Metrics and Measurement tools for Estimating Wireless Channel Condition

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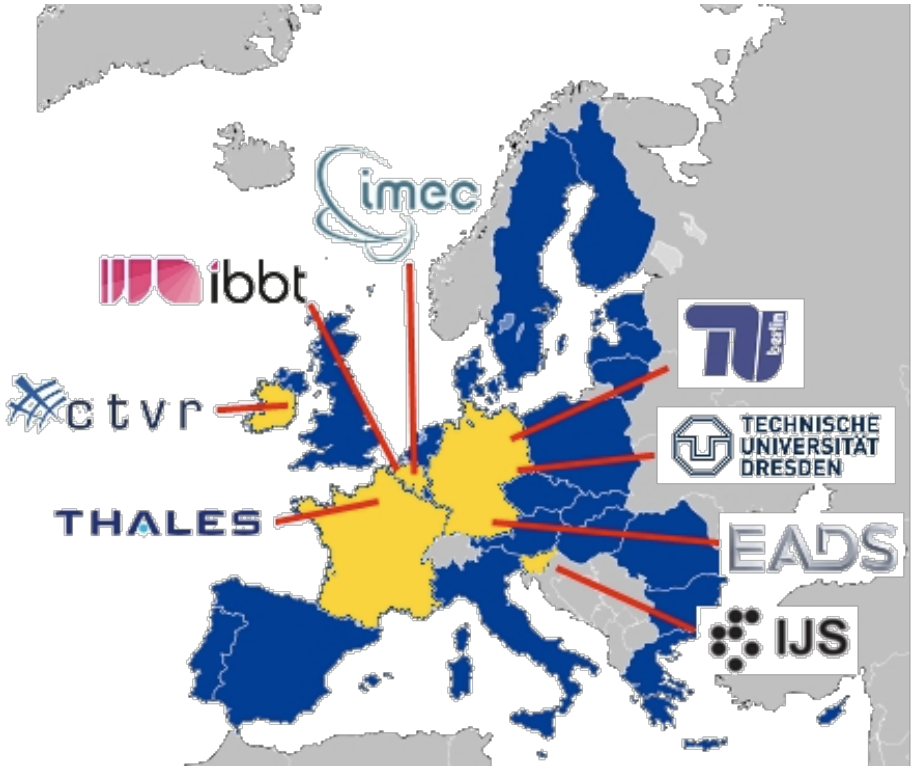
IP CREW: www.crew-project.eu

- **Cognitive Radio Experimentation World**
  - FP7 call 5
  - Project started October 2010
  - 8 core partners
  - 3 experimentation partners

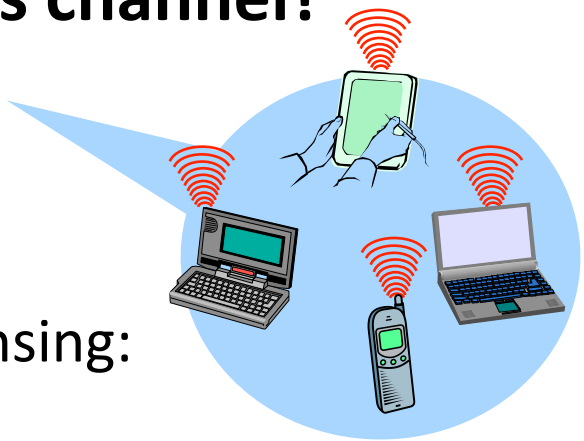
Target: to establish an **open federated test platform**, facilitating experimentally-driven research on

- advanced spectrum sensing
- cognitive radio
- cognitive networking
- spectrum sharing
  in licensed and unlicensed bands



Background

- **Why do we need to assess the wireless channel?**
  - **For cognitive radio solutions**
    - ISM band is getting overcrowded
    - increasing TX power is not a solution
    - cognitive radio demands spectrum sensing:

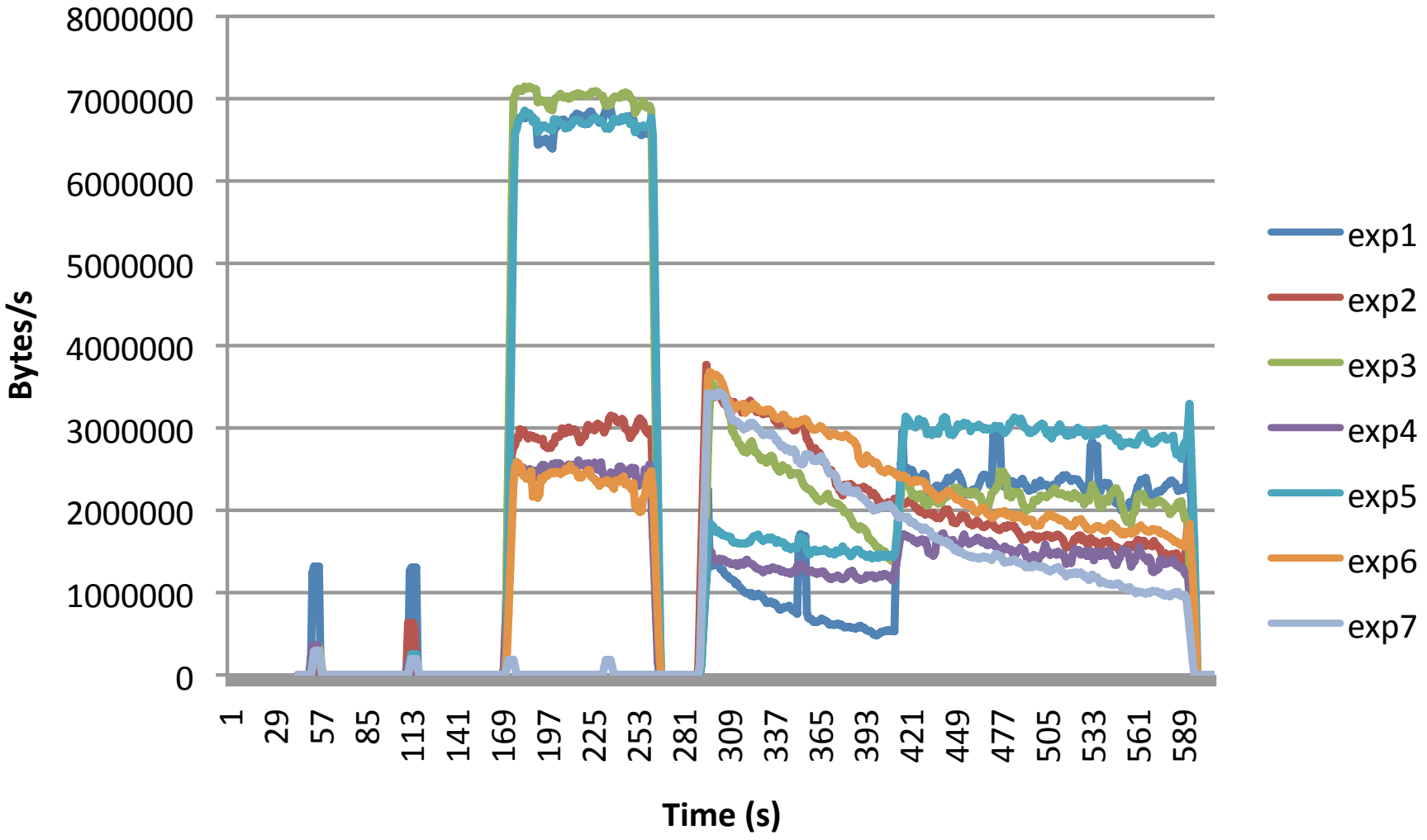


first  and then talk

    - spectrum sensing = part of the cognitive solution
  - **For measurements during wireless experimentation**
    - main issues
      - lack of (external) interference control
      - lack of repeatability
    - spectrum sensing = experimentation tool

Wireless experimentation

- **Problem: repeatability**
  - due to unwanted external interference



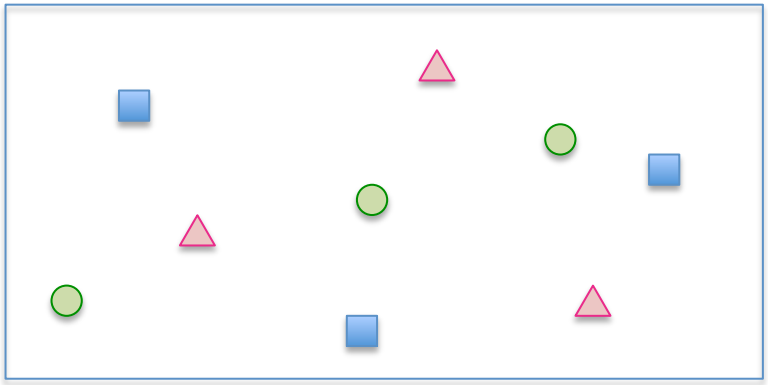
Challenge

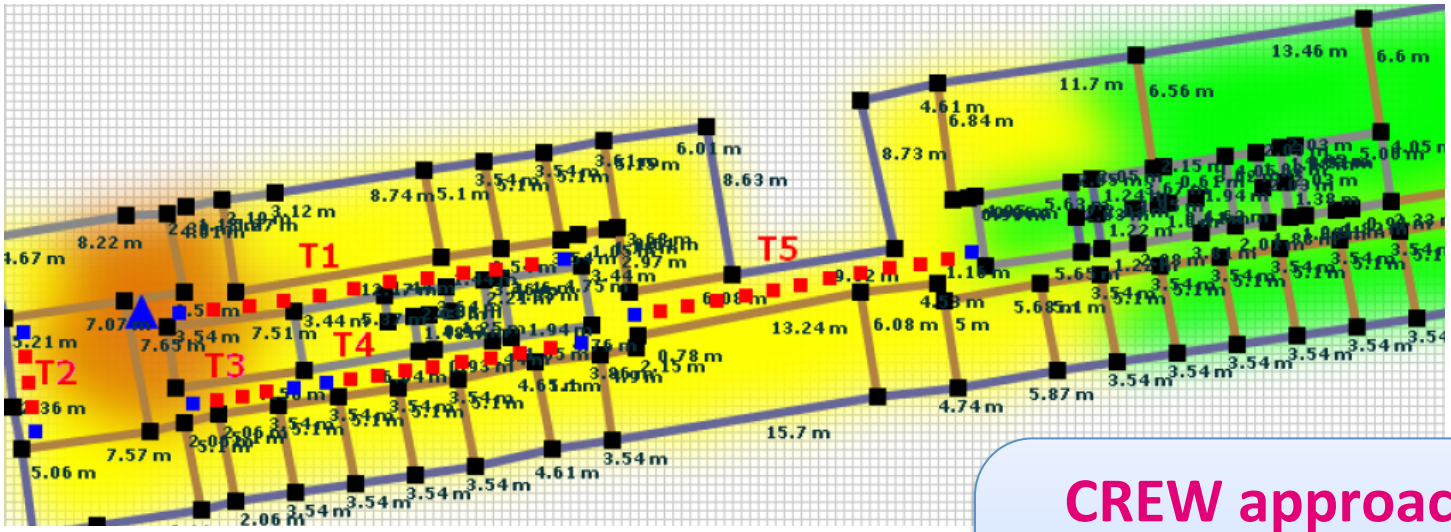
- **Observation**: In real life, channel estimation is achieved by small, portable and heterogeneous devices, in a distributed manner.

- **Challenge**: How to combine the measurement results obtained by heterogeneous devices?

Wireless Channel Estimation

Goal: to establish a dynamic map of power spectrum density (PSD) via distributed heterogeneous devices



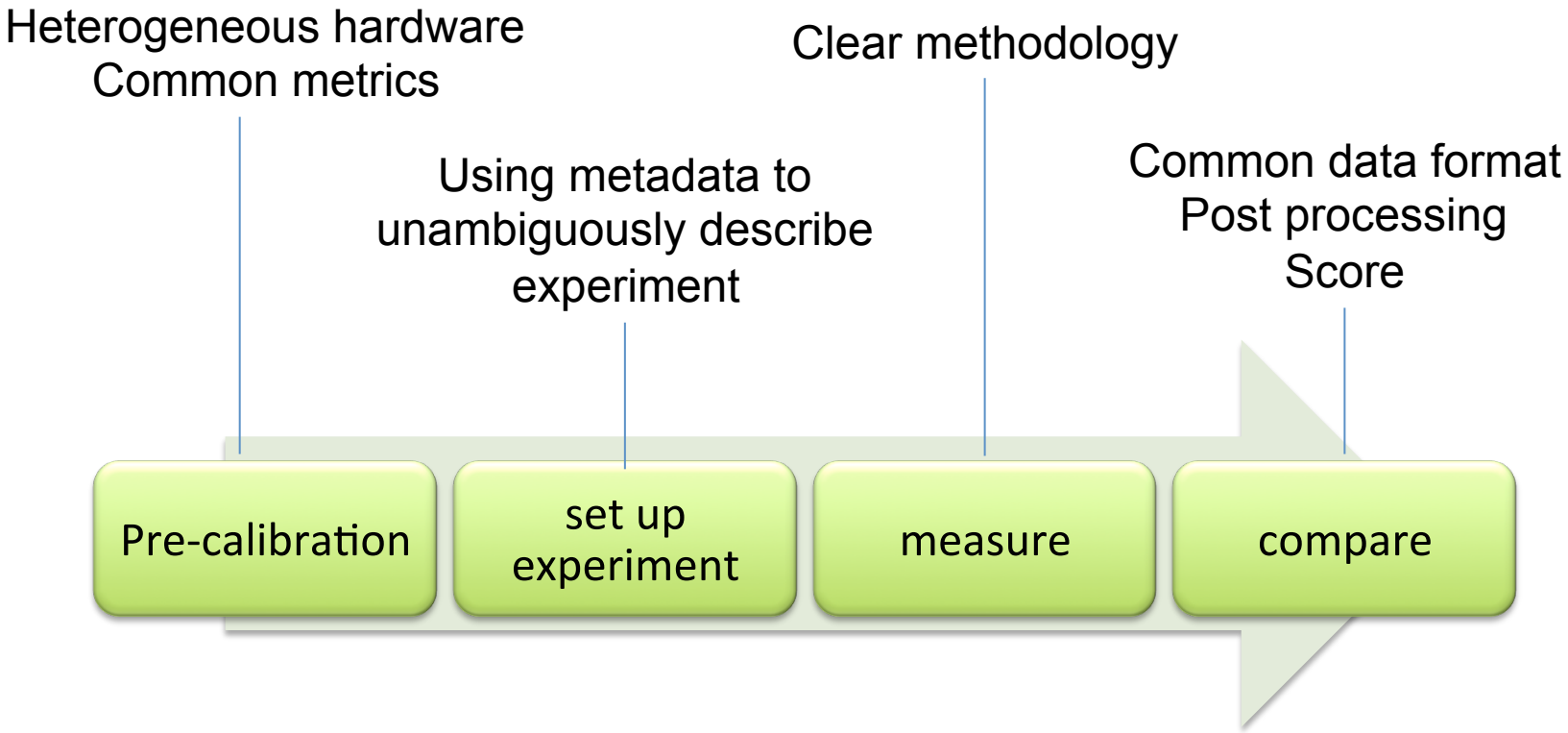


CREW approach

- heterogeneous devices
- common metrics
- benchmarking framework

This presentation

- **CREW benchmarking framework**
- **Benchmarking of heterogeneous CR technology**



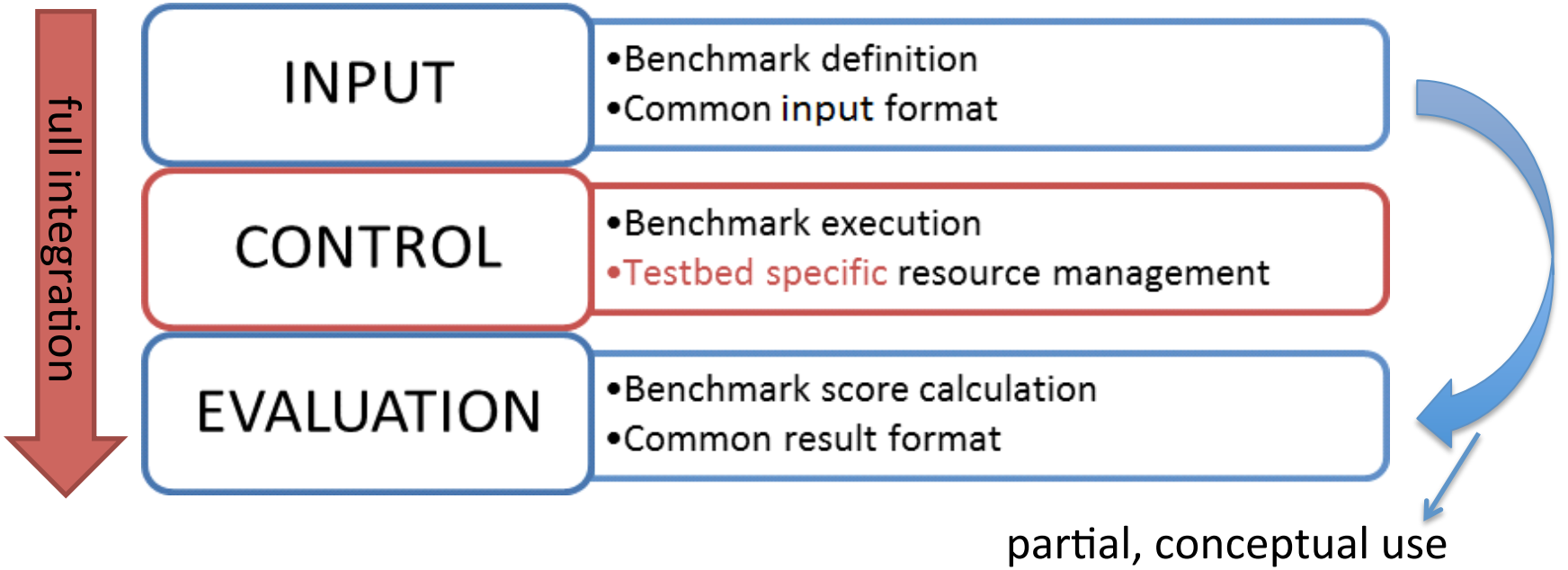
- **Assess wireless channel during experiment**
  - Applying distributed heterogeneous spectrum sensing

CREW benchmarking framework

Benchmarking = the act of measuring and evaluating computational performance, networking protocols, devices and networks, under reference conditions, relative to a reference evaluation

Goal = enable fair comparison between different solutions, or between subsequent developments of a System Under Test (SUT).

High level abstraction



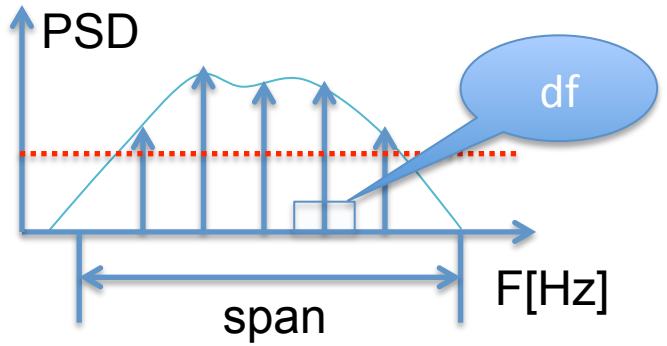
CREW benchmarking terminology

- **Metric =**
  - quantitative measure of a certain quality of the SUT
- **Score =**
  - abstraction of a set of metrics

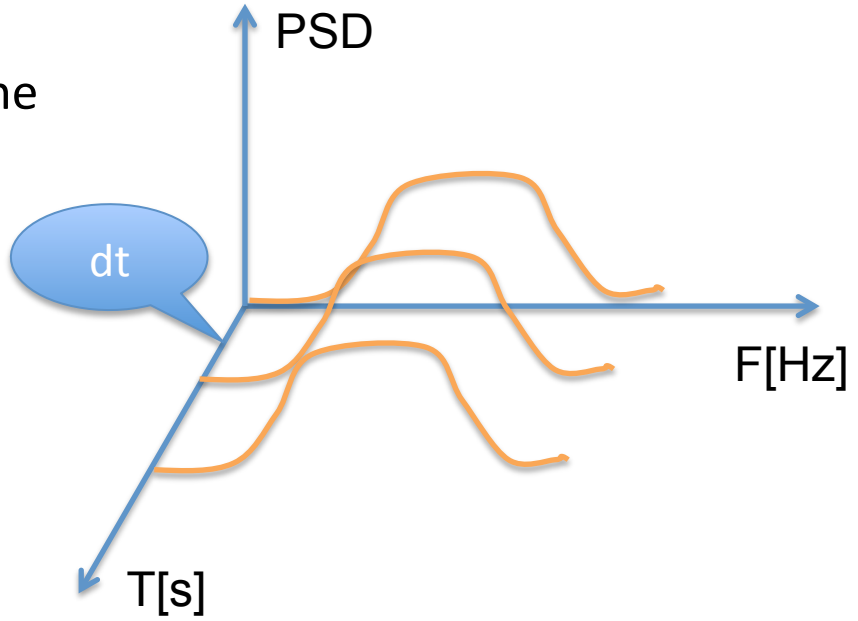
- **Score hides performance evaluation details**
  - use
    - comparing a large number of experiments
    - evaluation of solutions by non-experts
    - automation of performance evaluation

Pre-calibration: common metrics (1)

- **Power spectrum density (PSD)**



  - span
  - resolution bandwidth (df)
  - sweep time
    - actual time used to collect samples for each scan of the entire frequency span
  - time resolution (dt)
    - dt = sweep time + processing time
  - energy detection threshold



Pre-calibration of heterogeneous hardware

- **Spectrum sensing hardware used in CREW**

cost ↗

- TelosB
  - Commercial IEEE 802.15.4 transceiver for sensor network
  - Customized application for sensing

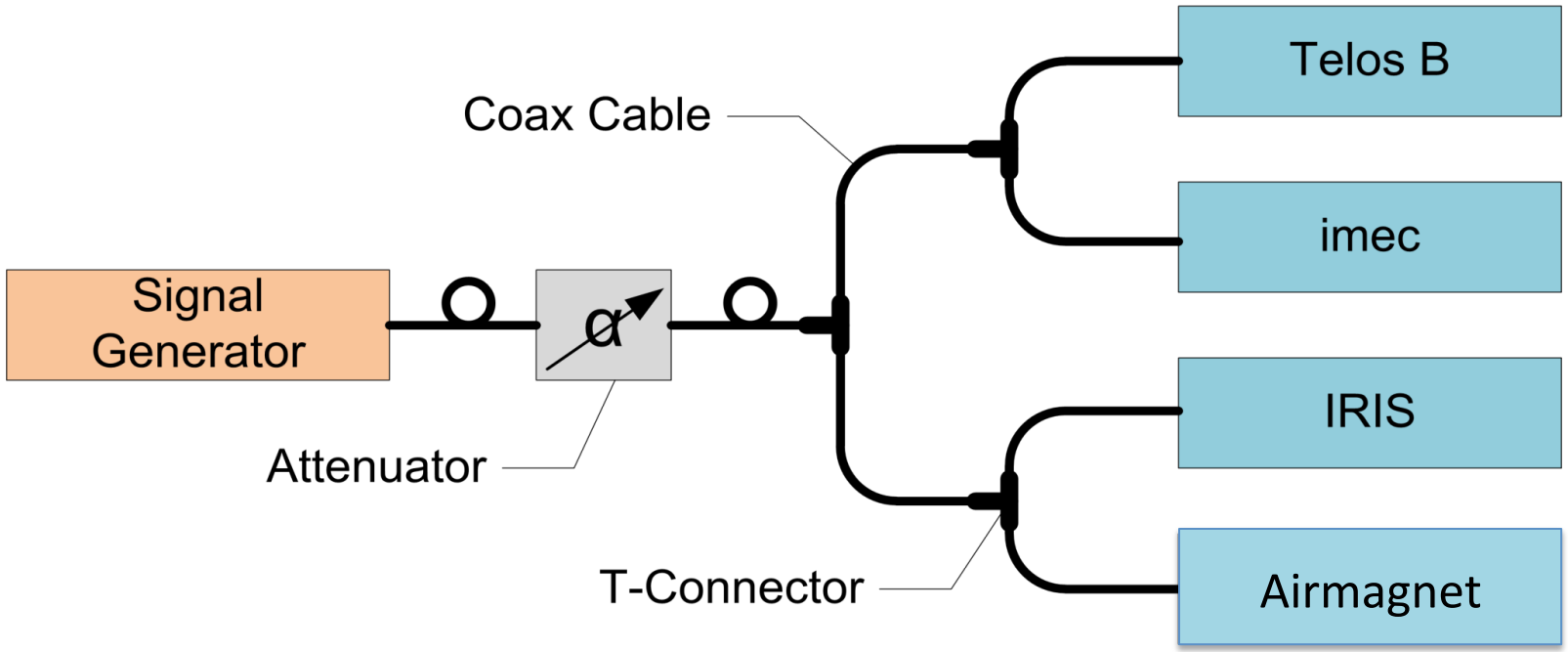
- Airmagnet
  - Commercial USB device from Fluke
  - Bundled software was used to record spectrum activity

- SDR-Iris
  - Universal Software-defined Radio Peripheral
  - Commercial hardware with customized software (Iris platform) for sensing

- IMEC sensing engine
  - Both hardware and software are customized design

Pre-calibration of heterogeneous hardware

- **Compensate for hardware heterogeneity**
  - Power offset refers to the overall signal strength attenuation in the receiver chain
    - Power Offset = TxPower – Attenuation – Measured Power
  - Measure the power offset of different devices with known input signal power for later processing



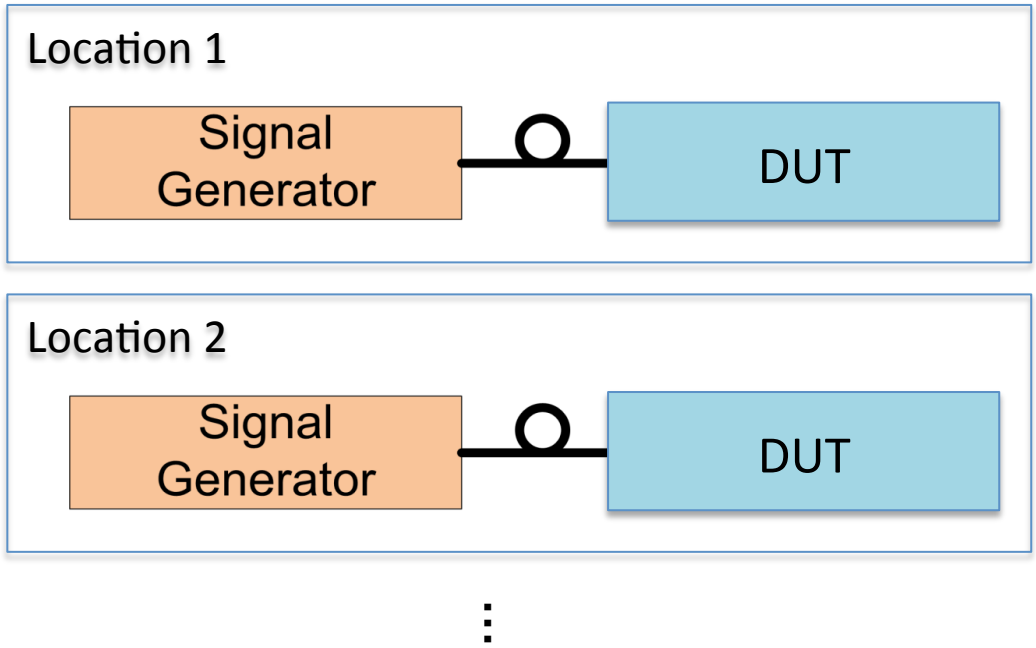
Experiment set-up: metadata

- **Metadata of the experiment**
  - Tx signal pattern, Tx power level, background environment

- **Metadata of each trace**
  - Device name
  - Location of the device
  - Calibration offset (obtained by pre-calibration)
  - Frequency bins
    - Array defining center frequencies of the rows of the power matrix
  - Resolution bandwidth
    - Bandwidth around each center frequency
  - Start time
    - Start time of the experiment
  - Relative time
    - The time stamp of each sweep relative to the start time

Experiment

- **Target**
  - characterization & comparison of heterogeneous spectrum sensing devices
- **Approach**
  - select frequency band (e.g. 2.4 GHz)
  - configure Tx signal (cf. metadata)
  - measure PSD



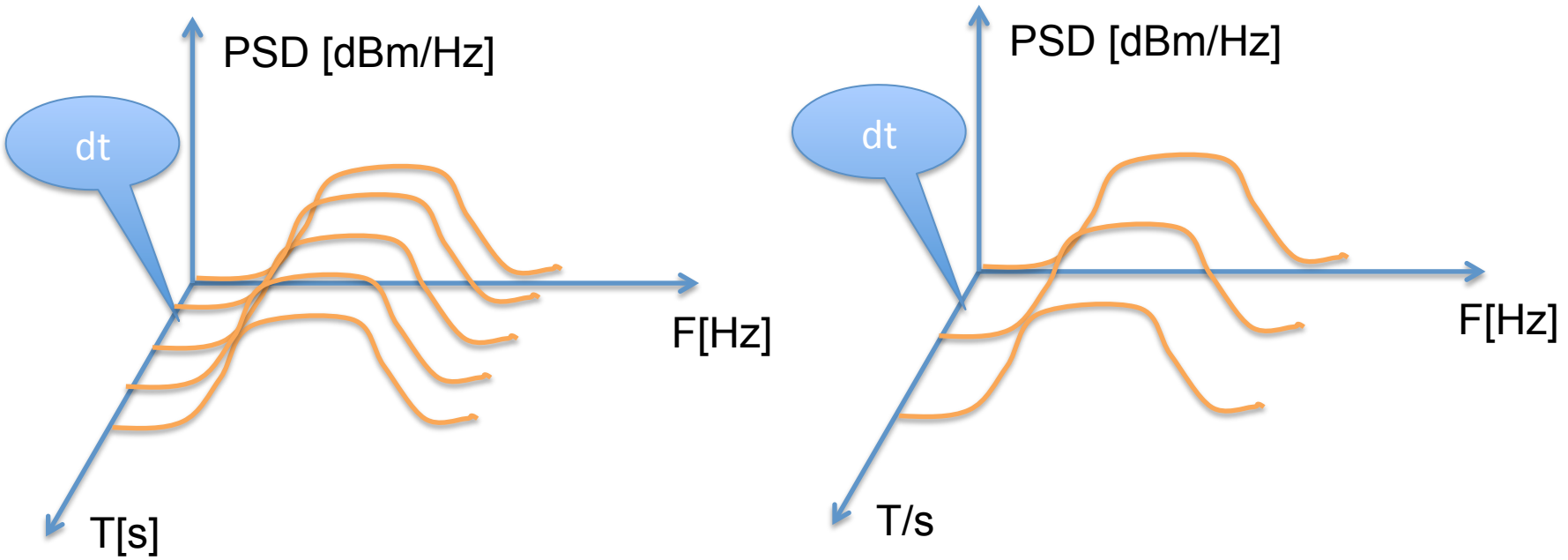
Compare: common data format

- **Data - Power matrix**
  - The matrix containing PSD and relative time stamp.
  - The unit of PSD is dBm/Hz

0	-101	-90	-82	-94	-91	-91	-89
T1	-98	-90	-90	-93	-95	-94	-92
T2	-76	-75	-92	-72	-92	-96	-92
⋮			⋮				

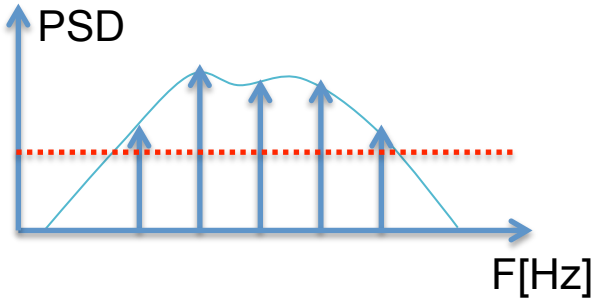
Compare: post-processing

- **Compensate for hardware heterogeneity**
  - calibrate power measurement with the offset obtained in pre-calibration phase
- **Compensate for software heterogeneity**
  - Average / Resample the PSD matrix so all devices have the common reporting rate in time domain



Compare: post-processing

- **Common metrics**

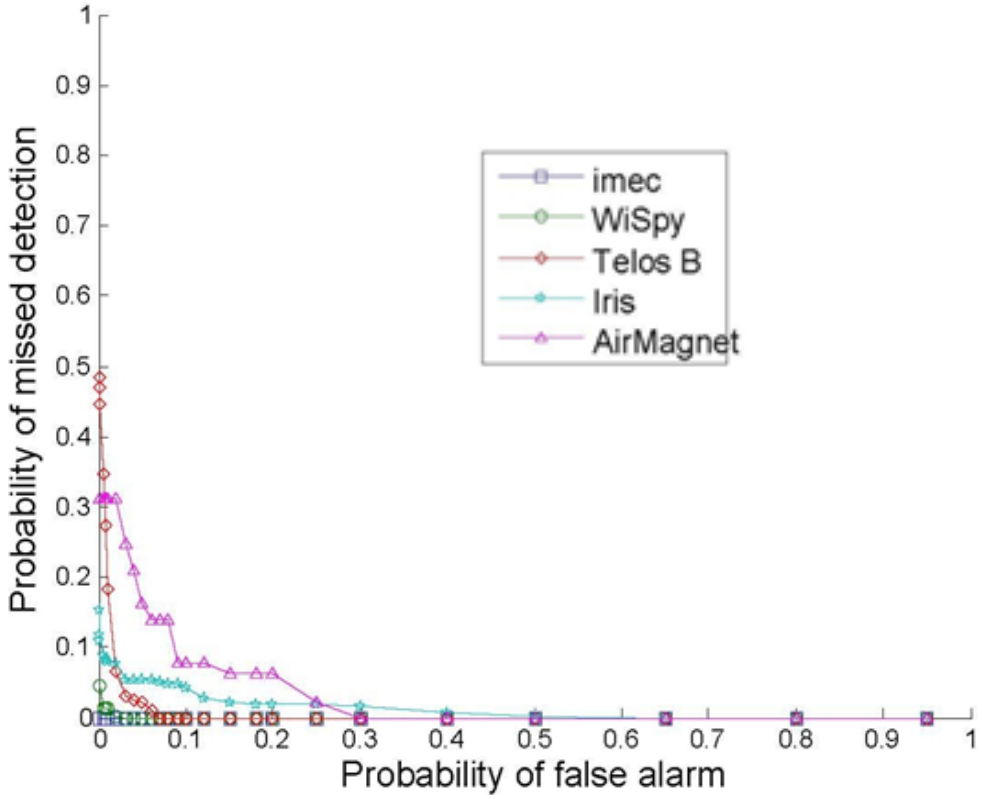


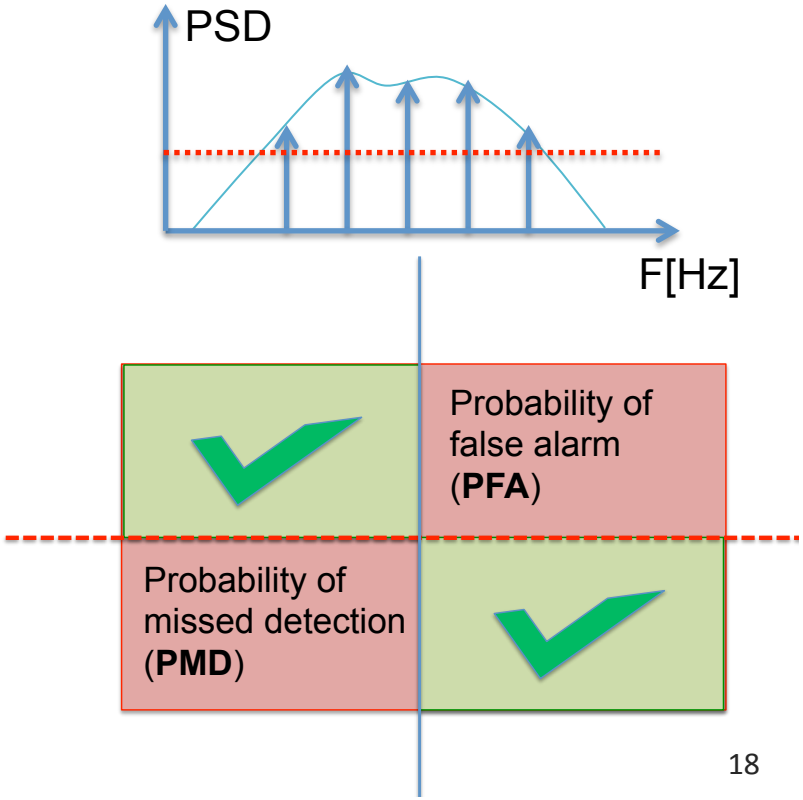
	The fact: signal present	**The fact: signal not present**
Signal detected	Probability of correct detection ✓	Probability of false alarm (**PFA**)
Signal not detected	Probability of missed detection (**PMD**)	Probability of correct detection ✓

Energy Detection Threshold

Compare: post-processing

- **Calculate receiver operation characteristics**
  - Vary probability of false alarm (PFA) from zero to 100%
  - For each PFA, calculate the threshold of energy detection
  - Use this threshold to calculate PMD
  - Obtain the receiver operation characteristic (ROC) plot





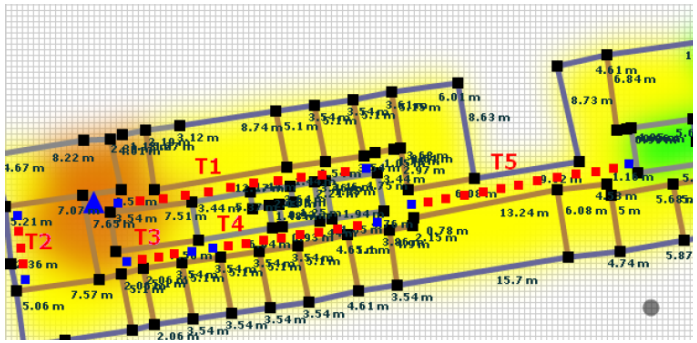
Compare: post-processing

- **Calculate 'performance score' from ROC plots**
  - score heterogeneous devices based on a PFA performance for a required PMD (e.g., 0.05)
  - e.g. SCORE = 10 – 10*PFA

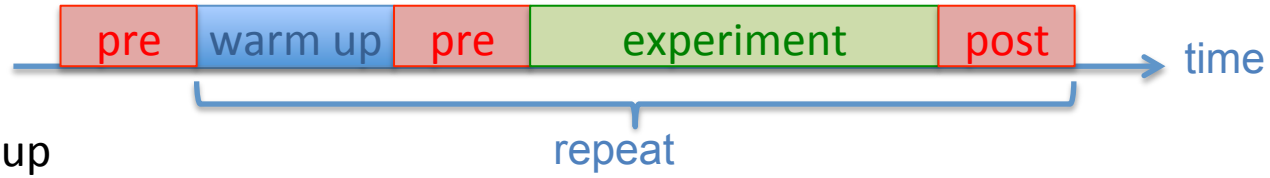
@ PMD 0.1	PFA	SCORE
imec	close to 0	10
Wispy	< 0.01	9.9
TelosB	0.03	9.7
Iris-USRP	0.1	9
Airmagnet	0.22	7.8

Assess wireless channel during experiment

- **Heterogeneous distributed sensing**
  - Collect PSD measurements from (calibrated) geographically distributed sensing devices
  - Analyze spectrum occupation
  - Locate wireless sources



- **Experiment cycle**
  - phases
    - w u warming up
    - pre pre-assessment of wireless environment (create PSD map)
    - exp in situ assessment of wireless environment (create PSD map)
    - post post-assessment of wireless environment (create PSD map)



  - Assess presence of external interference through
    - analysis of pre/post/in situ PSD maps
  - If needed, repeat experiment cycle
    - correlation between subsequent in PSD maps
  - Give global score for validity of experiment
    - Drop experiments with a low score

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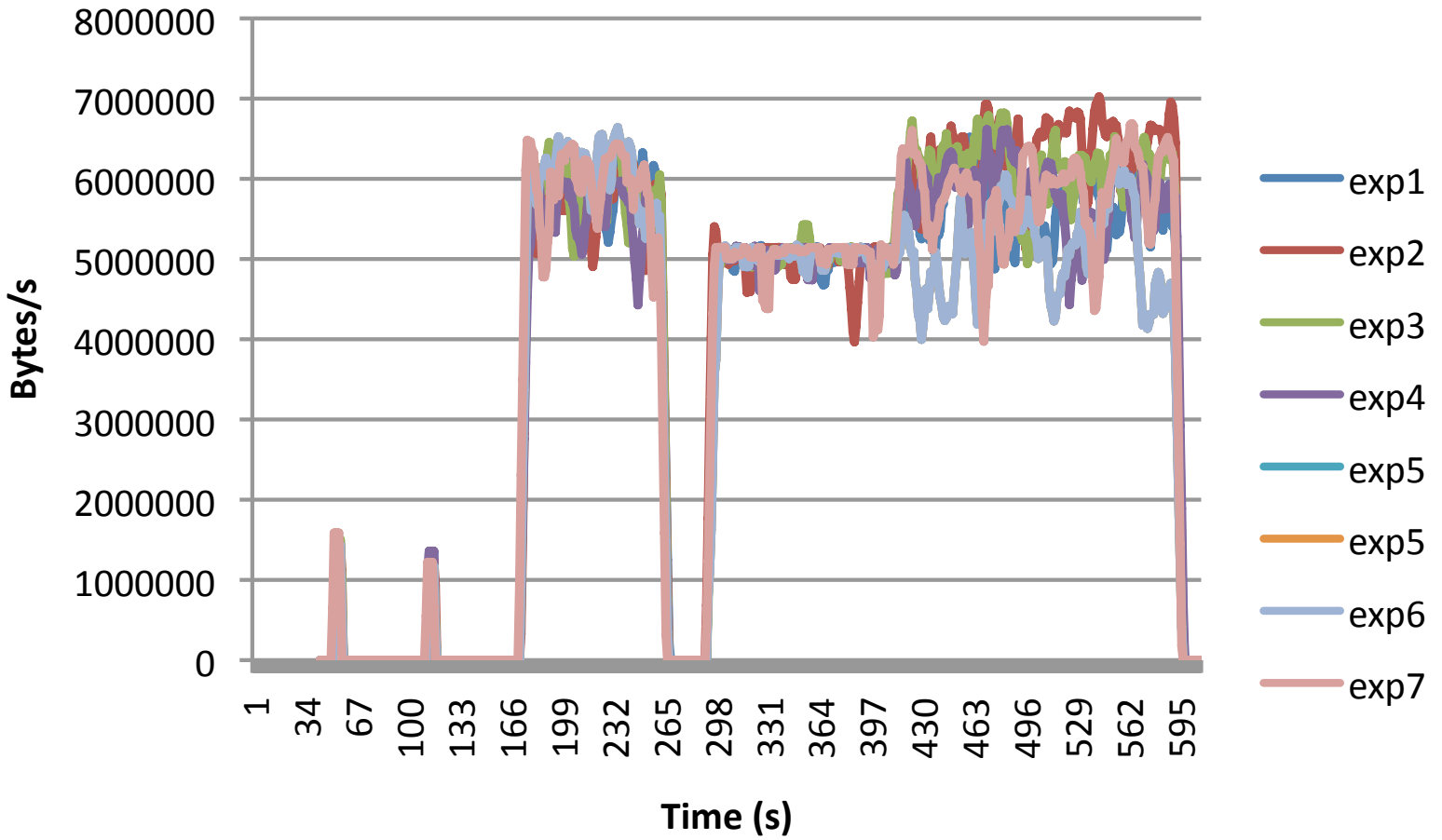
QoExp

Assess wireless channel during experiment

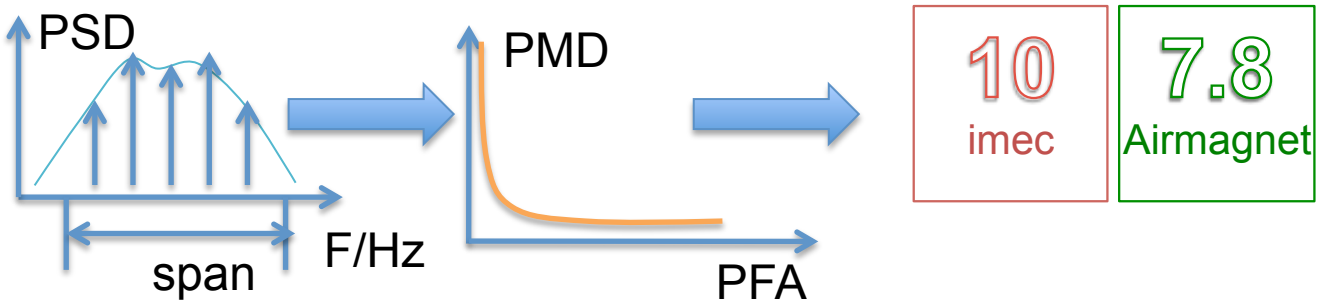
- **Repeatability**
  - experiments with high ‘Quality of Experiment’ score
  - limited impact of unwanted interference

9
QoExp

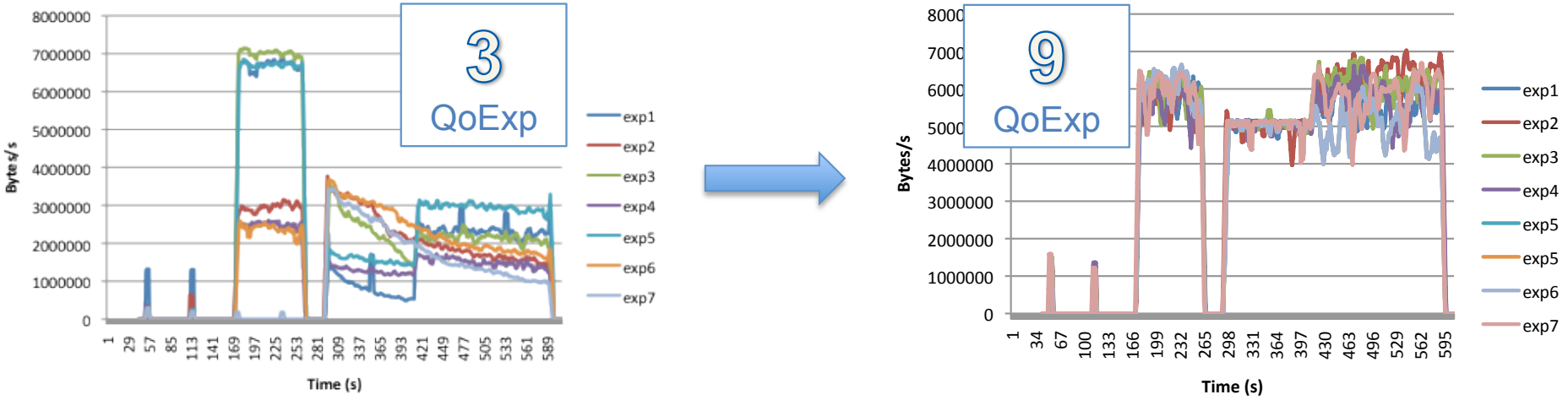


Summary

- **Benchmarking of CR technology**
  - Calibration of heterogeneous devices
  - From low level metrics to abstract score



- **Repeatable experiments due to distributed sensing**
  - pre/in-situ/post assessment of wireless environment
  - detect presence of interference



Thank you!

Q&A

- **CREW open call 2**
  - When?
    - Announcement: @ FuNeMS (4-6 July 2012, Berlin)
    - Submission deadline: September 2012
  - More info
    - http://www.crew-project.eu/
    - Contact for information:

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