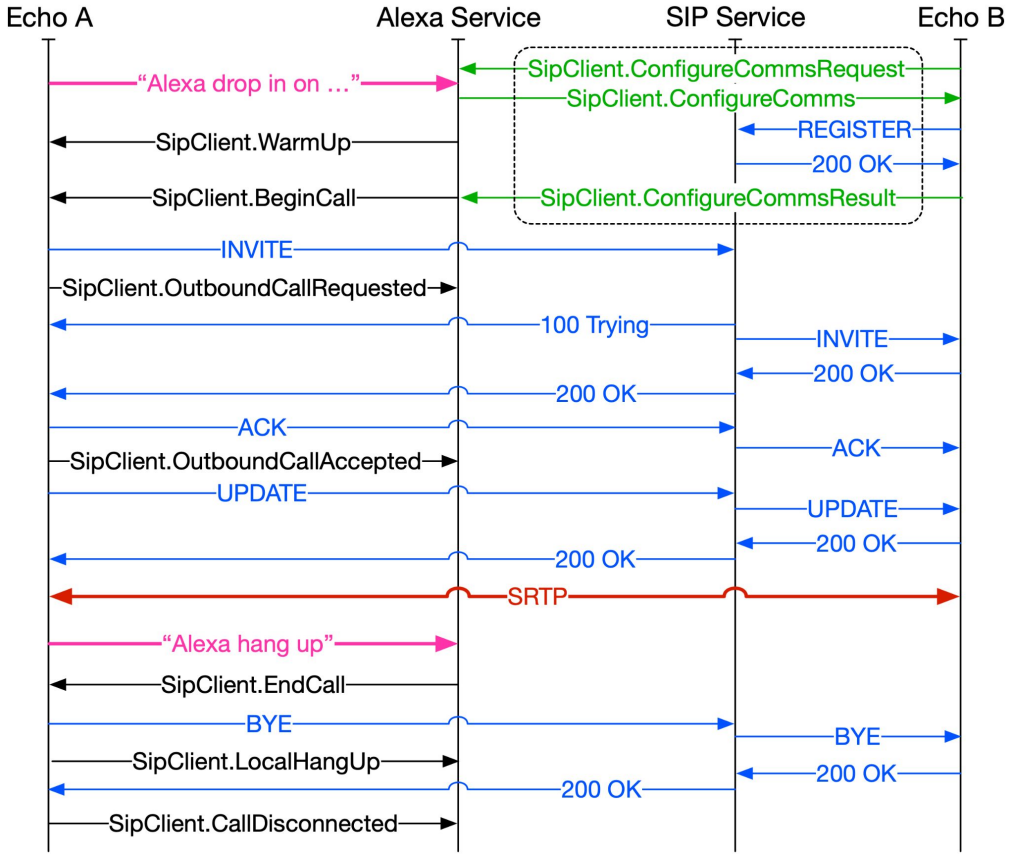


Alexa Drop-in Calling

- Place calls to Alexa-enabled devices, phone numbers, or Skype
- Voice activated:
  - “Alexa drop in on …”
  - “Alexa call …”
  - “Alexa answer”
- Two modalities: regular call, intercom
- Amazon Echo answers intercom calls automatically

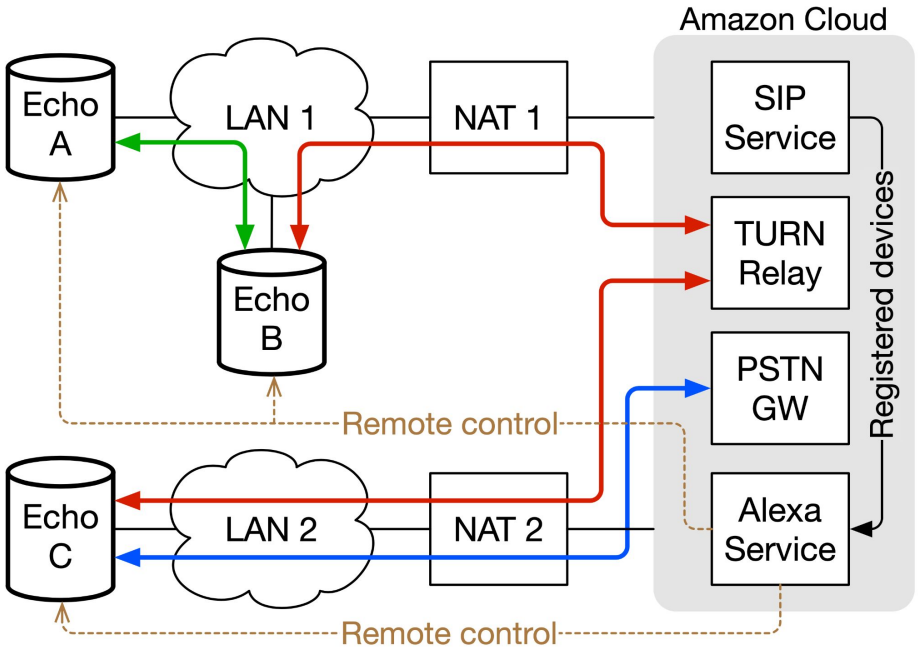
Alexa Call Flow Diagram

- Based on the Session Initiation Protocol (RFC 3261)
- Audio encoded with Opus codec
- Encrypted with sRTP (AES-256)
- UA remotely managed by Alexa
- Calls individually authorized by Alexa cloud service



Alexa Drop-in Calling System Architecture

- Calls are end-to-end encrypted
- Amazon cloud has access to the key
- Calls within single LAN (home) remain local
- Calls between LANs (homes) relayed through Amazon cloud



Discussion

- Our MITM approach is only effective with 1st generation Amazon Echo
- However, the described protocols are compatible with newer devices
- OOBE vulnerable to eavesdropping and MITM
  - Hijacking of de-registered Echo prevented by pre-registration during purchase
- Calls are end-to-end encrypted authorized in all scenarios
  - Per-INVITE authorization prevents intercom misuse
  - Passive eavesdropping won’t reveal audio
  - Amazon cloud can force calls through a relay and decrypt audio

The 1st generation Amazon Echo is a well designed device with respect to network behavior

Summary

1. Made 1st generation Amazon Echo vulnerable to MITM attacks
2. Launched a MITM attack, recorded, decrypted, and analyzed:
    a. Out-of-box-experience (OOBE) Wi-Fi pairing protocol
    b. Alexa Voice Service (AVS) protocol
    c. Alexa Drop-in Calling protocols
3. Found OOBE vulnerable to eavesdropping
4. Found drop-in calling end-to-end encrypted and secure

ArXiv paper version: https://arxiv.org/abs/2105.13500

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