Beek en Donk
Oirschot
Best
Helmond
Nuenen
Mierlo
Eindhoven
Geldrop
Waalre
Heeze
Hapert
Eersel
Valkenswaard
Leende
Bergeijk
Maarheeze
Budel
Hamont-Achel
Lommel
Pelt
Hamburg
Groningen
Bremen
Amsterdam
Hanover
Bielefeld
Netherlands
Rotterdam
Essen
Antwerp
Brussels
Cologne
Germany
Lille
Liège
Belgium
Frankfurt
Luxembourg
Mannheim
Paris
Karlsruhe
Stuttgart
Strasbourg
Recklinghausen
Waltrop
Lünen
Castrop-Rauxel
Herne
Gelsenkirchen
Dortmund
Bochum
Witten
Schwerte
Hattingen
Herdecke
Wetter
Sprockhövel
Hagen
Gevelsberg

Amplifying Threats: The Role of Multi-Sender Coordination in SMS-Timing-Based Location Inference Attacks

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Maastricht University
Department of Advanced Computing Sciences

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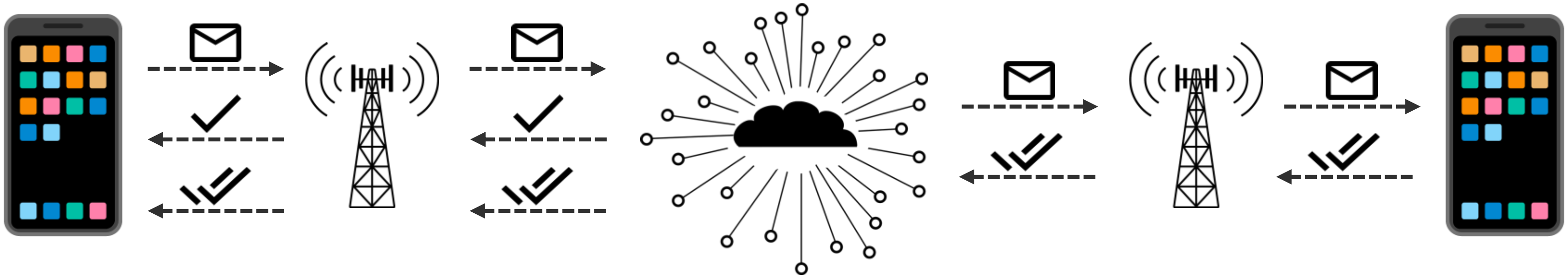
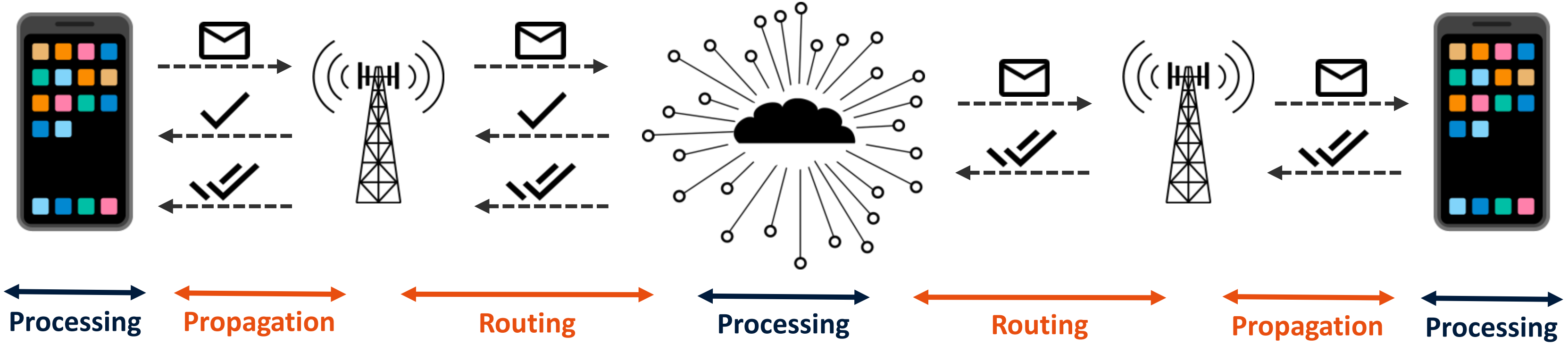
Problem Statement



Problem Statement



Processing · Propagation · Routing · Processing · Routing · Propagation · Processing

Sender: *Philadelphia*

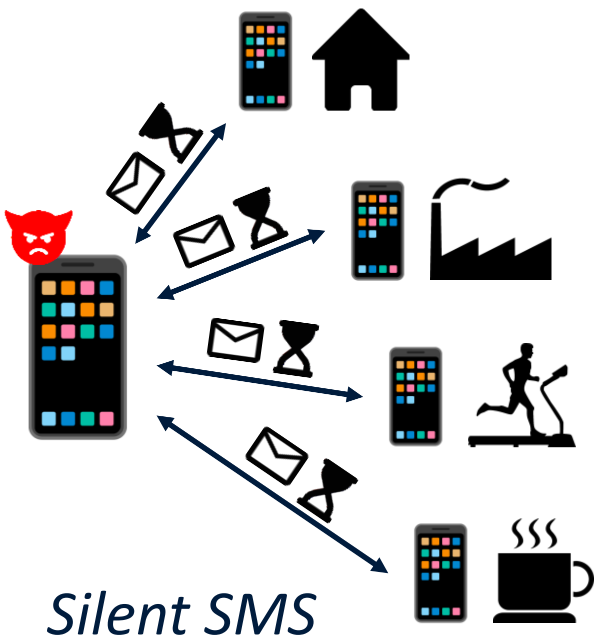
c = 299 792 458 m/s

Receiver:	$2 * \ dist_{e2e}$	$RTT \ \ (v_{Internet} = \frac{2}{3}c)$
Boston	≥ 870 km	≥ 4.35 ms
Maastricht	≥ 12 200 km	≥ 61.04 ms

Timing Side Channel for Location Inference

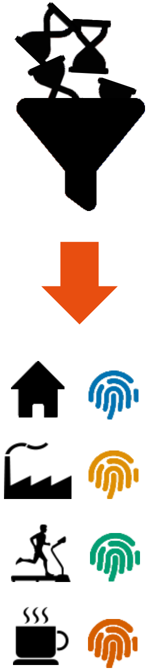
SMS-based Location Inference

(1) Data Collection

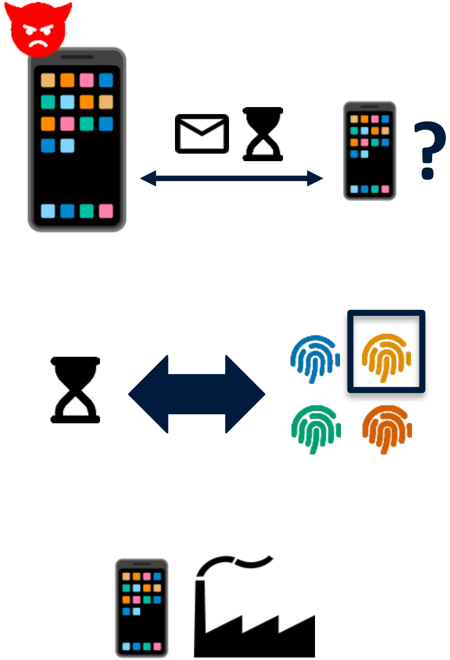


Silent SMS

(2) Evaluation

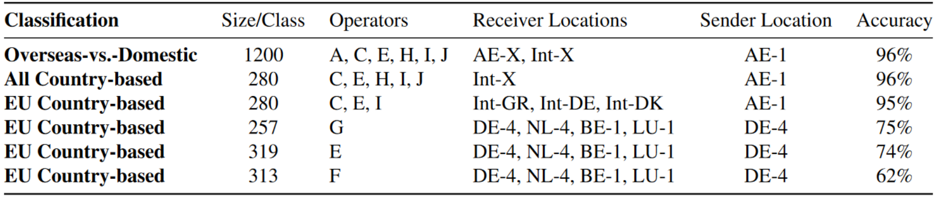


(3) Location Inference

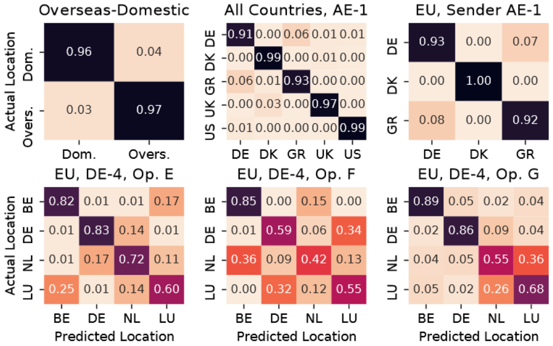


SMS-based Location Inference

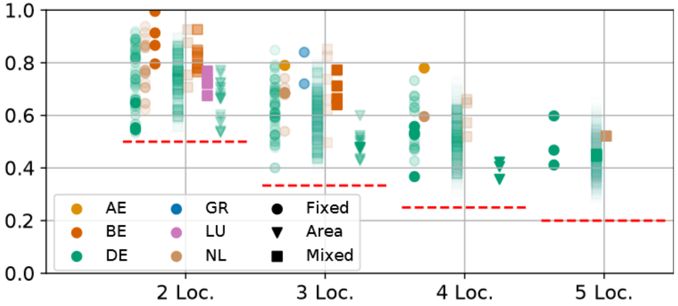
Locations in different countries



Classification	Size/Class	Operators	Receiver Locations	Sender Location	Accuracy
Overseas-vs.-Domestic	1200	A, C, E, H, I, J	AE-X, Int-X	AE-1	96%
All Country-based	280	C, E, H, I, J	Int-X	AE-1	96%
EU Country-based	280	C, E, I	Int-GR, Int-DE, Int-DK	AE-1	95%
EU Country-based	257	G	DE-4, NL-4, BE-1, LU-1	DE-4	75%
EU Country-based	319	E	DE-4, NL-4, BE-1, LU-1	DE-4	74%
EU Country-based	313	F	DE-4, NL-4, BE-1, LU-1	DE-4	62%

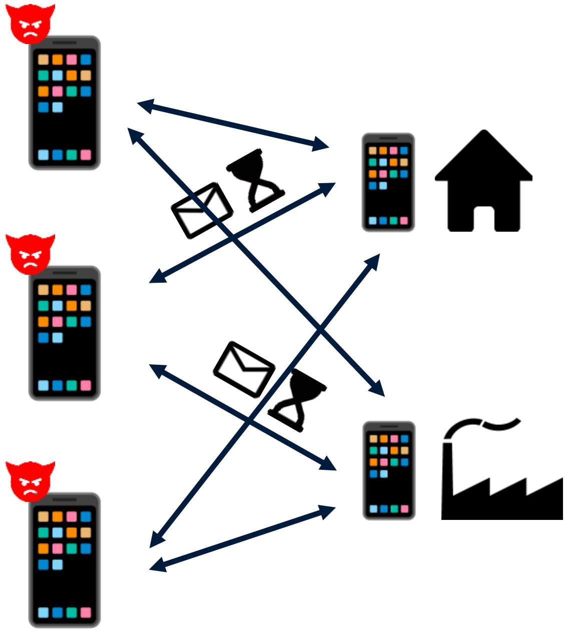


Locations within the same country



Bitsikas et al.:
Freaky Leaky SMS: Extracting User Locations by Analyzing SMS Timings

Contributions of This Paper



The Role of Multi-Sender Coordination

How does controlling multiple senders

in different positions

affect the attacker‘s capabilities

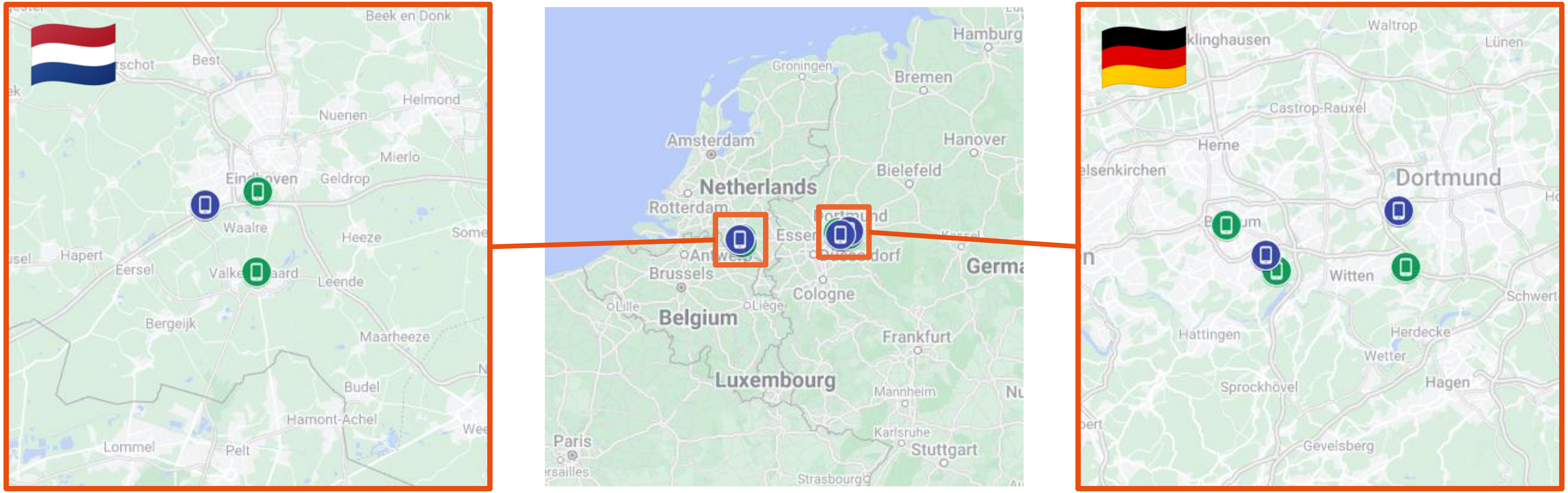
to infer the receiver‘s location?

Experimental Setup: Locations

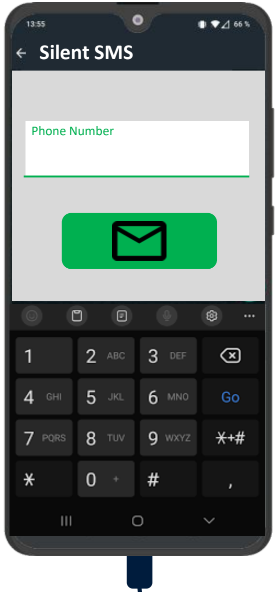
Sender: **V**eldhoven
3 Receiver Locations

2 Clusters
approx. 130km apart

Senders: **B**ochum, **D**ortmund
5 Receiver Locations



Data Collection



ADB-USB
Android Debug Bridge

Sending SMS

1 fixed sending device per location

- Iterate through receivers
  - Send 20 SMS
  - Wait for sent + delivery reports
  - Store timings
- Hourly repeated
  - hh:00 to Rec. 1, hh:15 to Rec. 2, …
  - Best-effort syncing (local clocks)
- Σ 262.980 SMS

Receiving SMS

	PX6a	HuaP8	A53	OP7P
NL-1	✓	✓	✓	
NL-2	✓	✓	✓	✓
NL-3	✓	✓	✓	✓
DE-1	✓	✓		✓
DE-2	✓	✓		
DE-3	✓	✓	✓	✓
DE-4	✓	✓		
DE-5	✓	✓		

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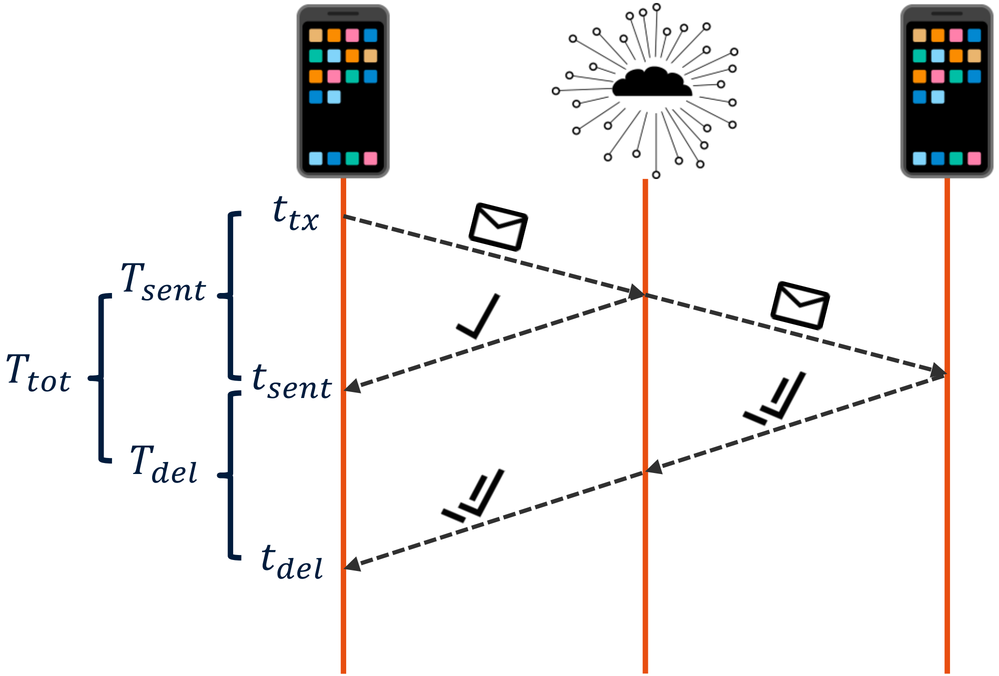
Timing Features



Single-sender features

- Durations ($T_{sent}, T_{del}, T_{tot}$)
- Ratio T_{del} / T_{tot}
- Relative timing difference for two consecutive SMS

➔ *baseline from previous paper*

Multi-sender features

- Mean, median, stddev of **pairs** of senders of **5** consecutive SMS

➔ *9 additional features*

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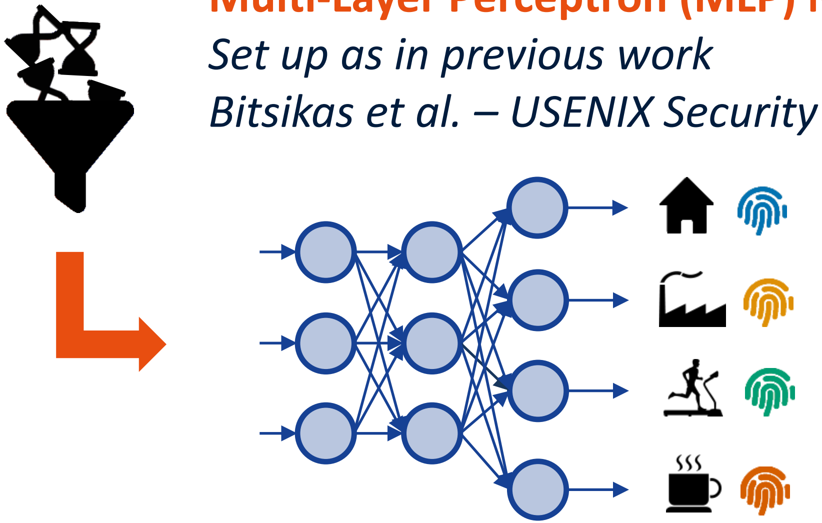
Location Inference Evaluation

Multi-Layer Perceptron (MLP) NN

Set up as in previous work
Bitsikas et al. – USENIX Security 2023



Classifications

- All possible combinations of *n* receiving locations
- *n = {2,3,4}*

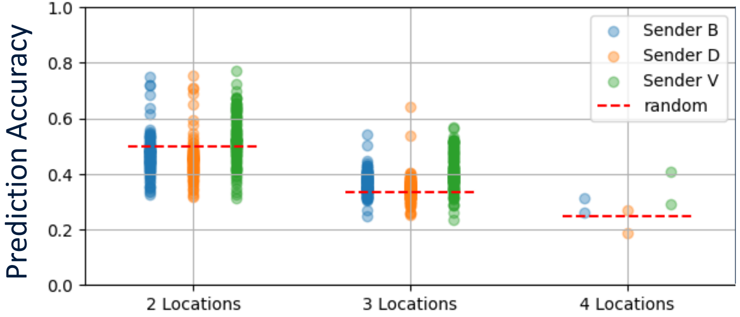
Focus on Accuracy

Share of samples that are classified correctly

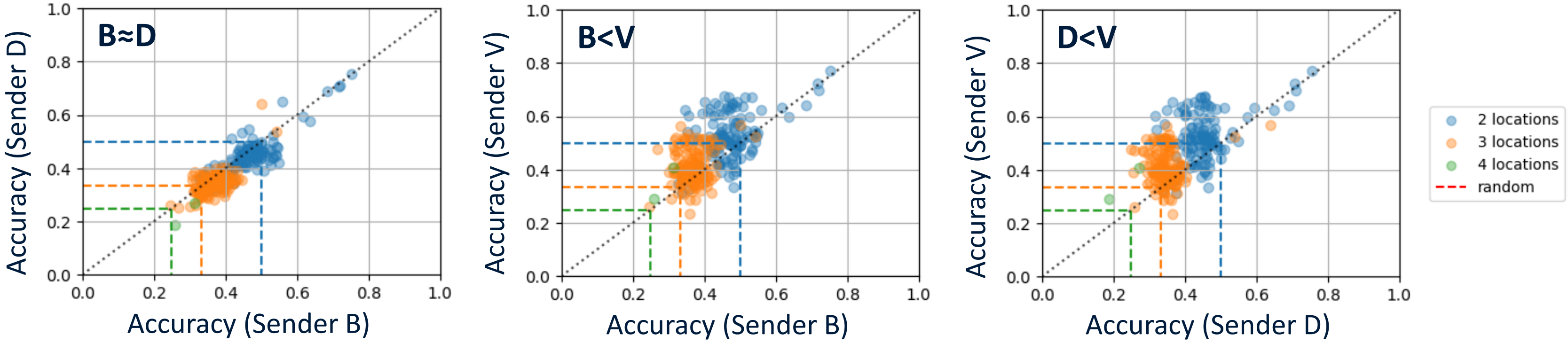
Consistency Across Senders

Compare prediction accuracy
between senders
by number of receiver locations

Overall



Pair-wise



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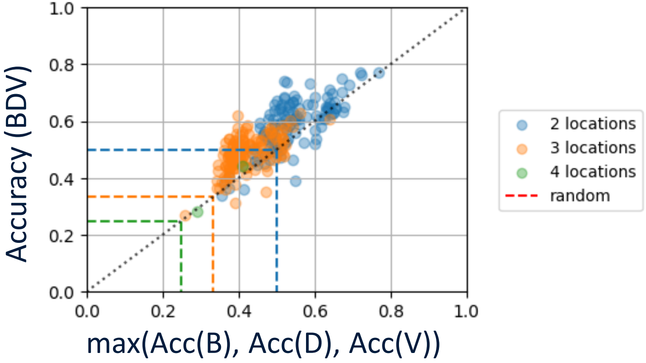
Combining Senders

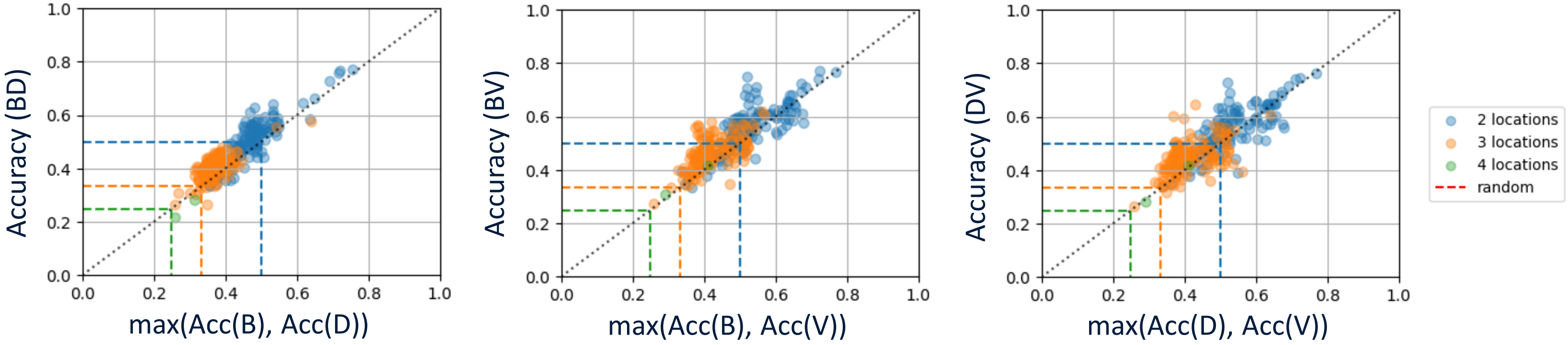
Combine timings from multiple senders and compare with maximum accuracy achieved by single sender

(single-sender features only)

All 3 Senders



Pair-wise



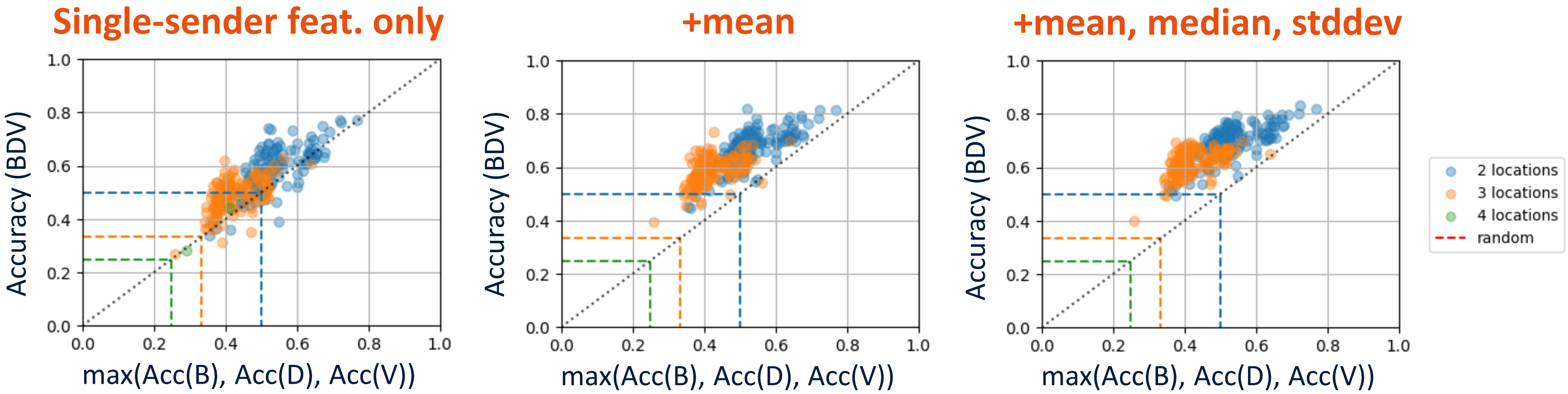
Adding Multi-sender Features

Combine timings from multiple senders and compare with maximum accuracy achieved by single sender

*(**with multi-sender features**)*

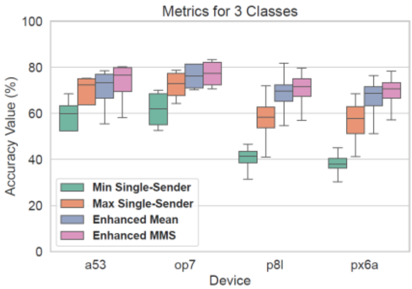
Multi-sender features

Mean, median, stddev
of **pairs** of senders
of **5** consecutive SMS

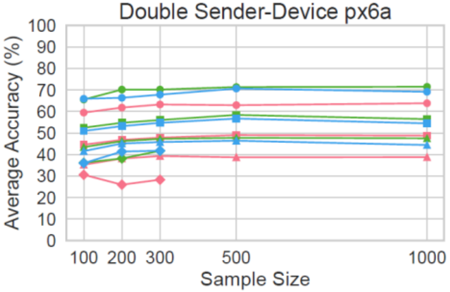


In the Paper

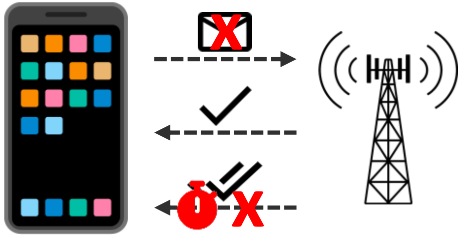
Per-device Analyses



Sample Sizes



Countermeasures



Network operator level only

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Key Takeaways

- Stealthy and targeted attack
- Technically easy (send SMS) but operationally difficult (send **many** SMS)
- Operating multiple senders can improve SMS-based location inference

Paper

Code & Data (Github)

USENIX Security 2023
Freaky Leaky SMS: Extracting User Locations by Analyzing SMS Timings

NDSS 2023
Hope of Delivery: Extracting User Locations From Mobile Instant Messengers

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