USENIX Security 2022

Watching the Watchers: Practical Video Identification Attack in LTE Networks

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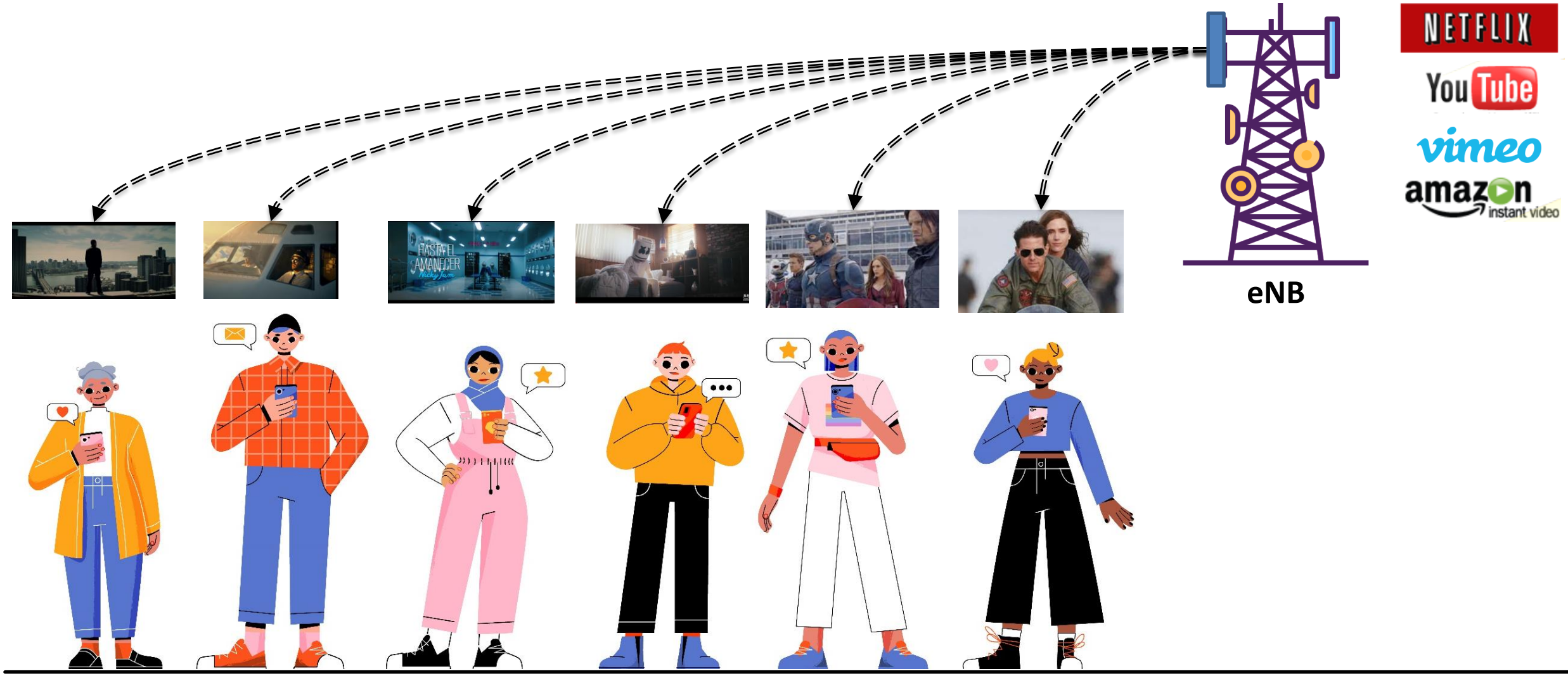
KAIST

We Now Use Smartphone To Watch Videos



What Someone Watches Reveals Who They Are

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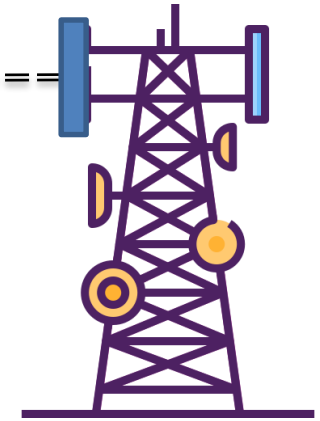

eNB

NETFLIX

YouTube

vimeo

amazon instant video

Video Privacy Protection Act (VPPA)

"wrongful disclosure of video tape rental or sale records"

Someone's watching history is privacy-critical information

Watching the Watchers?

Q1. Can the adversary identify the video that victim is watching without any access?

Q2. Can we physically expose victims watching a particular video?

Is Video Traffic Fingerprintable?

Usenix Security '17

Beauty and the Burst:
Remote Identification of Encrypted Video Streams *

INFOCOMM '18

Walls Have Ears: Traffic-based Side-channel Attack in Video Streaming

Jiaxi Gu*, Jiliang Wang†, Zhiwen Yu*, Kele Shen†
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TIFS '17

I Know What You Saw Last Minute—Encrypted HTTP Adaptive Video Streaming Title Classification

Ran Dubin, Amit Dvir, Ofir Pele, and Ofer Hadar, *Senior Member, IEEE*

Codaspy '17

Identifying HTTPS-Protected Netflix Videos in Real-Time

Andrew Reed, Michael Kranch
Dept. of Electrical Engineering and Computer Science
United States Military Academy at West Point
West Point, New York, USA
{andrew.reed, michael.kranch}@usma.edu

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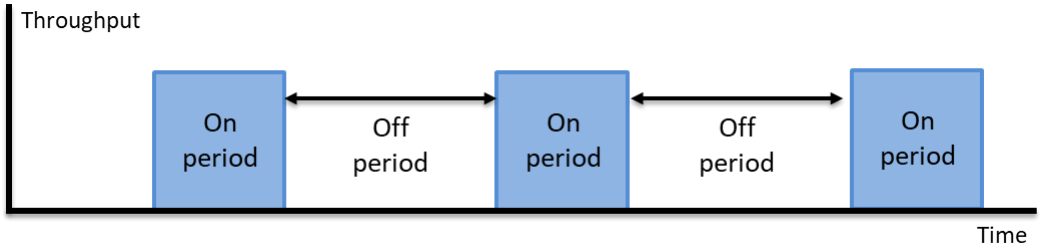
Video identification attack
through traffic analysis
over the encrypted traffic in ***wired network***

How? → HTTP adaptive streaming (HAS)'s working logic generates fingerprint

- Video is segmented into smaller chunks
- Chunk's sizes vary according to the content due to VBR

→ ***Produce distinctive On-Off traffic pattern***



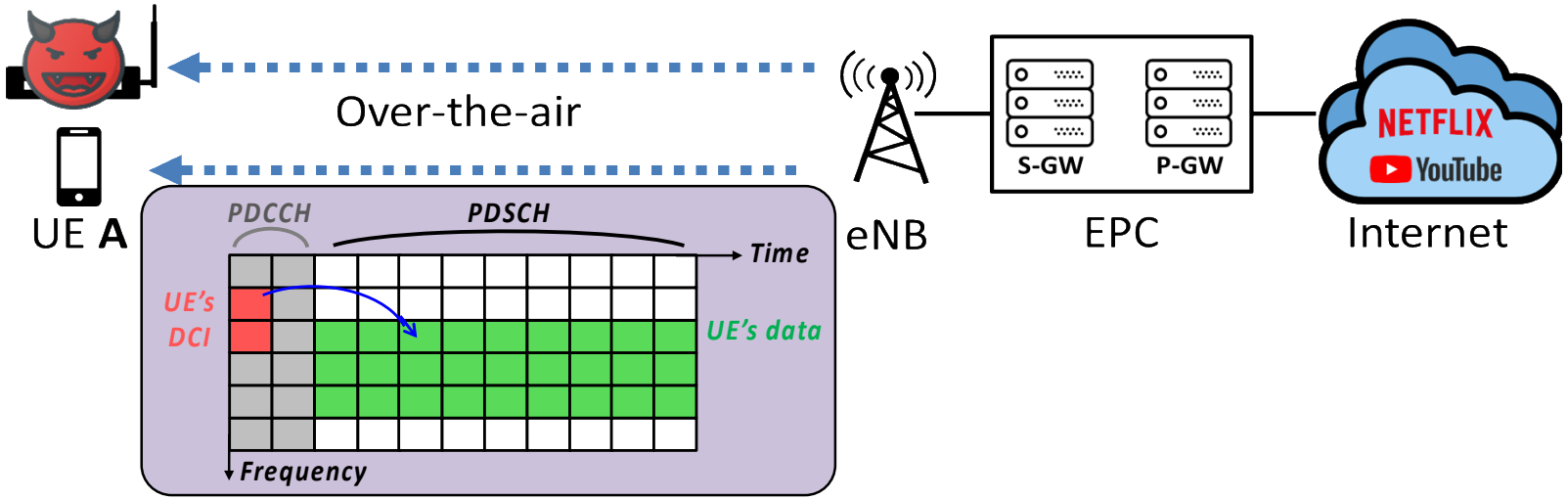
They are required to
1) **Direct access to a victim's network infrastructure**
2) **Ability to run malicious apps or websites in a victim's device**

SysSec System Security Lab

Can Adversary In LTE Monitor The Victim's Traffic?

- In LTE, unprivileged adversary can monitor the victim's downlink traffic.
- eNB (base station) controls DL data transmission by broadcasting DCI
- Downlink Control Indicator (DCI)
  - Descriptions about DL data transmitted to the UE
    - Data volume, modulation scheme, allocated resource blocks (RB)
  - Distinguished by RNTI (radio network temporal Identifier)

This information is broadcast in plain text



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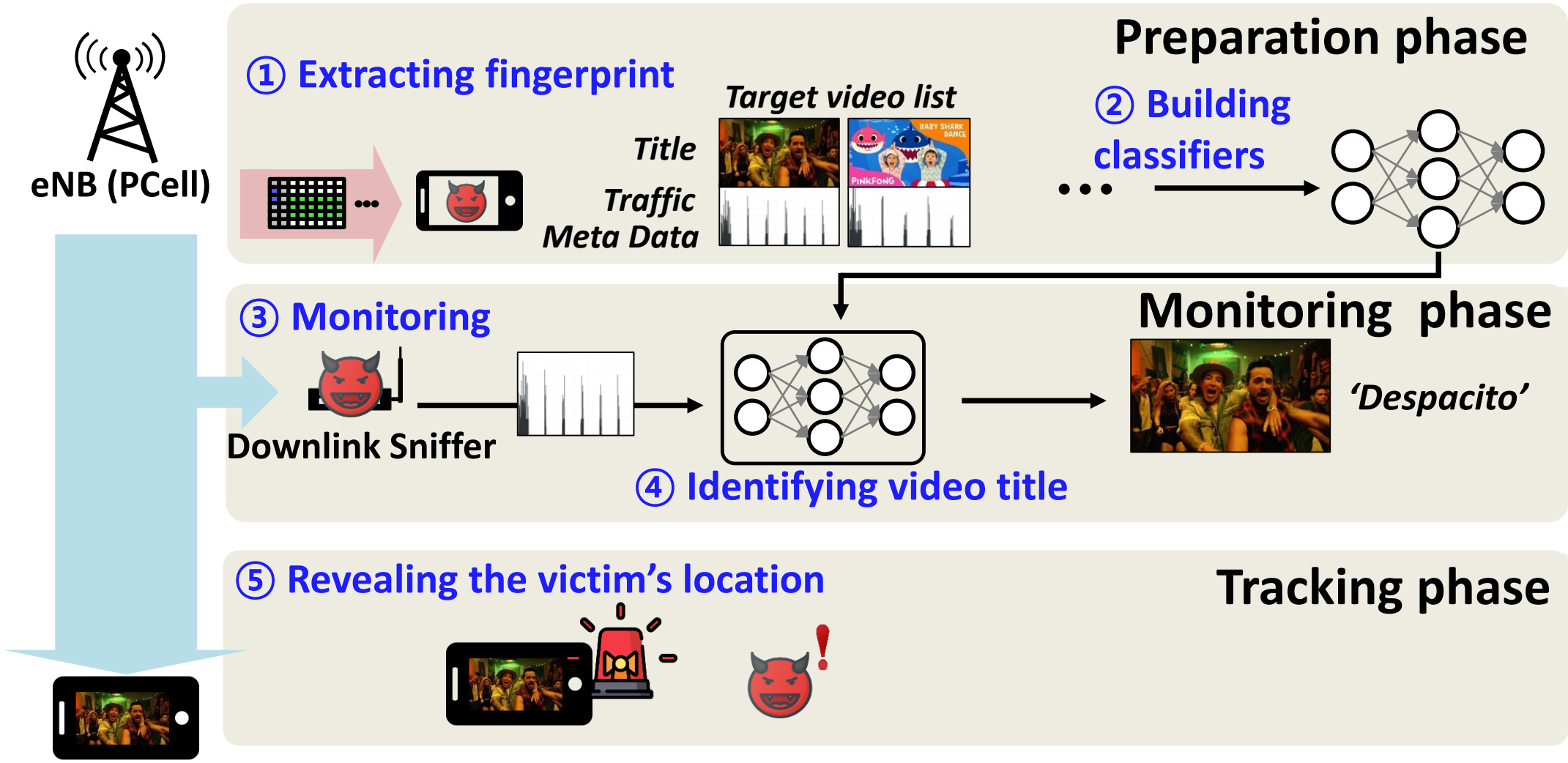
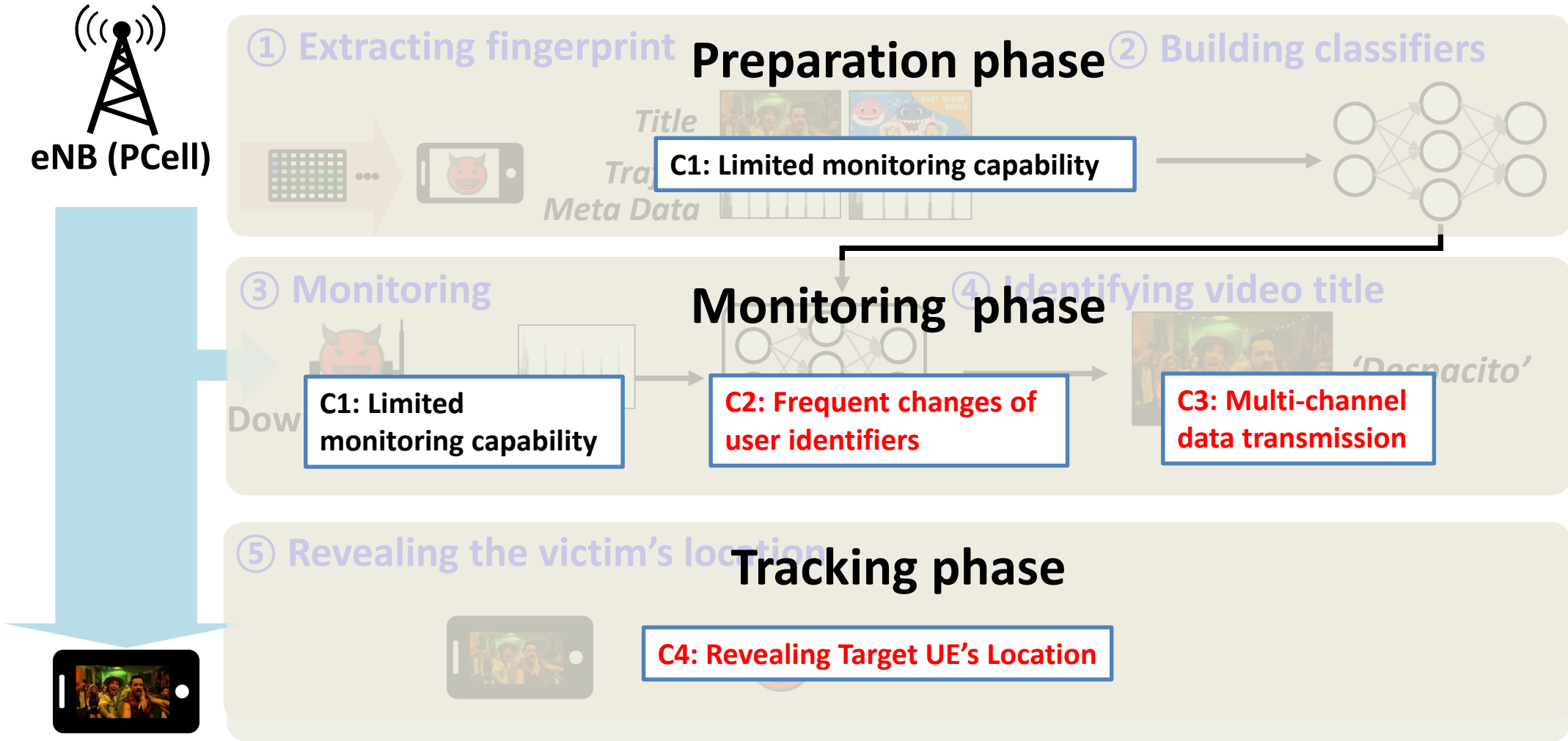
Overall Procedure



Challenges of Video Identification Attack in LTE



C2: Frequent Changes of user identifiers

HAS

During OFF period, there is no data transmission

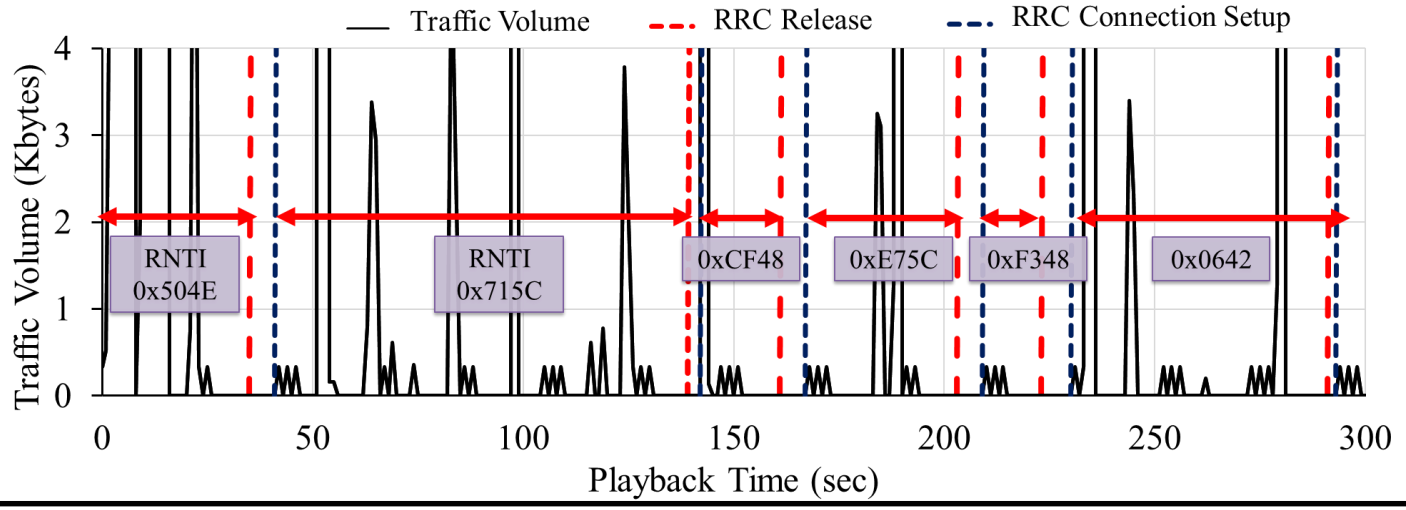
+

LTE

UE releases its connection to an eNB when there is no traffic for a certain period (~10s)

UE's RNTI is changing during the video streaming at (every) OFF period

Time series of received traffic volume and the changing RNTIs when a client plays a Netflix video*

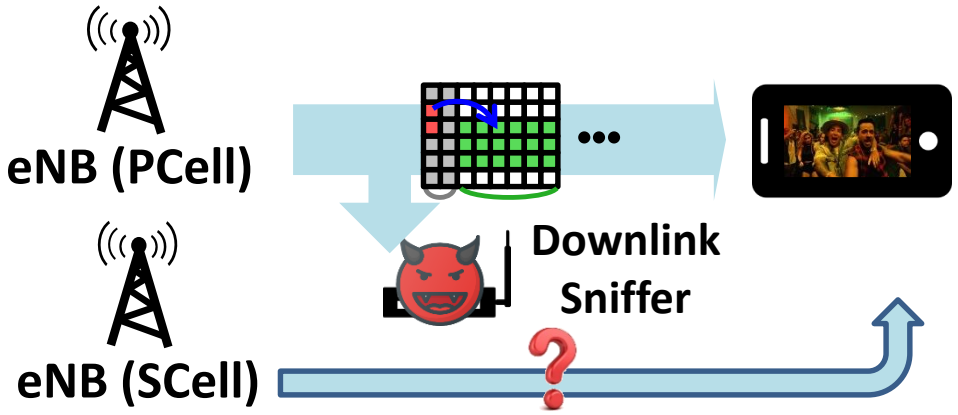


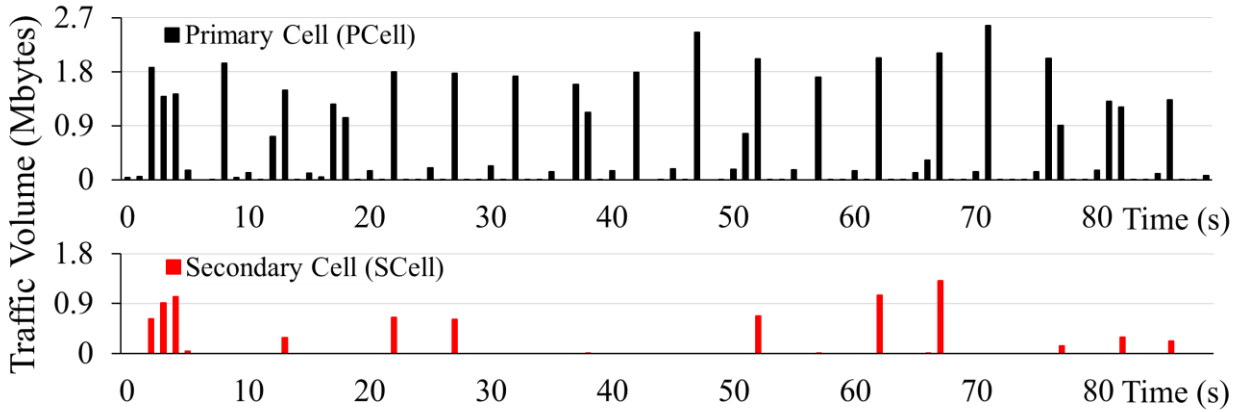
*Sherlock (Season 1, EP. 1)

C3: Multi-channel Data Transmission

- Carrier aggregation (CA)
  - Deliver a large volume of data over multiple channels (secondary cells: SCell)
- large amount of data is likely to be transmitted using CA
  - A typical streamed video consists of large video chunks

Single downlink sniffer loses the traffic information





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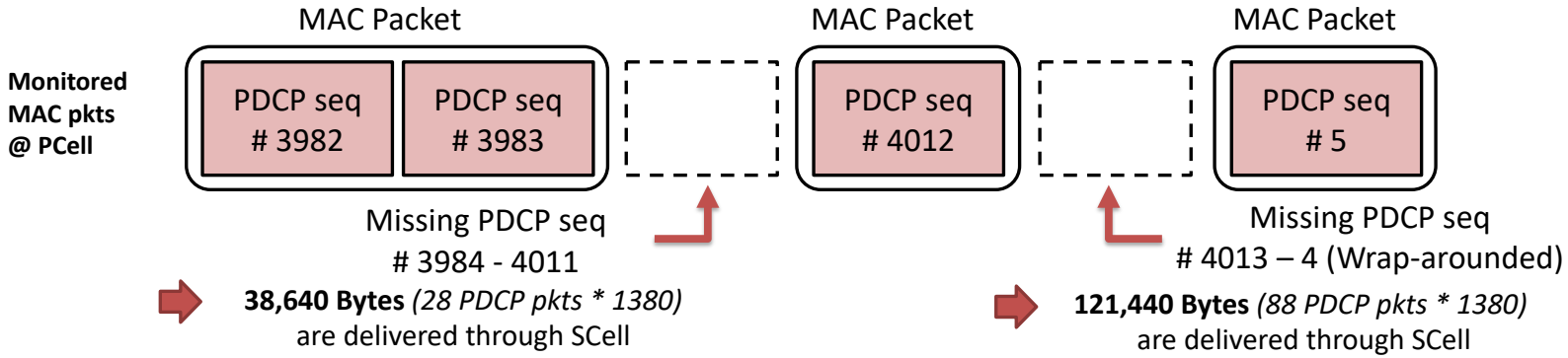
Utilize Broadcast/Exposed Information

C2: Frequent changes of user identifiers
- RNTI is changing during the video streaming

C3: Multi-channel data transmission
- Data is delivered through unmonitored cell

Utilize broadcast information
- Exposed Temporary/ (semi) permanent identifier
- Unencrypted packet header

- Temporary and (semi) permanent identifiers are exposed at the same message
  - GUTI is temporary identifier, but it is not changed frequently
  - → **Track the identifier (RNTI) by monitoring RNTI allocation procedure**
- Estimate the traffic volume with only one SDR device at PCell
  - Unencrypted packet header information in PDCP & MAC

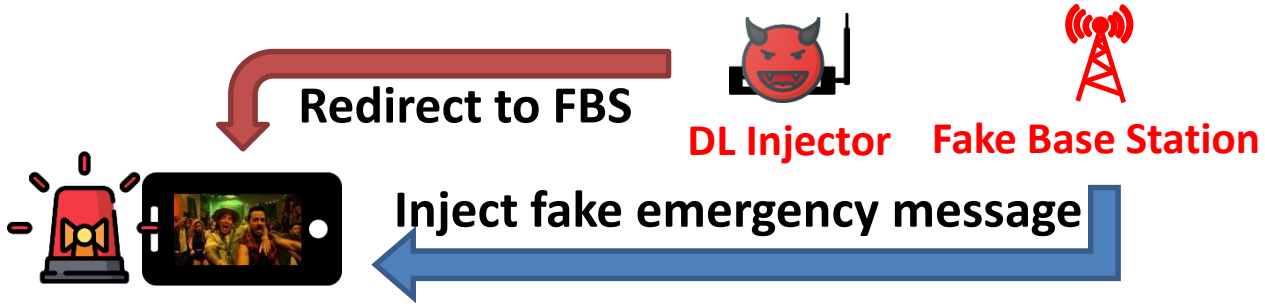


Utilize Unprotected Protocol Layer (PHY)

C4: Revealing target UE's location

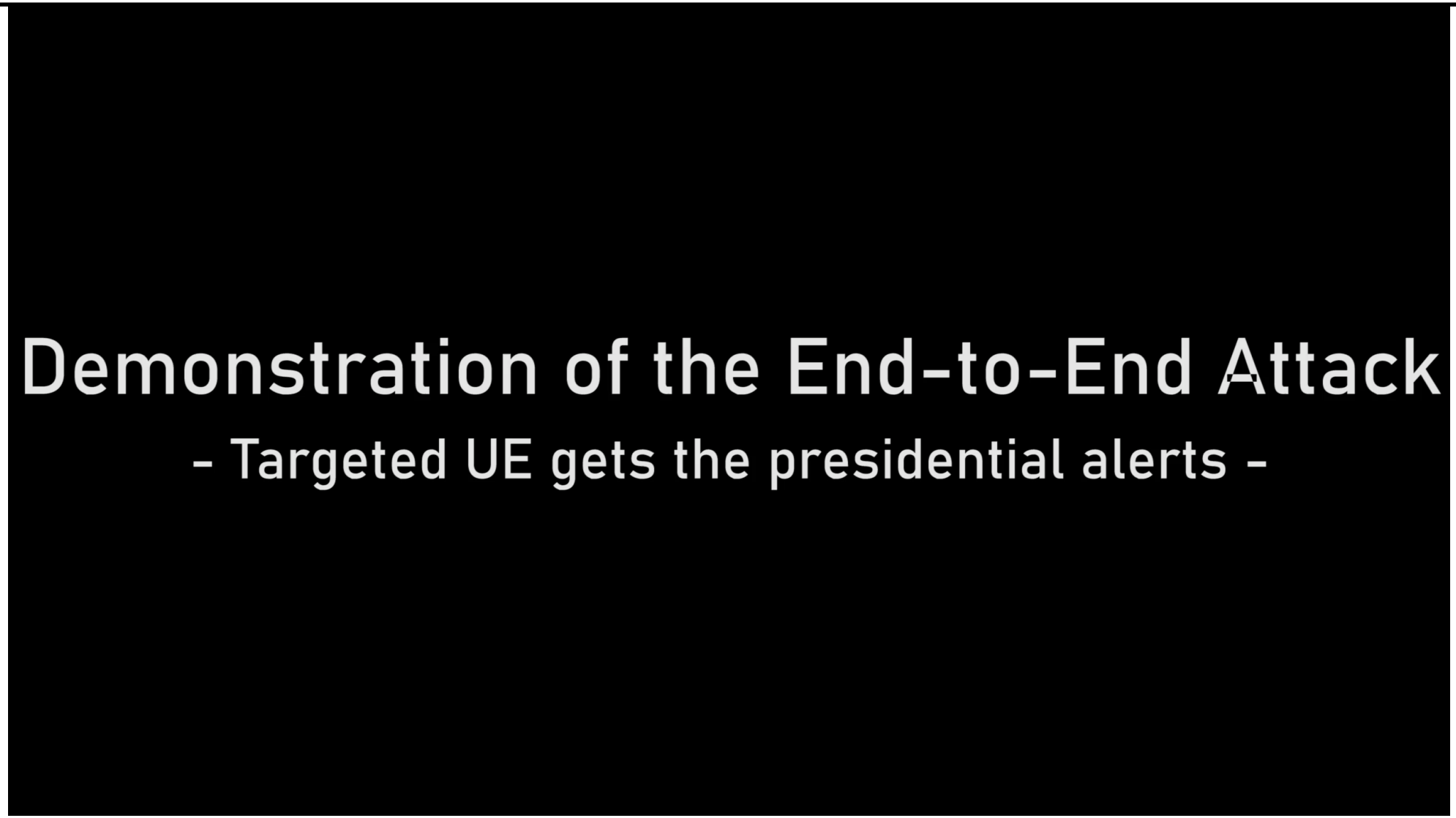
Utilize unprotected protocol layer (PHY)
- Inject targeted emergency SMS

- Key purpose: only the target UE receives the presidential alert
- Force target UE to redirect to FBS by injecting malicious control plane messages
  - Extend **signal overshadowing attack** (SigOver) [USENIX 19]
- FBS sends fake emergency message to the target UE
  - FBS operates in unused frequency
- UE makes a loud alarm → revealing its physical presence



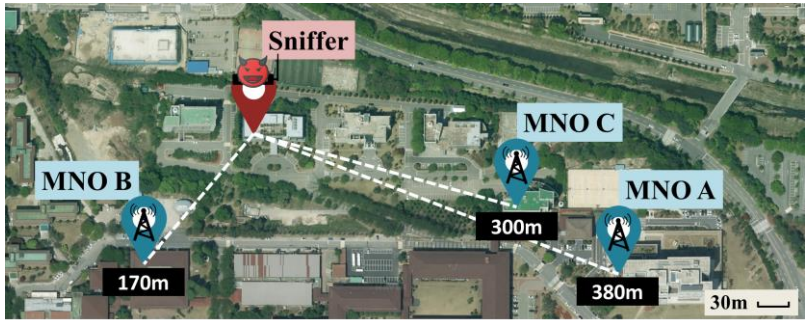
Hojoon Yang, **Sangwook Bae**, Mincheol Son, Hongil Kim, Song Min Kim, and Yongdae Kim. "Hiding in Plain Signal: Physical Signal Overshadowing Attack on LTE" in USENIX 19

Demo


Demonstration of the End-to-End Attack
- Targeted UE gets the presidential alerts -

Dataset & Implementation

- Total of 46,810 data traces
  - **2,035 hours** of streaming time, 1.79 TB of video traffic
  - **3 operational MNOs** in Korea
  - Types and # of video titles (class size)
    - Video traffic: YouTube (300), Amazon (68), and Netflix(50)
    - Non video traffic: web surfing (Alexa Top 50), teleconference (Google Meet)
  - **Three different resolution**: 480, 720, 1080p



- Implementation
  - Downlink sniffer: AirScope and Optis-S DM analyzer
  - Video title identifier: CNN classifier
    - Keras with a TensorFlow backend
  - Video service type identifier: decision tree
    - Python Scikt-learn

Conclusion

- Watching the watchers: Video identification attack
  - LTE design **exposes a lot of information**
  - Unprivileged attacker can monitor the victim's traffic **without any access**
  - Especially, there are unique challenges in the video streaming through the LTE
  - Cellular network enables more critical privacy threatening attack
    - Unprivileged attacker can revealing the victim's presence

- We open our dataset (over **2,035 hours** of streaming) & codes

  (Dataset & codes for data collection) https://github.com/SysSec-KAIST/WatchingTheWatchers

  (Unicast message injection) https://github.com/SysSec-KAIST/sigover_injector

- Questions?
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