RUTGERS
THE STATE UNIVERSITY
OF NEW JERSEY

PARADIS

PAssive
RAdiometric
Device
Identification
System

:Identifying Transmitters via Radiometric Signatures

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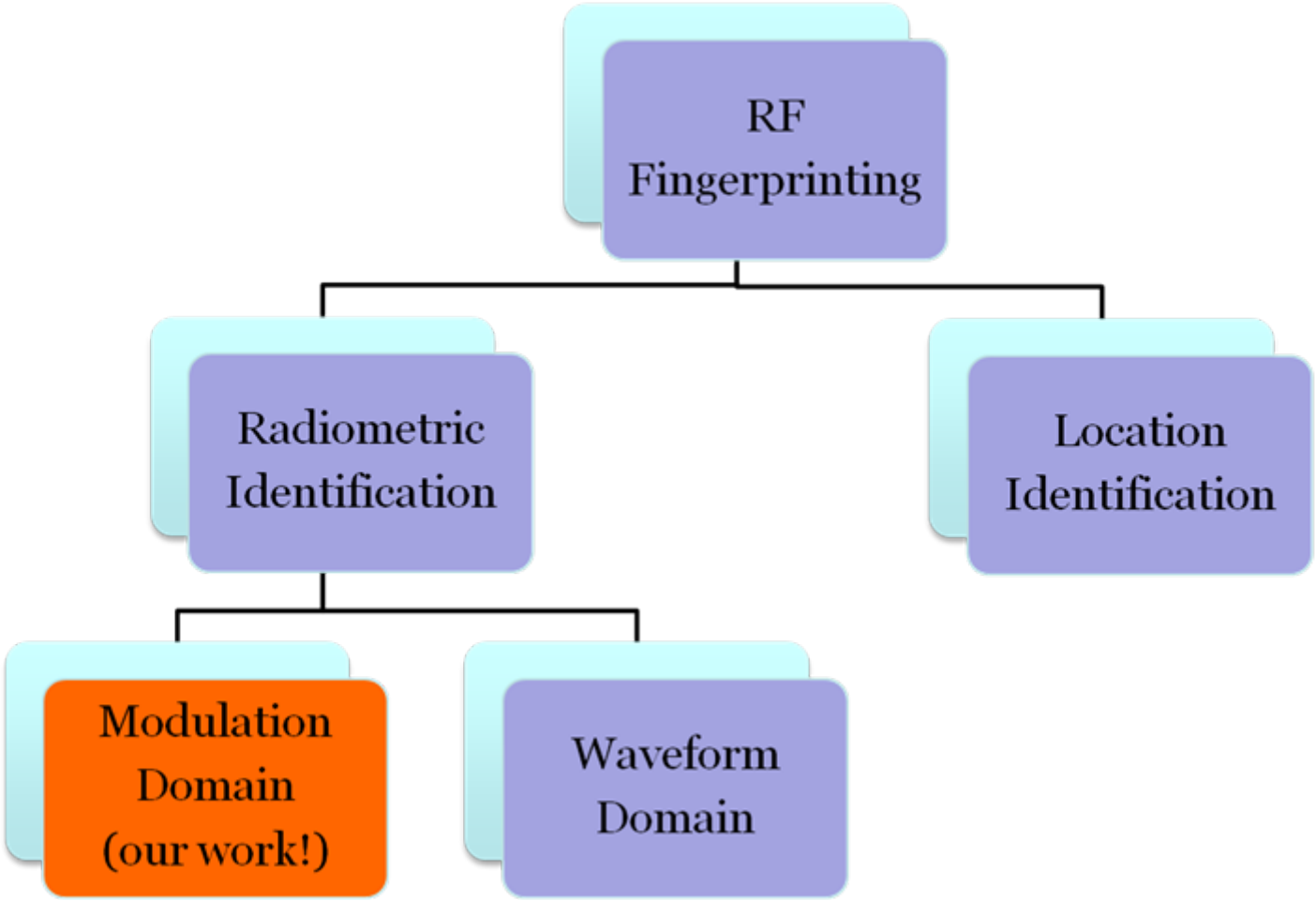
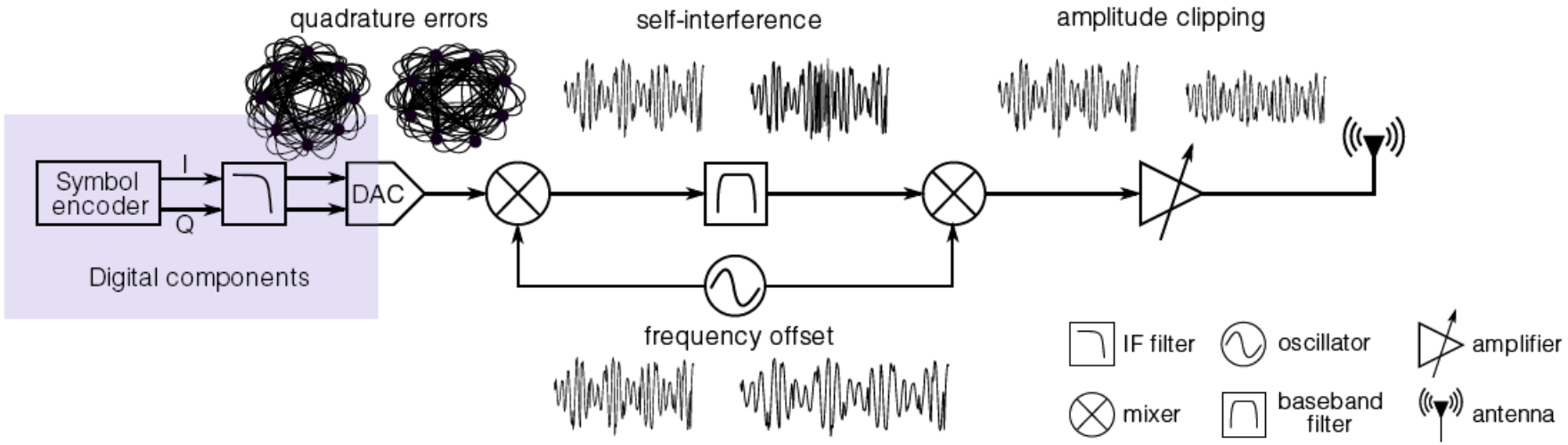
Radiometric Identification

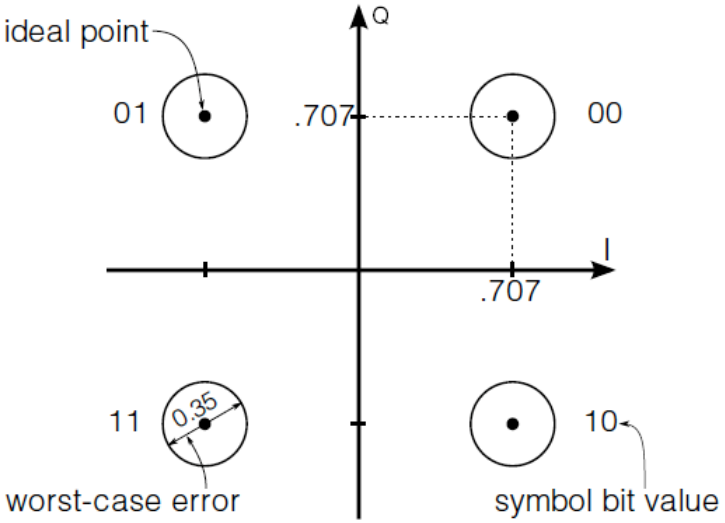


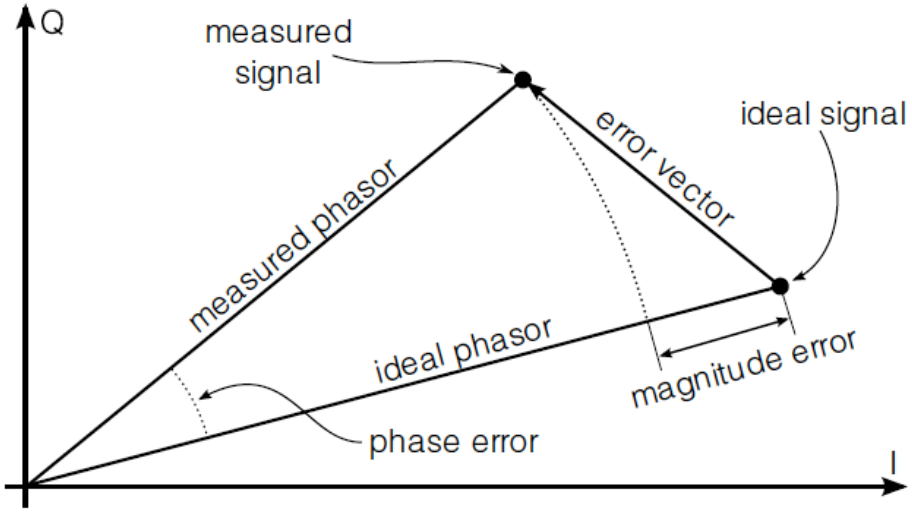
Waveform Impairments in Analog Frontend

- Transmitter
  - Hardware imperfection
  - Design architecture
- Receiver
  - Allows certain level of difference for interoperability



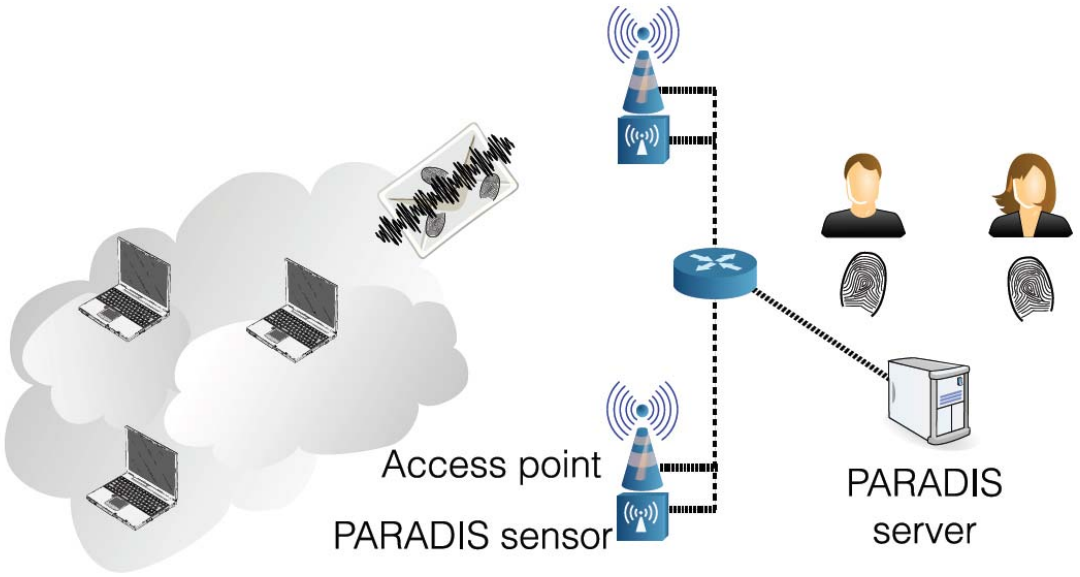
Error Signal Vector





- Measurement Tool
  - Vector Signal Analyzer: Agilent VSA 89641S

PARADIS (PAssive RAdiometric Device Identification System)



Training phase

Collect RF Fingerprints → Build Error Metric

On-line (Identification) phase

Measure the target Signal (Bin size = m) → Identify the Device

Training Phase

- Collect fingerprint of each transmitter (20 frames each)
- Build a Reference Table based on Error Metrics
  - User device = {A,B,C,D}
  - Collect frames per device $\{a_1,a_2,a_3,.....a_n\}$
  - Measure sample vector V = (v_1,v_2,v_3,v_4,v_5)

Error type	unit	reference	range	definition
frequency	Hz	2142 MHz	± 60.3	$\pm 25ppm\ f_c$
phase	$^\circ$	ideal symb	± 10	$\text{asin}(E_{max})$
magnitude	n/a	ideal symb	± 0.17	$\pm E_{max}$
EVM	n/a	ideal symb	$[0, .35]$	upto $2E_{max}$
I/Q offset	n/a	ideal origin	$[0, 0.17]$	upto E_{max}
SYNC	%	max corr.	$[0, 1]$	correlation

f_c – channel frequency E_{max} – max I/Q error

Classification Algorithms

- PARADIS-kNN (k-Nearest-Neighbor)
  - In training, discard ½ samples (outliers) of user A
    - Average value of the rest ½ is model M_a of user A
  - For given sample u_k, calculate similarity with models for all the users
    - Fine least value from $\{|M_a-u_k|, |M_b-u_k|, |M_c-u_k|, |M_d-u_k|\}$
- PARADIS-SVM (Supported Vector Machines)
  - Use of LIBSVM
    - Classification algorithm that builds N-1 dimensional hyper plane in N dimensional space

ORBIT

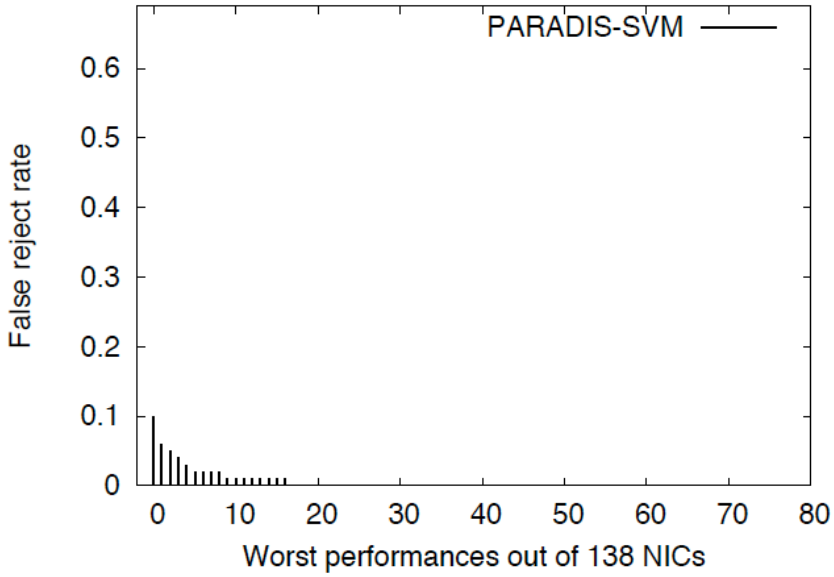
Performance

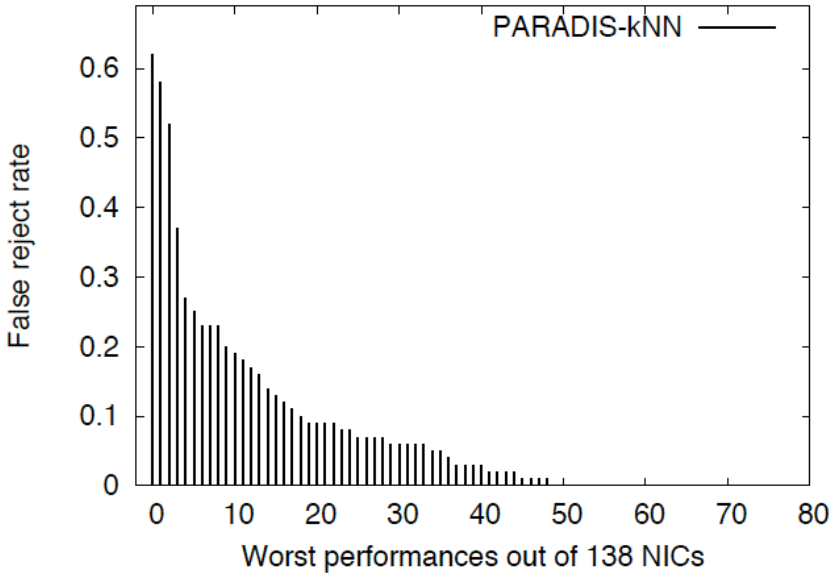
Approach	NIC population size	Bin size	Training fraction	Reported error rate[1]	Equivalent performance of PARADIS-kNN	Equivalent performance of PARADIS-SVM
Franklin et. al. [13][2]	17	8	5%	15%	0%	0%
Hall et. al. [18][3]	30	10	33%	8%	0%	0%
PARADIS	**138**	**4**	**20%**	-	**3%**	**0.34%**

- Franklin:
  - Use 802.11 device driver fingerprint
  - Detect implementation dependent probing algorithm
- Hall:
  - Detect signal transient time in the waveform domain
- PARADIS:
  - Error vector in the Modulation domain

Performance I

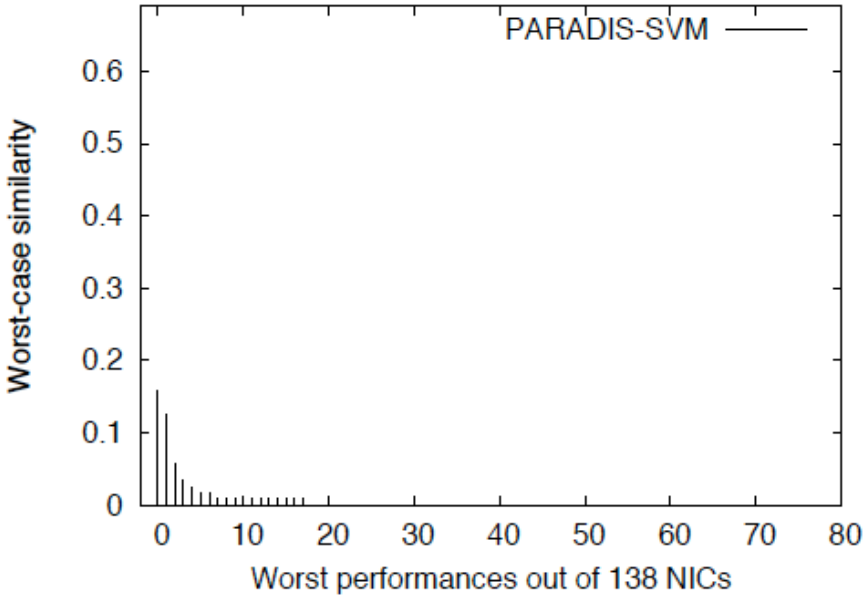
- False Reject Rate (FRR) – per NIC
  - System denies authentic users

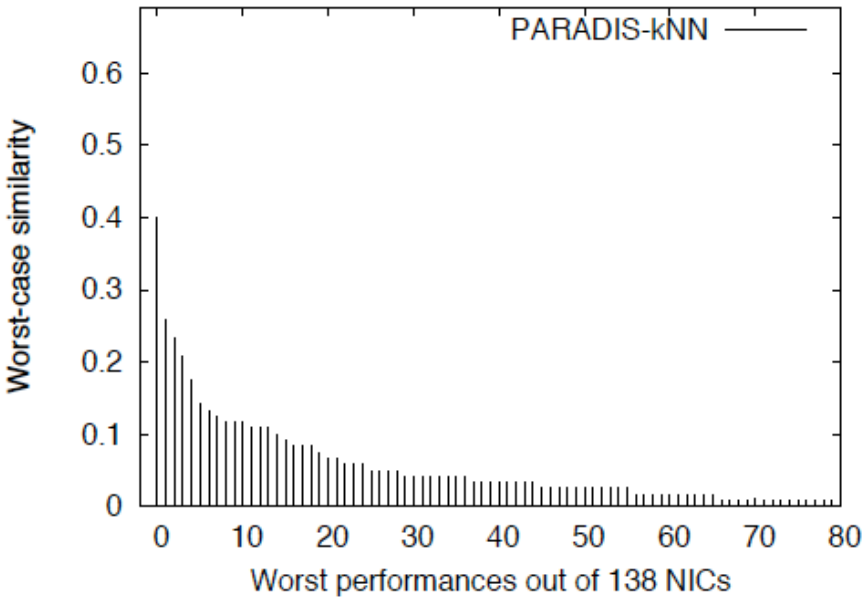




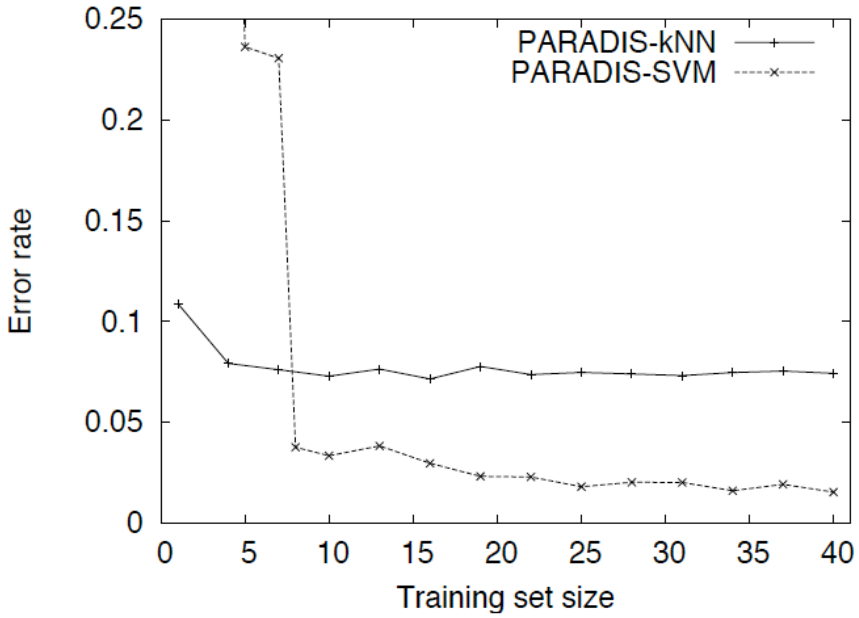
Performance II

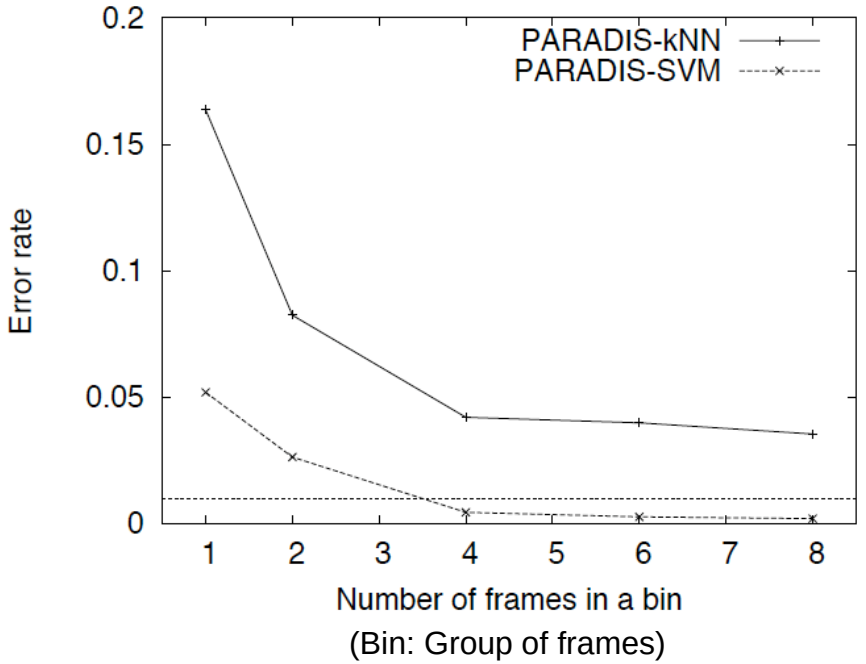
- False Accept Rate (FAR) – per NIC
  - System authenticate wrong user (imposter)
  - Worst case similarity: Select the most probable imposter





Calibration





- SVM algorithm need calibration time
  - But frame by frame identification is possible.

Conclusions

- PARADIS
  - Identifying devices using modulation domain fingerprint is possible with a great precision
  - Accuracy > 99%
  - Error < 1%
- Key features
  - Consistency
  - Unforgeable
  - Unescapable
- Implications
  - Could be used in intrusion detention systems
  - Possible privacy compromise