Spectrum Enforcement in a Spectrum Sharing World

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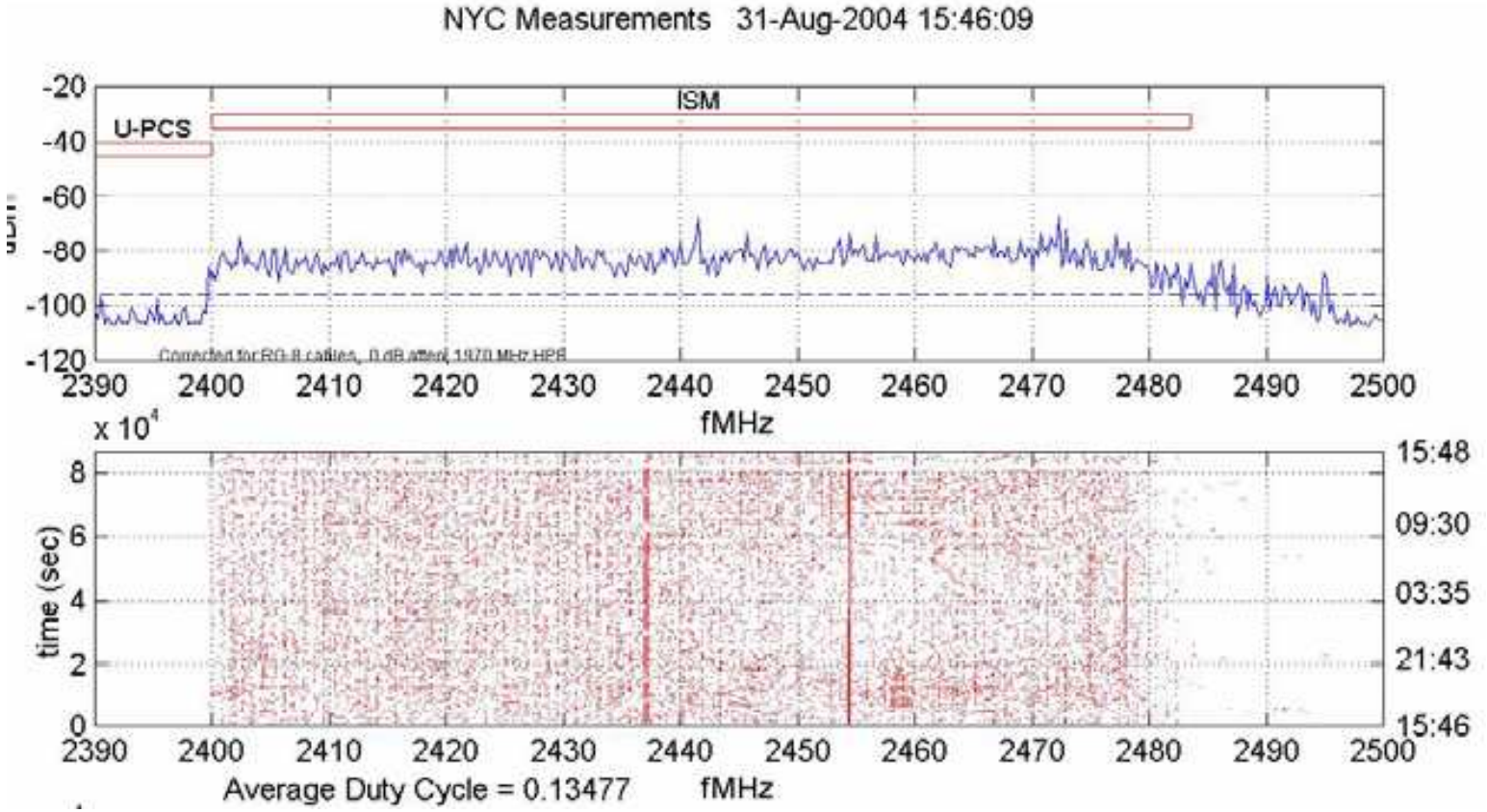
Marco Gruteser, Sangho Oh (Rutgers), Edward Suh (Cornell)
Jon Peha, Adrian Perrig (CMU)

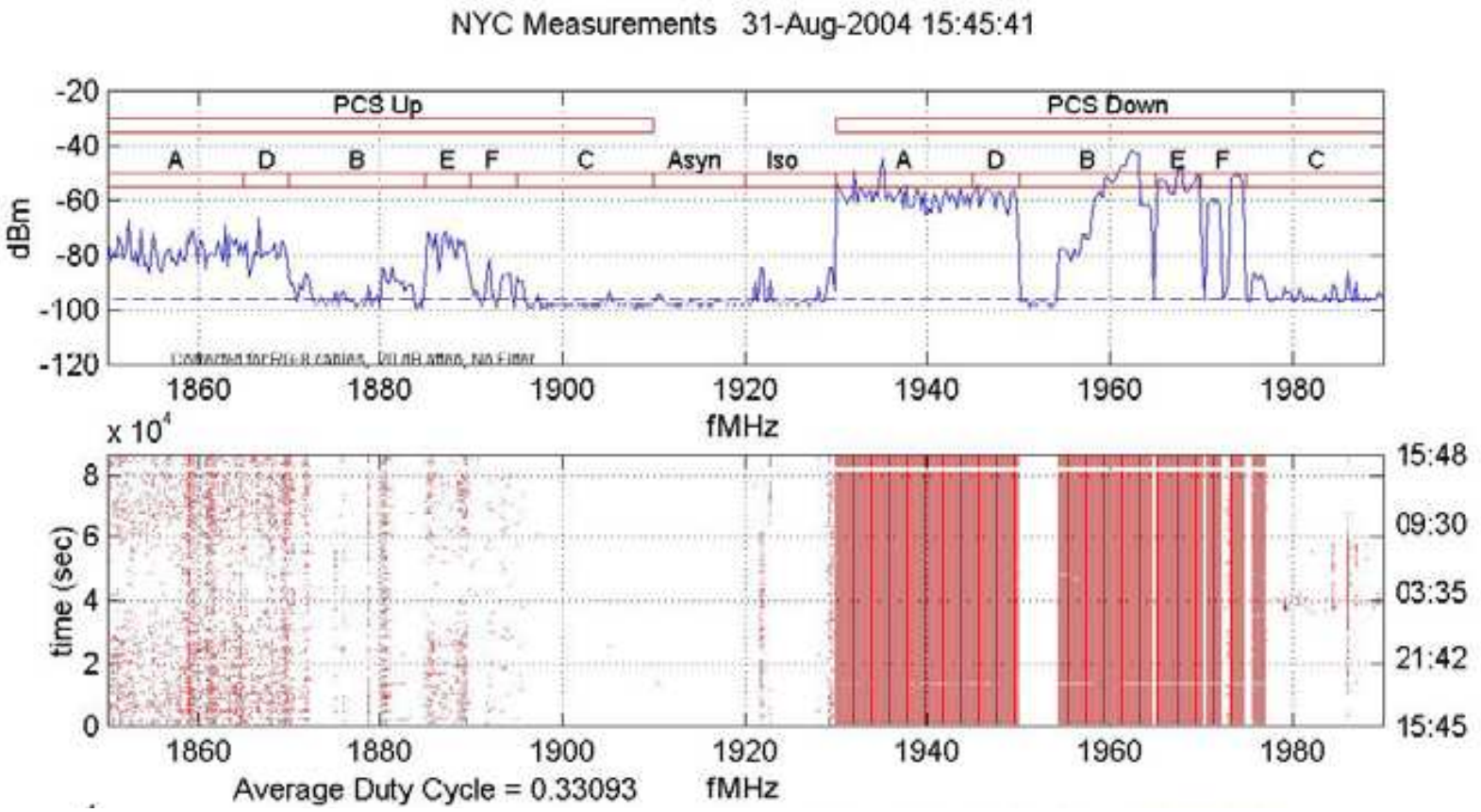
Measurement studies



ISM unlicensed band

[Data from SharedSpectrum.com report]

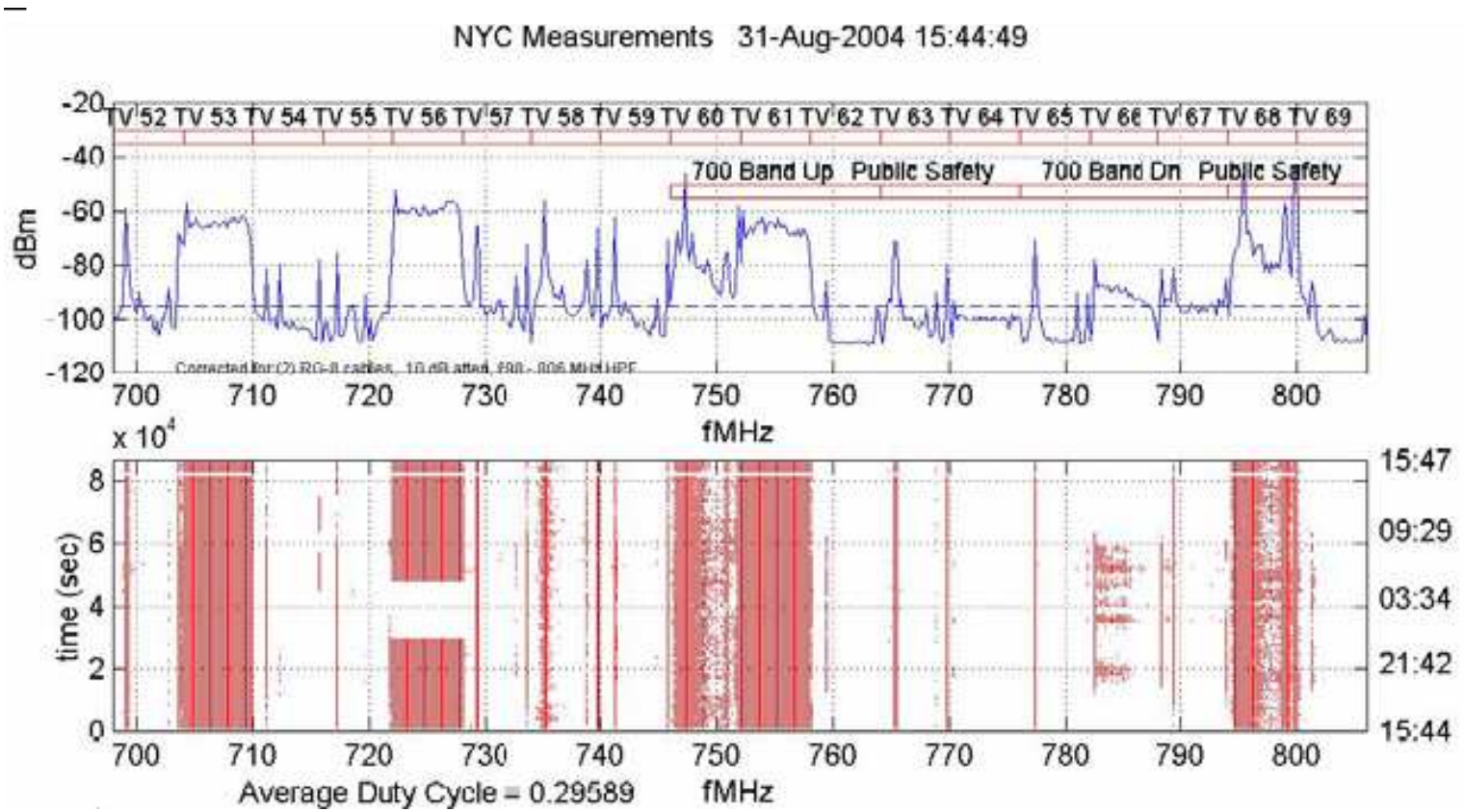
Measurement studies



PCS band

[Data from SharedSpectrum.com report]

Measurement studies



UHF TV channels

[Data from SharedSpectrum.com report]

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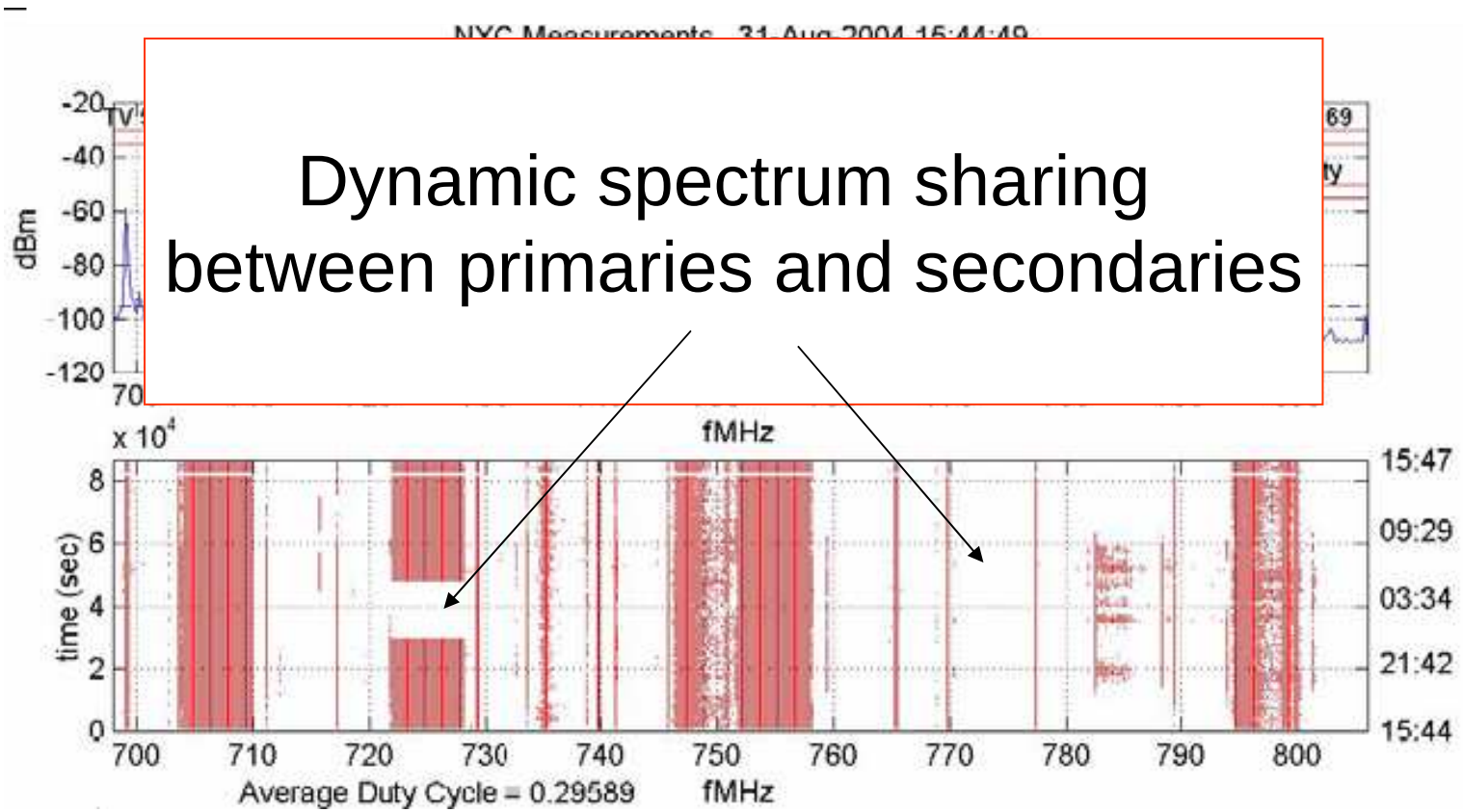
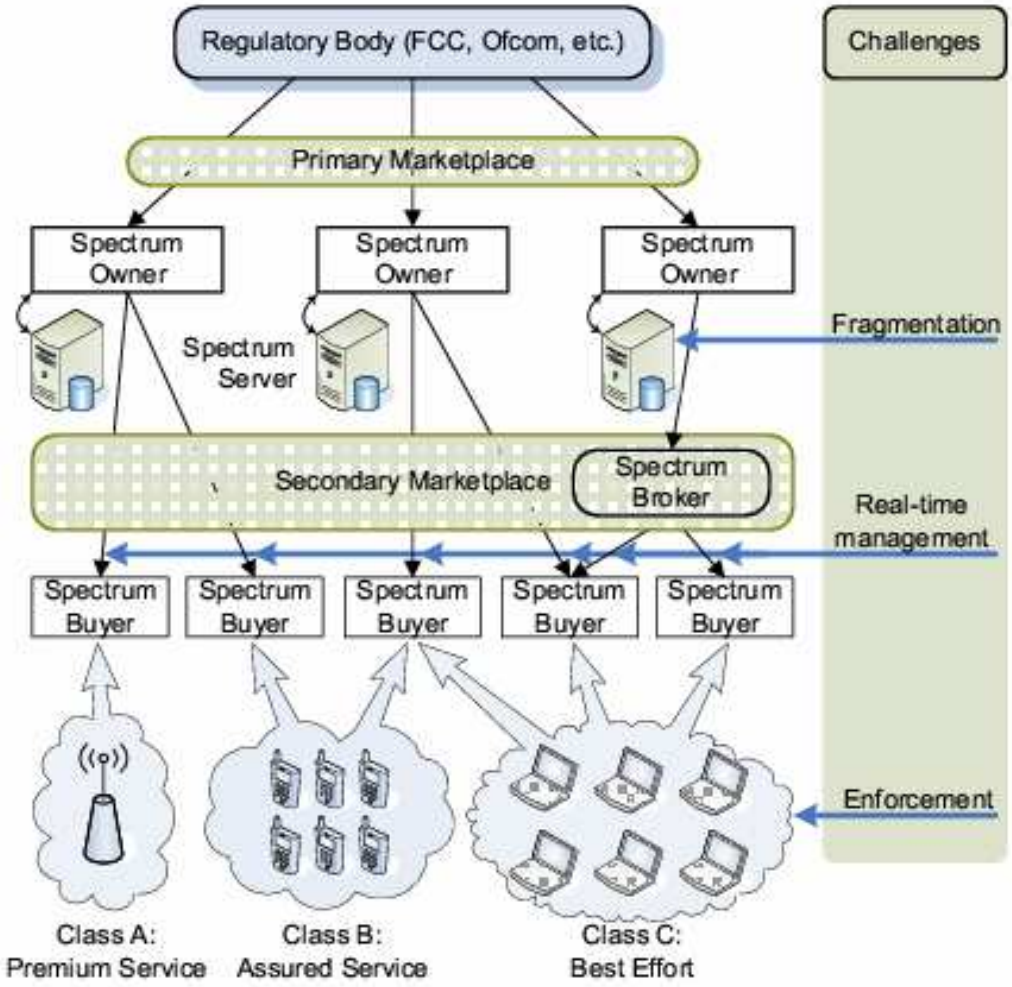


UHF TV channels

[Data from SharedSpectrum.com report]

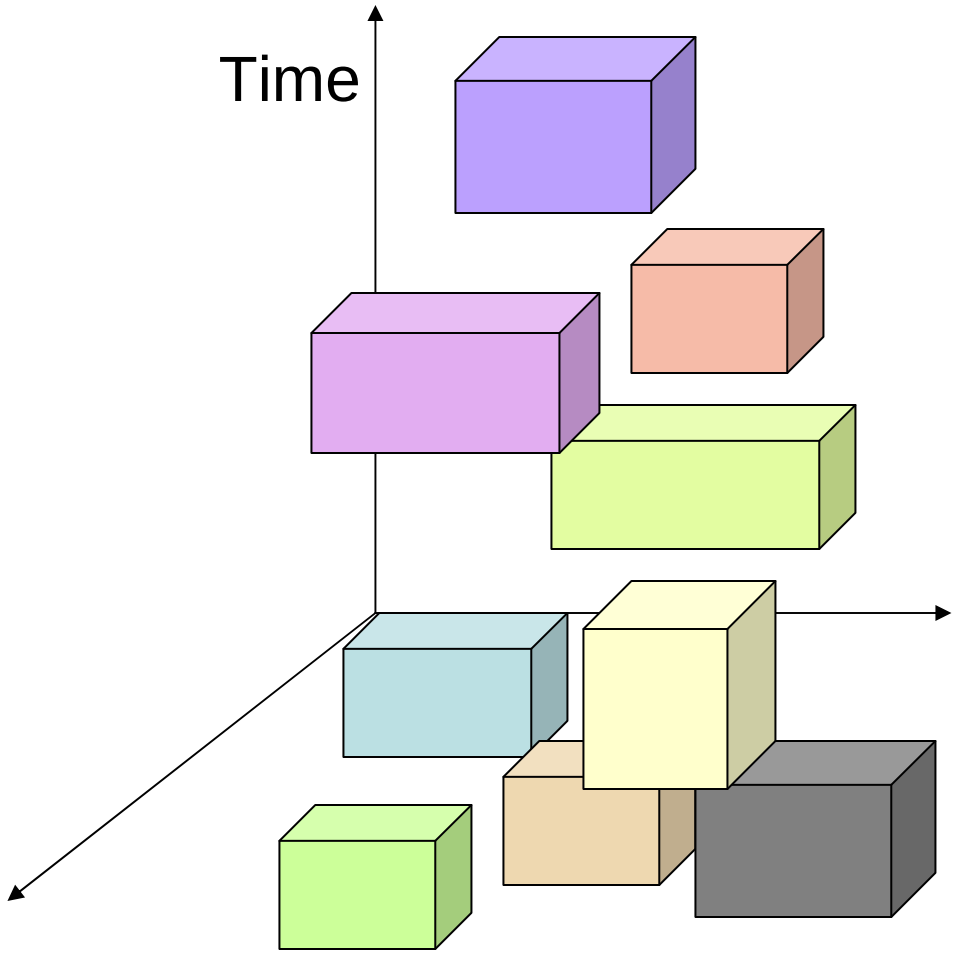
Dynamic spectrum sharing

- Regulatory bodies
  - Such as FCC, Ofcom
- Primary user
  - Owns the spectrum (through a long-term lease)
- Secondary user
  - Need limited, opportunistic, access to spectrum
- Spectrum brokers
  - Aggregates unused spectrum and makes it available to secondary users



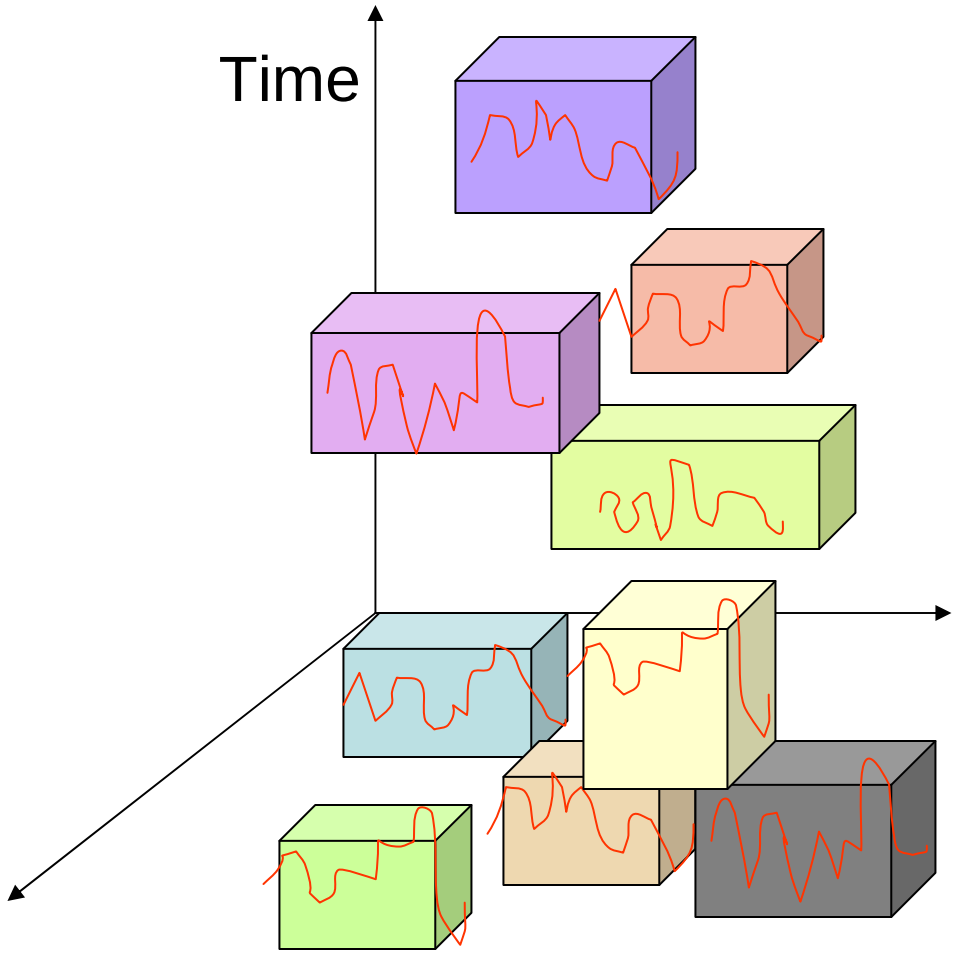
Design goals

- High utilization



Design goals

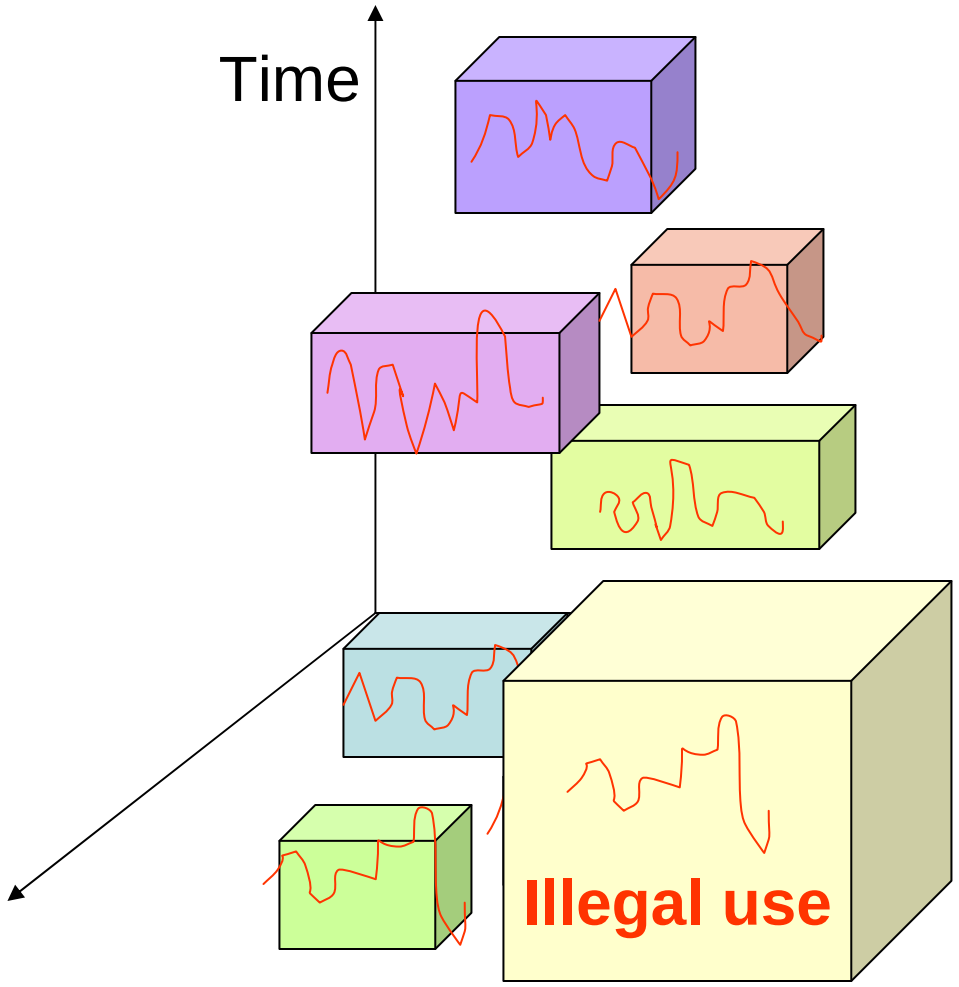
- High utilization
- Flexible usage



Unknown PHY/MAC modulations

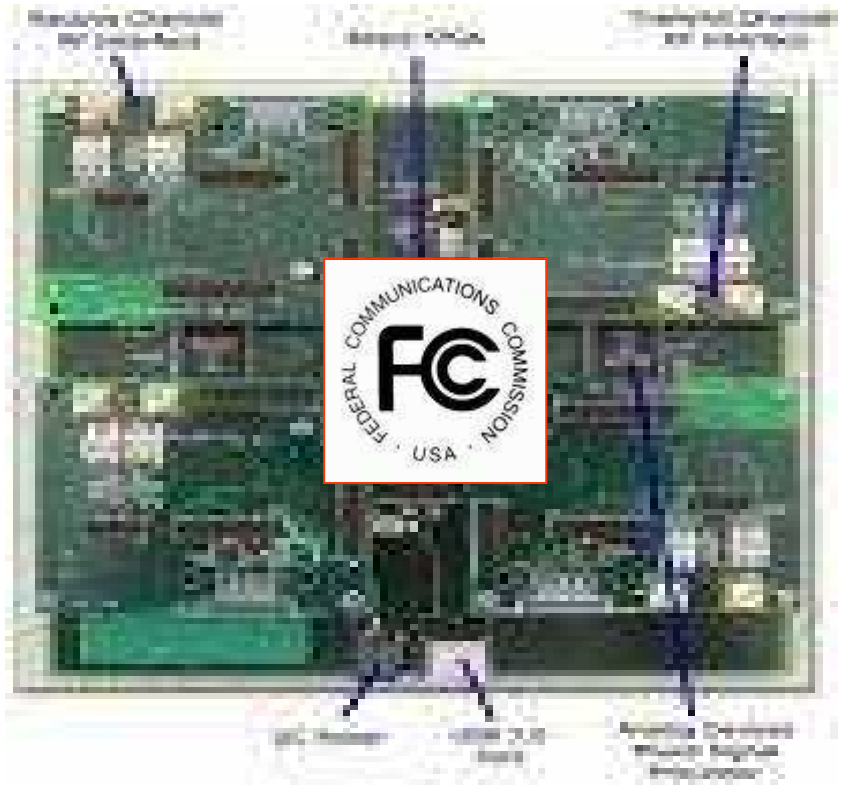
Design goals

- High utilization
- Flexible usage
- Verifiable use



Design goals

- High utilization
- Flexible usage
- Verifiable use
- Certifiable X-ware



Requirements

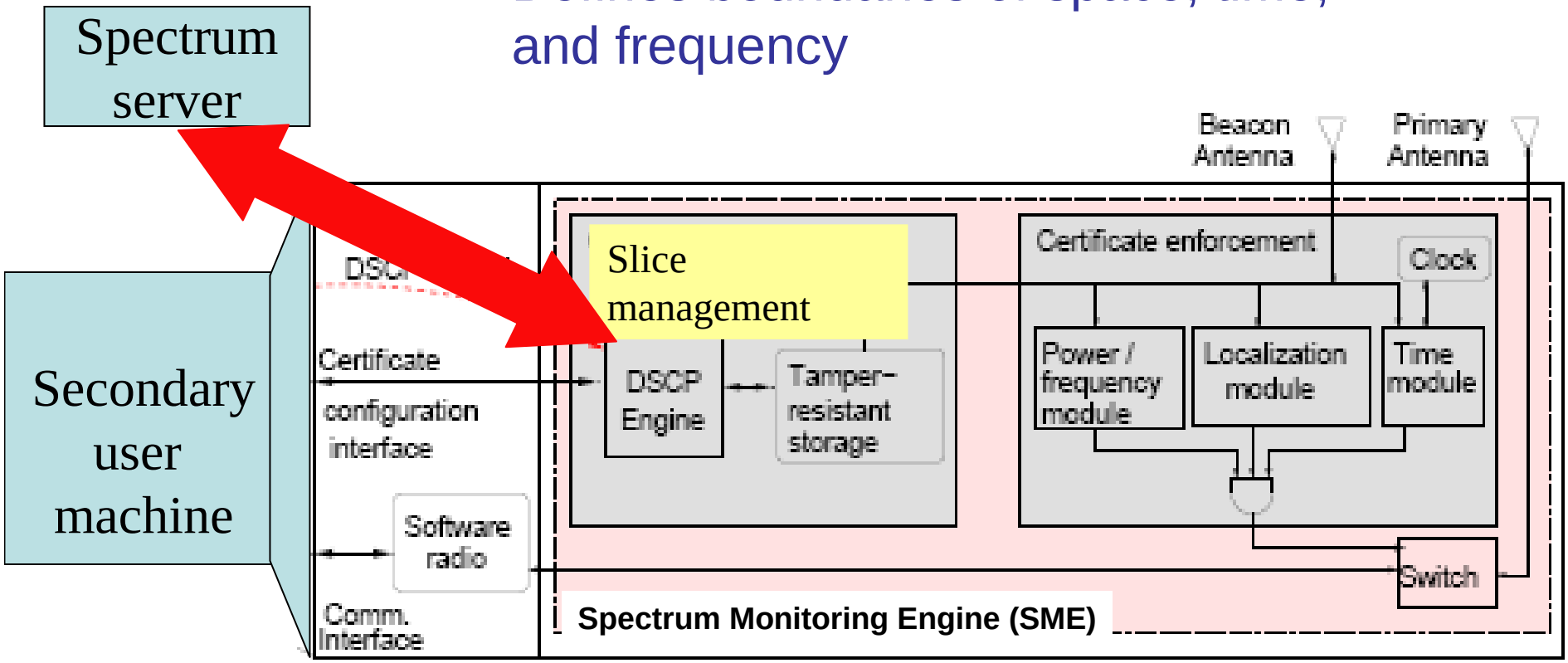
- Violation detection should be
  - Fast
  - Accurate
  - Automated

Build confidence among primary owners

Approach I

- Secure spectrum rights management
  - A **S**ecure secondary **lice**nse (slice)

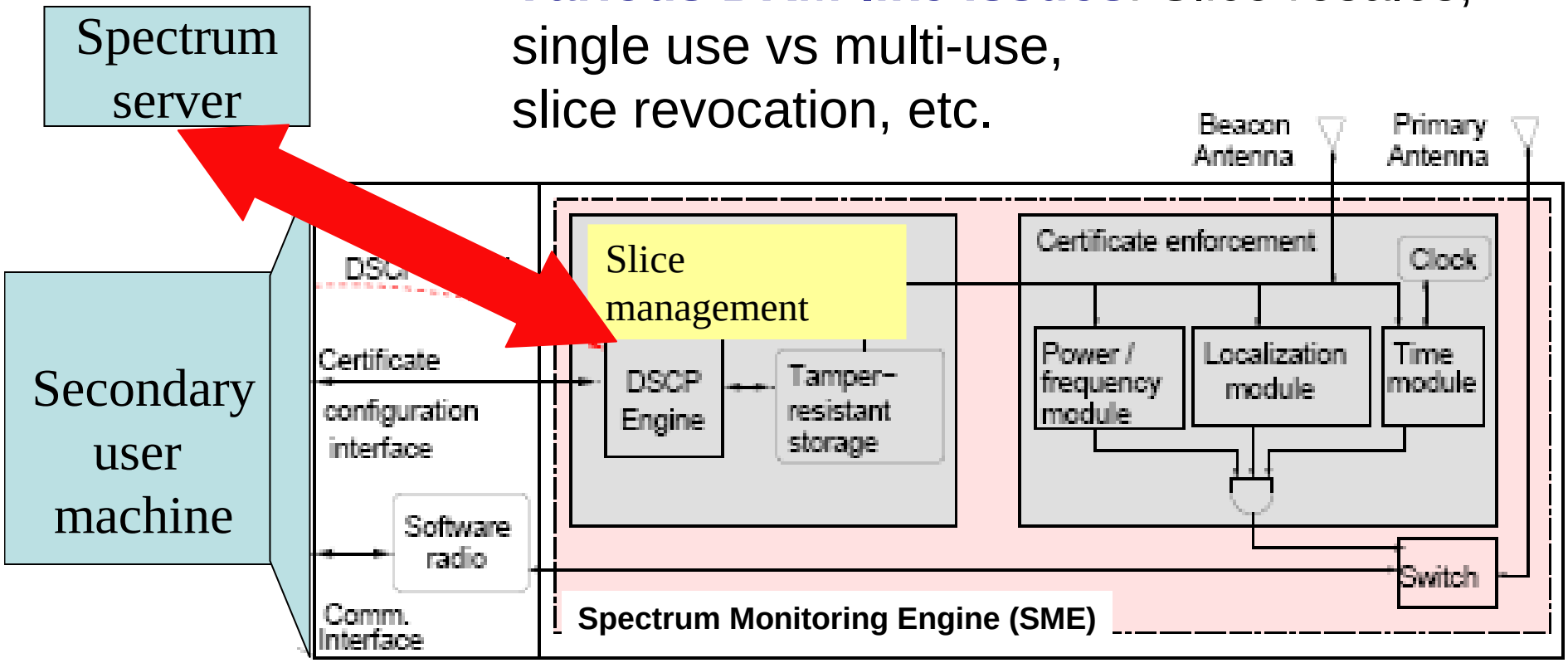
Defines boundaries of space, time, and frequency



Approach I

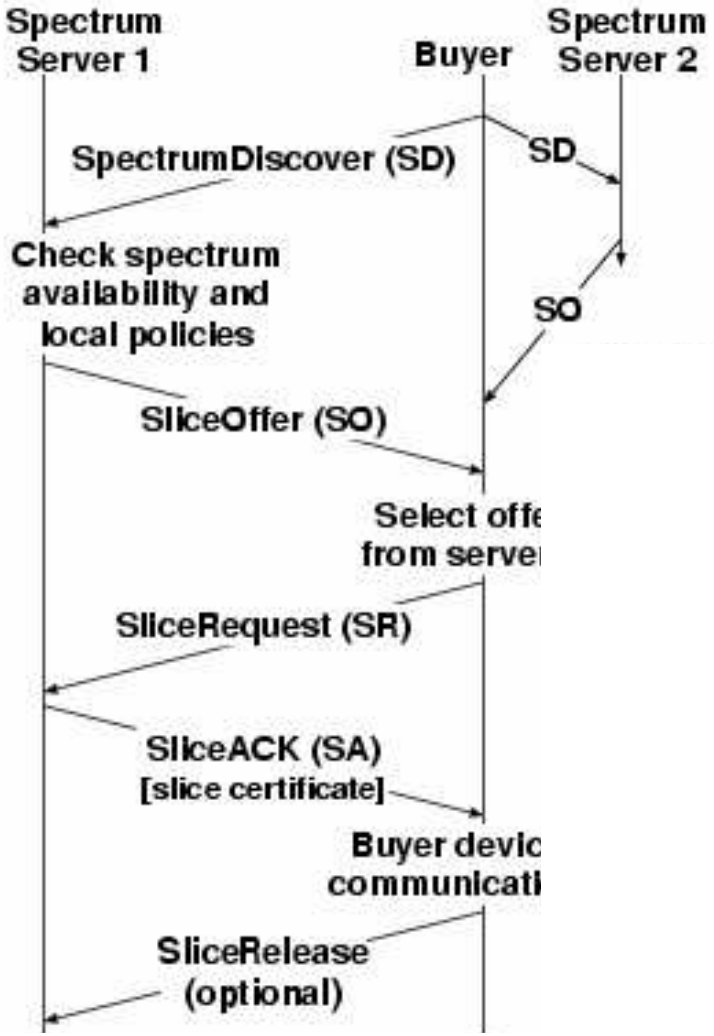
- Secure spectrum rights management
  - A **S**ecure secondary **lice**nse (slice)

Various DRM-like issues: Slice resales, single use vs multi-use, slice revocation, etc.



Real-time spectrum management

- Secure spectrum rights management

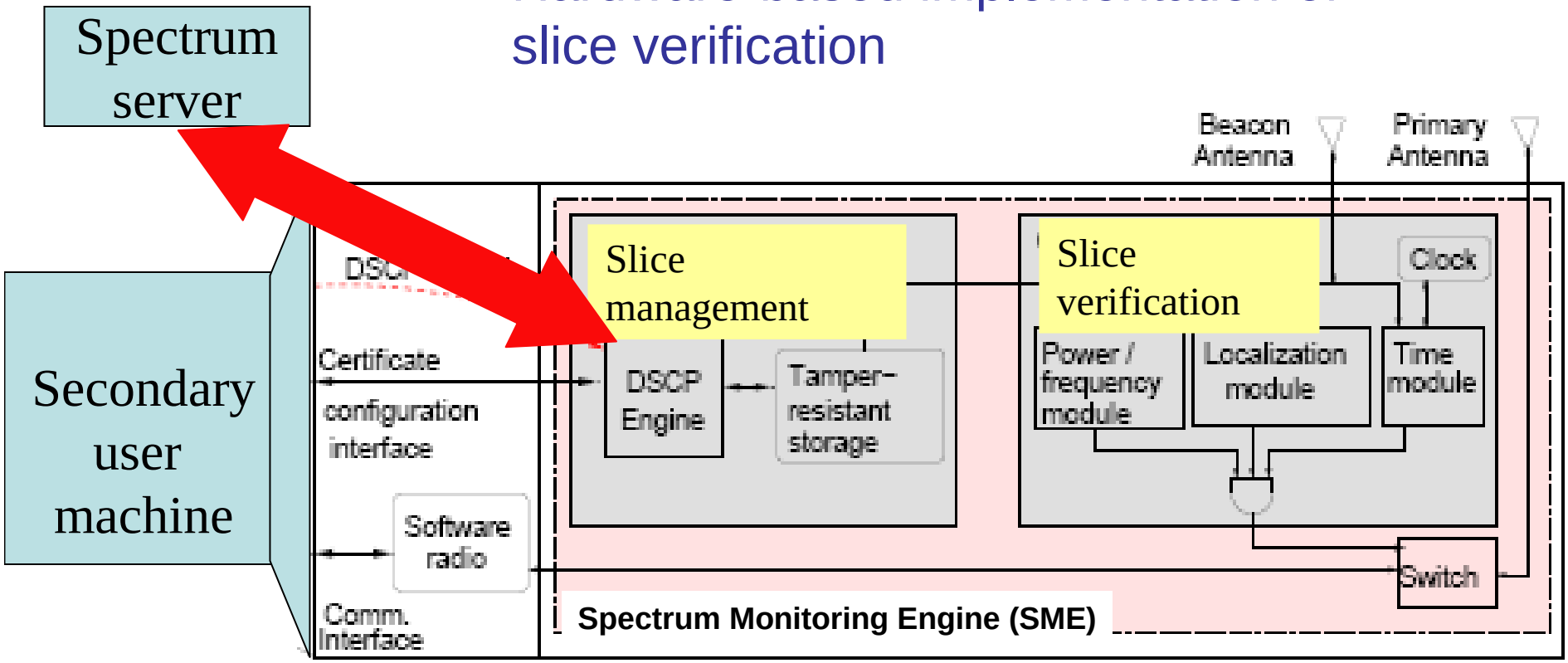


Some basic protocol mechanisms

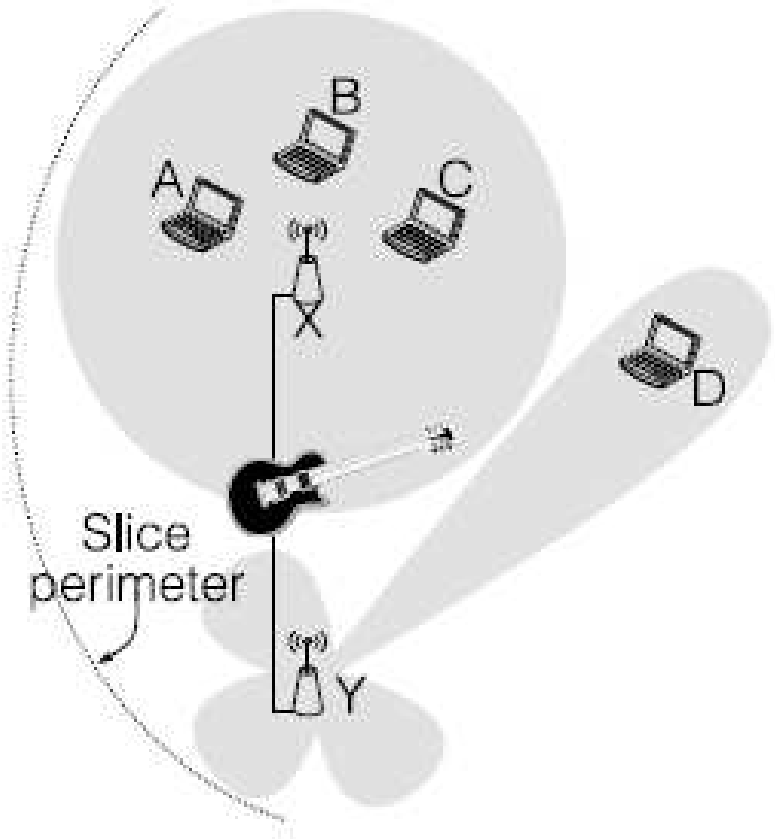
Approach I

- In-band spectrum enforcement
  - Disable communication on violation

Hardware-based implementation of slice verification

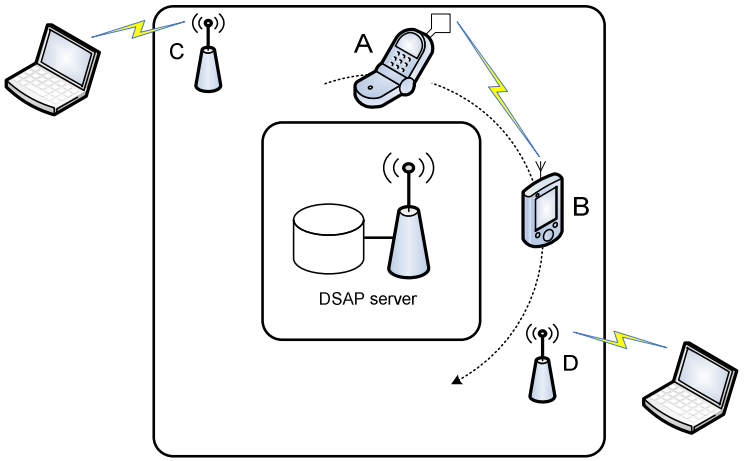


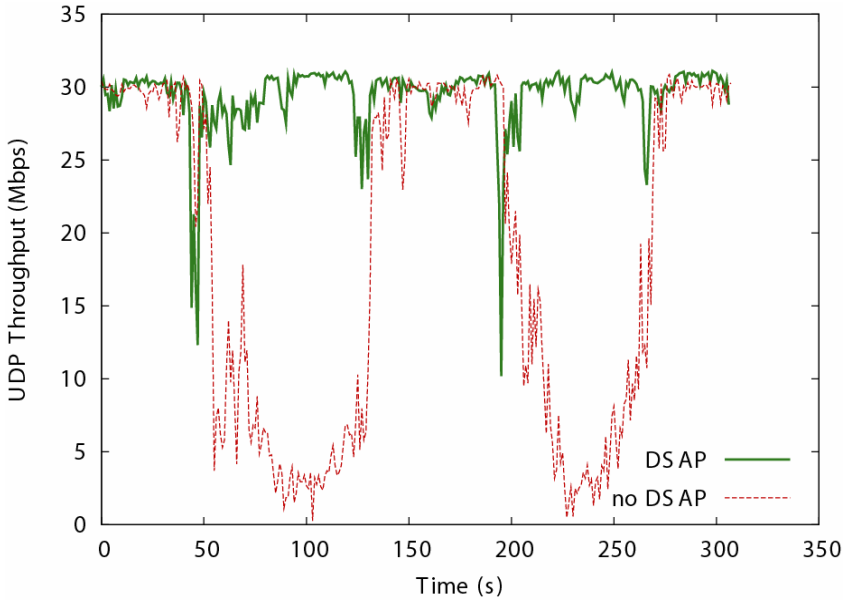
A power fence



Enforcing the power fence

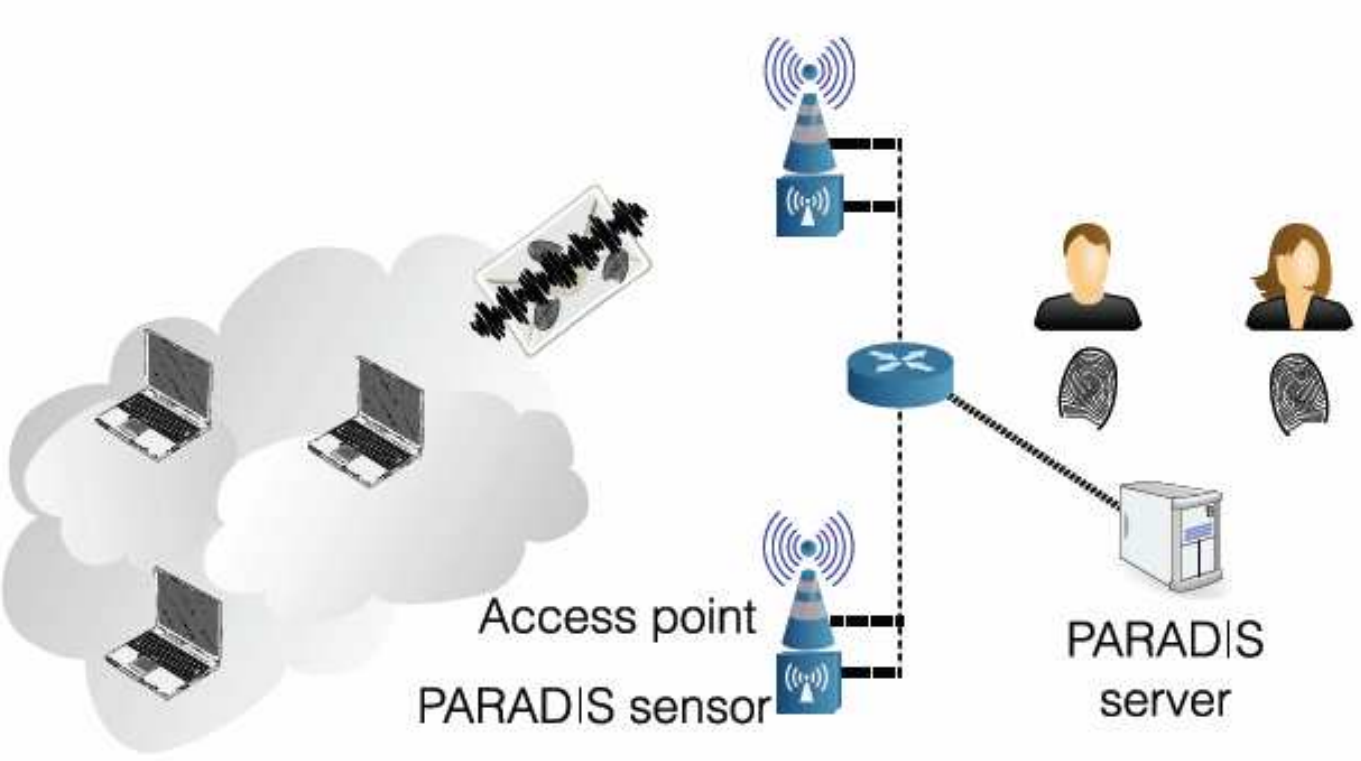
- In this example, implemented in software





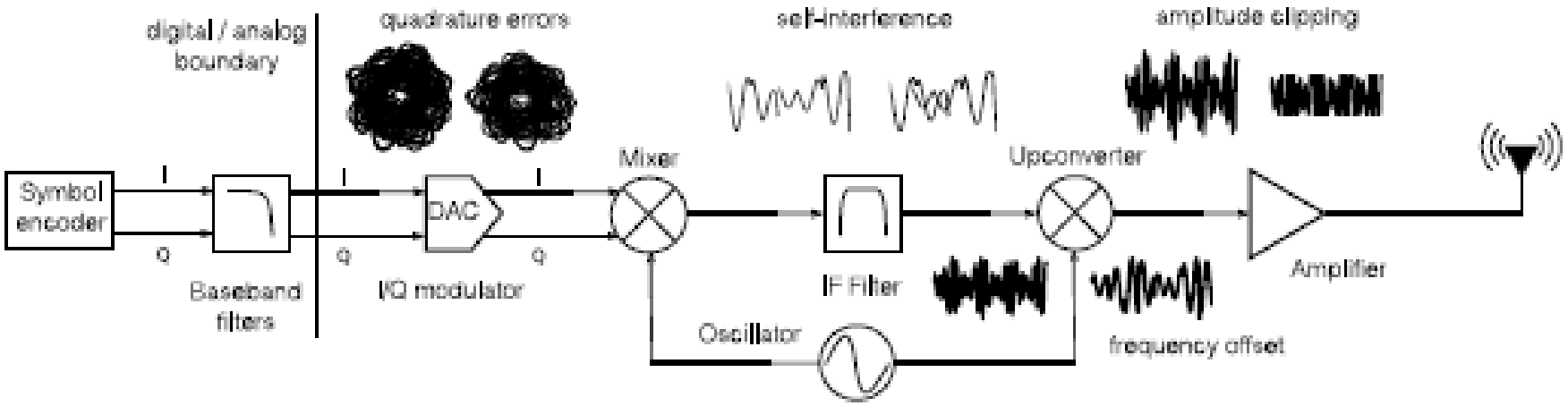
Approach II

- **Out-of-band spectrum violation detection**
  - **Radiometric identification (PARADIS)**
  - Automated localization (RADAR, Horus, others)

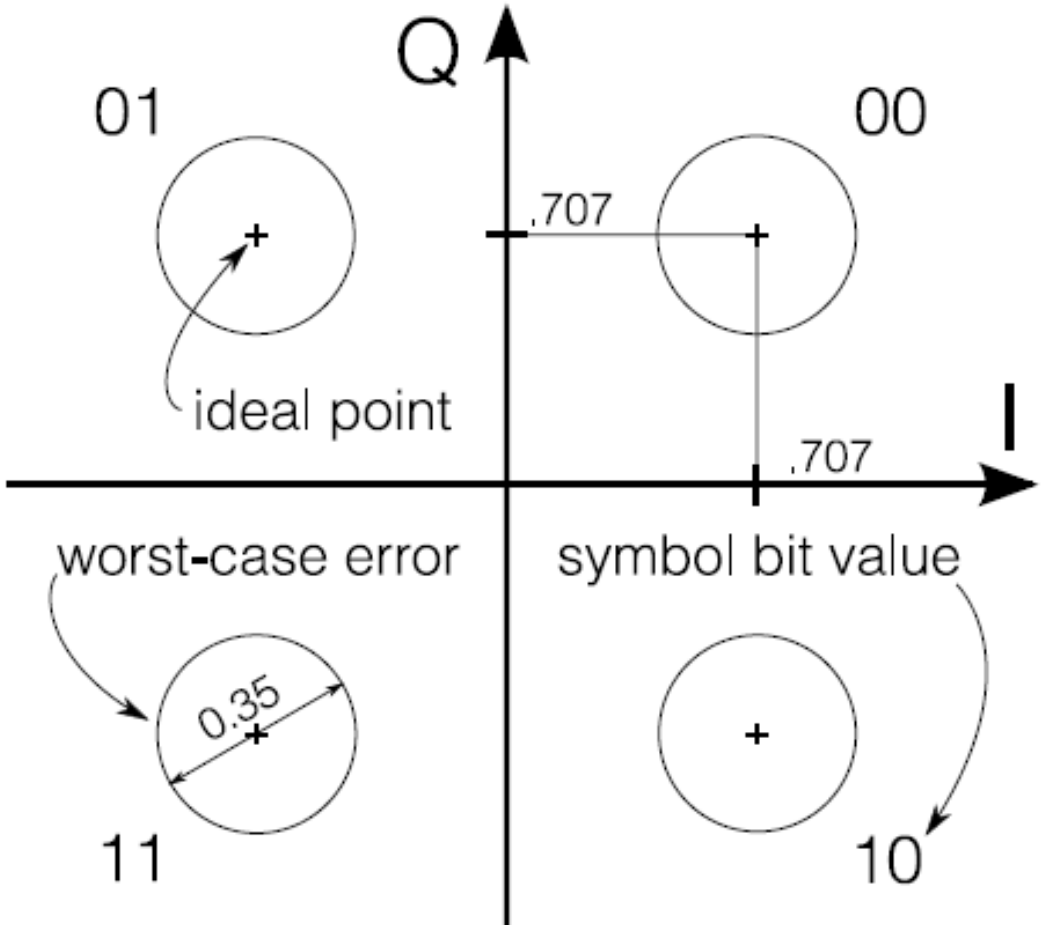


Radiometric identification

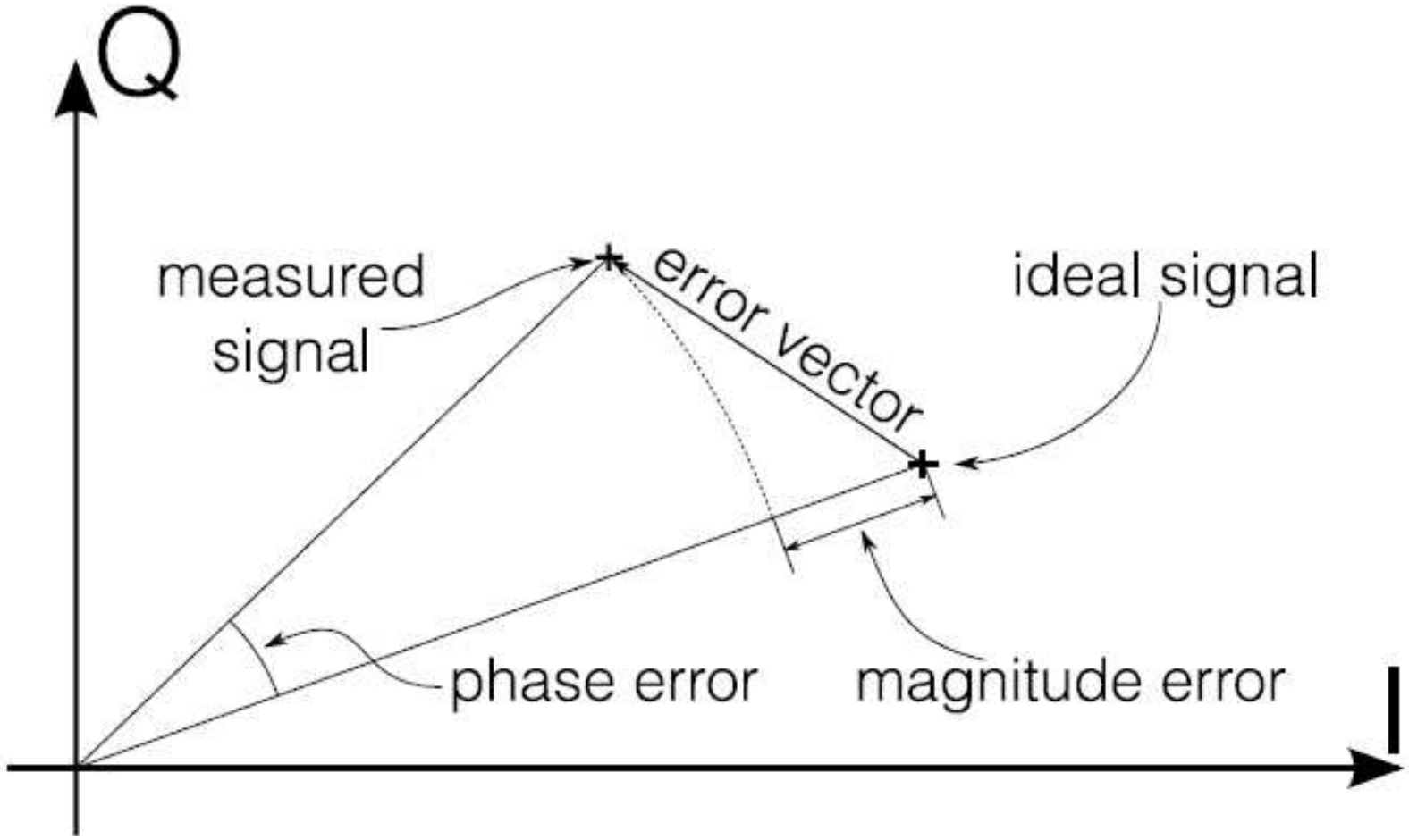
- Utilize unforgeable characteristics of wireless RF front-end
  - Usually imperfections acquired during manufacturing process



Errors do not inhibit decoding



Some examples



Others include: Frequency error, SYNC correlation, I/Q origin offset

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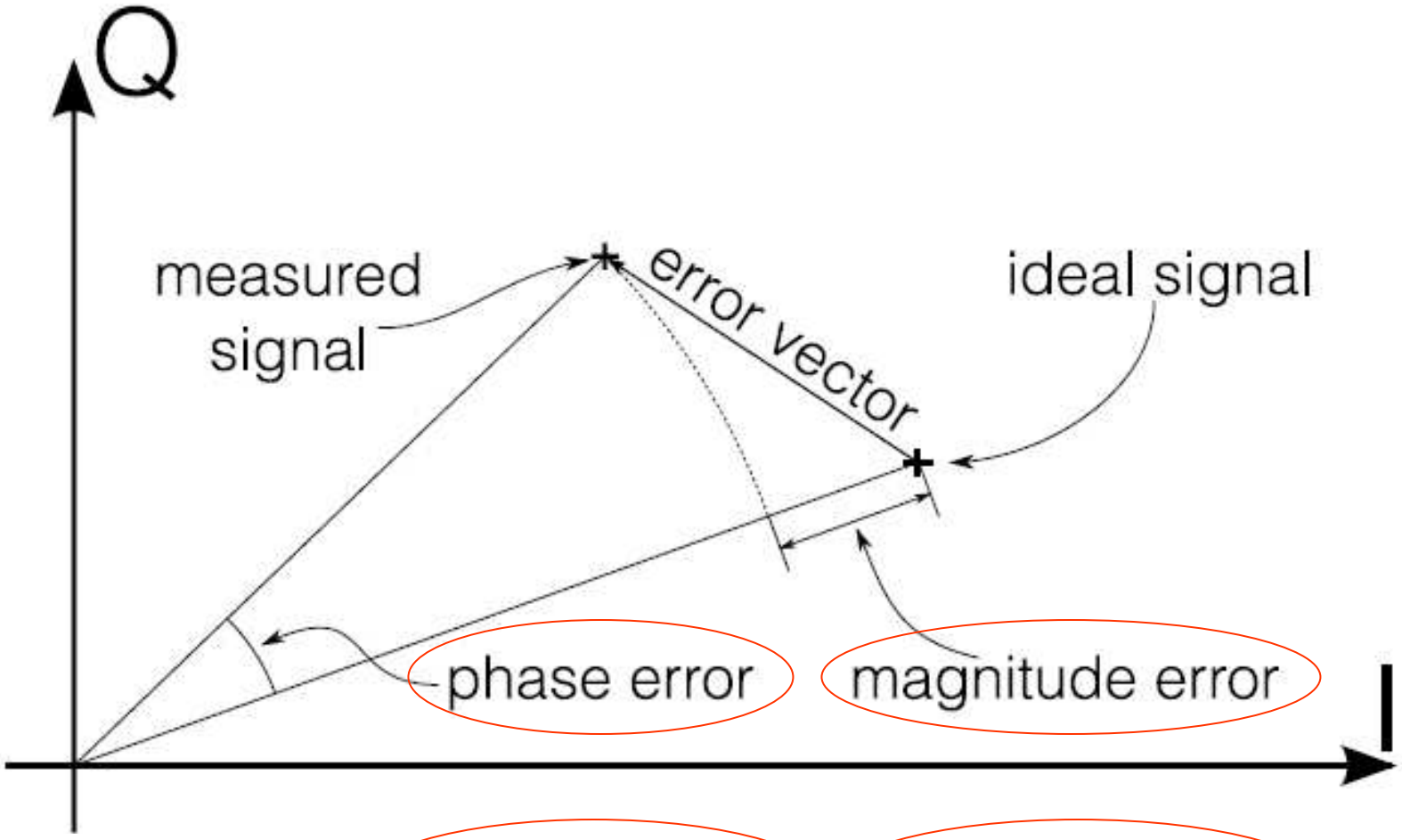

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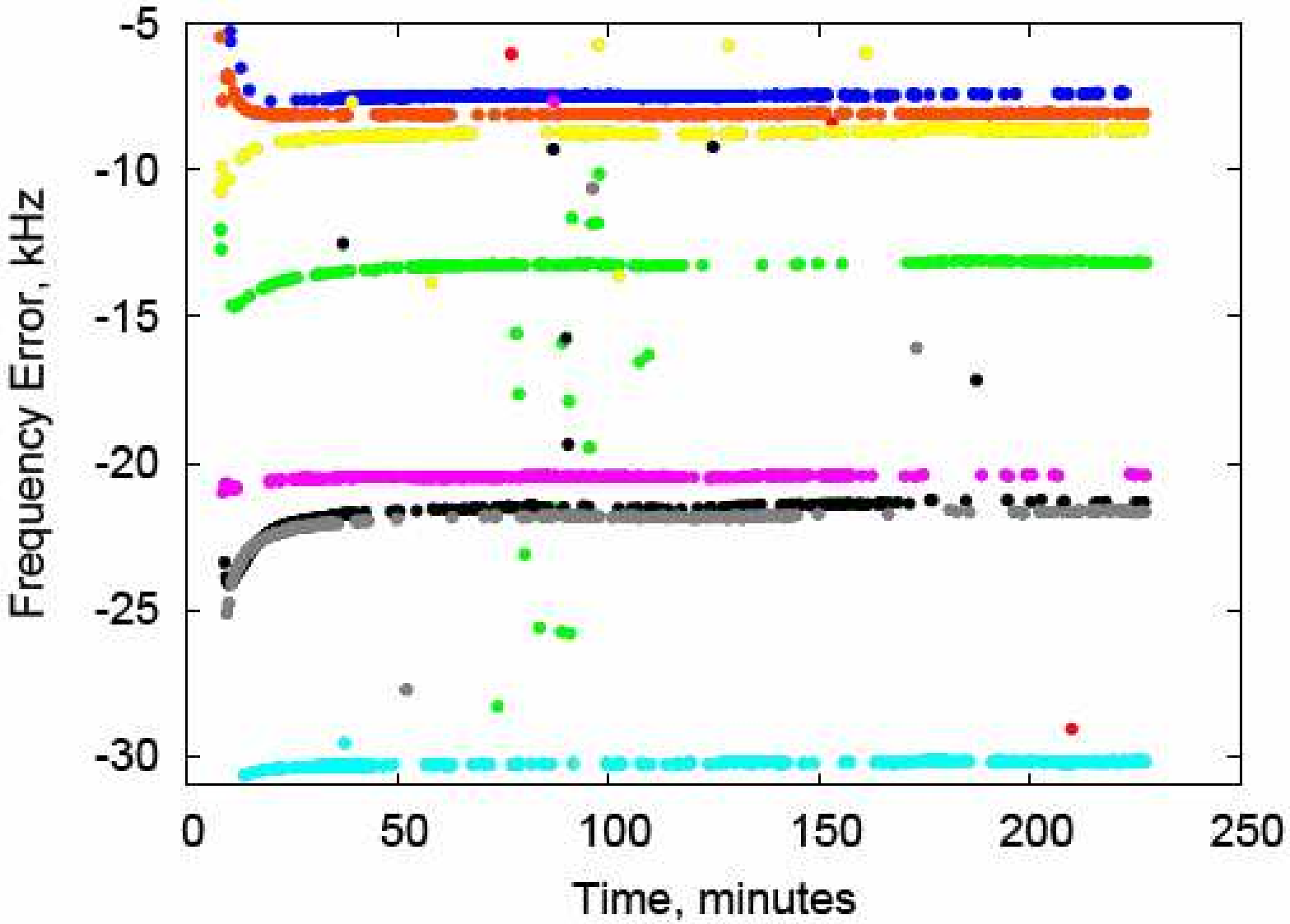
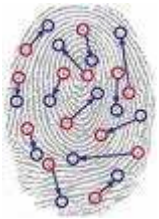
Frame frequency error



Identification overview

- Collect radiometric samples of permitted transmitters



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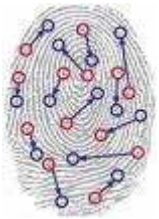
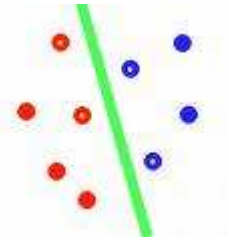


- Build radiometric profiles (models)



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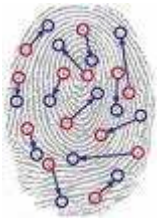

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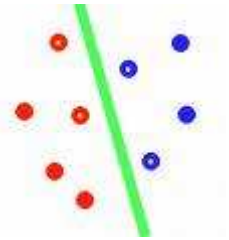

- Use profiles to classify incoming transmissions

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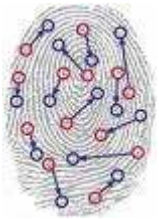

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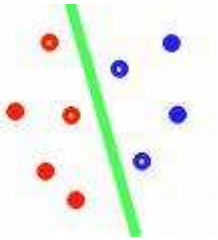
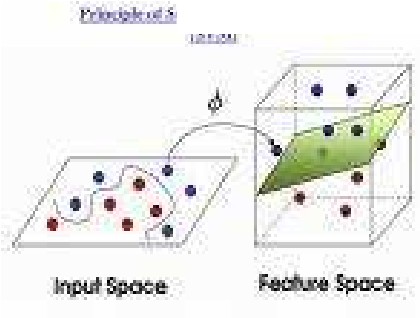


- Use profiles to classify incoming transmissions

- Currently implemented schemes
  - k-Nearest Neighbors (kNN)
  - Support Vector Machines (SVM)



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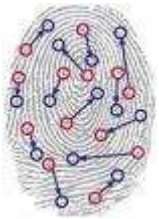

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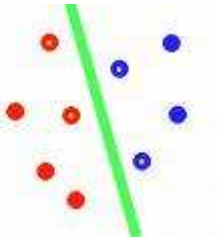

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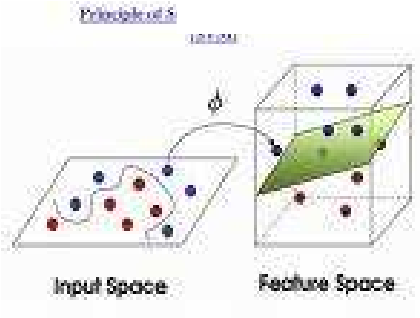
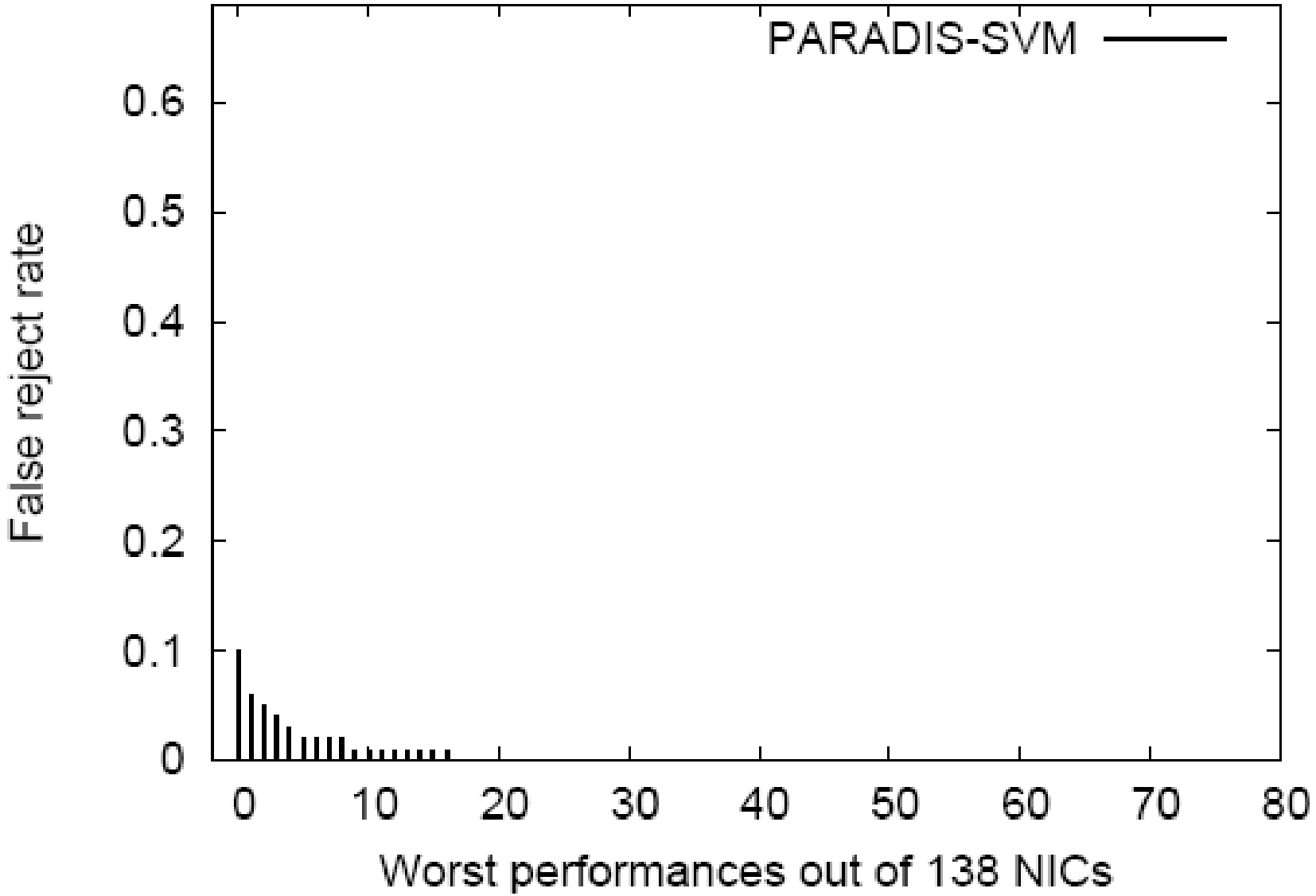


Overall performance

Scheme	NIC pop.	Bin Size	Training fraction	Error reported	Equivalent performance of PARADIS	
					kNN	SVM
Franklin et. al.	17	8	5%	15%	**0%**	**0%**
Hall et. al.	30	10	33%	8%	**0%**	**0%**
PARADIS	138	4	20%	-	**3%**	**0.0034%**

Experimented on ORBIT testbed with identical Atheros-based 802.11 NICs

A more careful look



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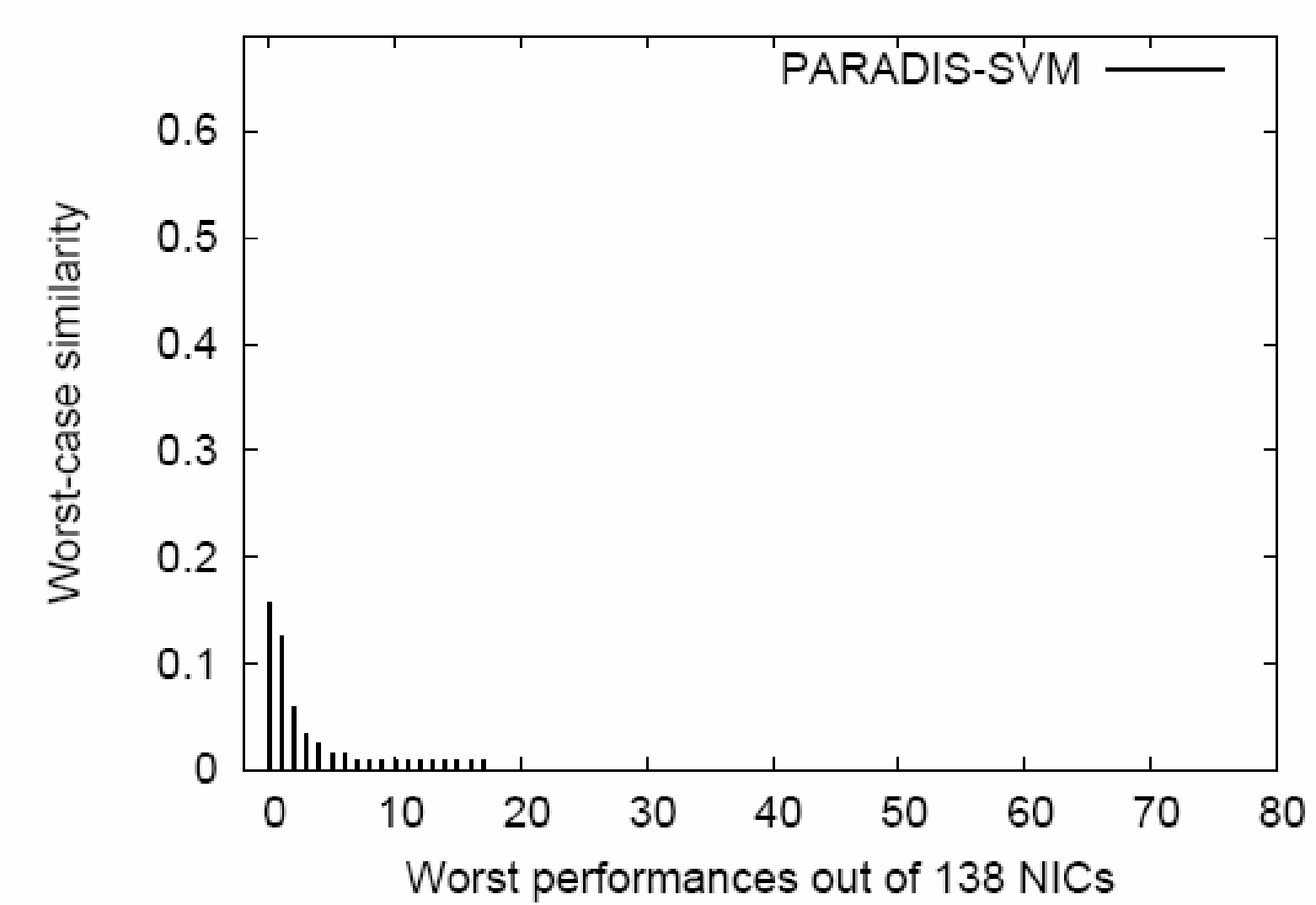
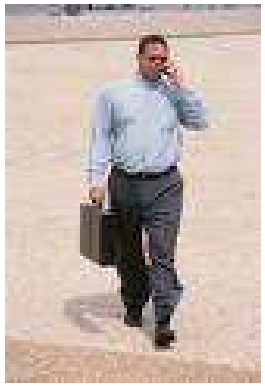


More results

- Designed against **temperature** changes

- Can deal with node **mobility**



- Can handle NIC **aging**

Summary

- Spectrum enforcement may be a critical piece in facilitating dynamic spectrum sharing
- Needs planned hardware and software design
- Requires regulatory processes as well