Practical testbed demonstration of REM enabled transmitter localization in indoor environments

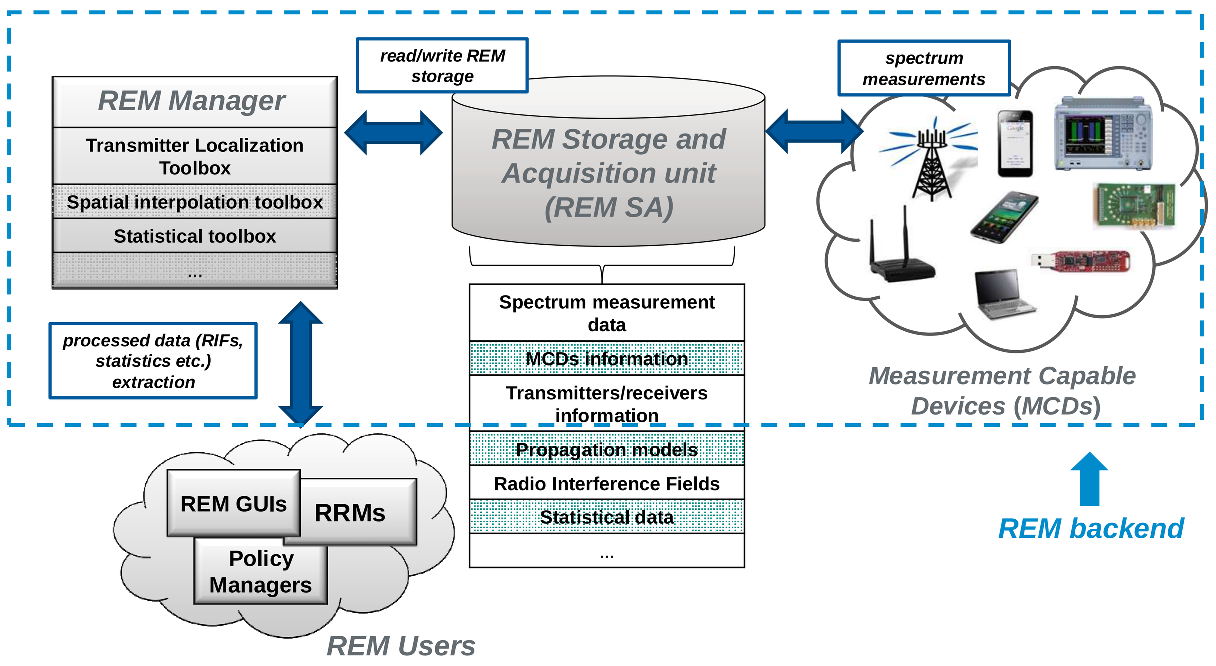
Daniel Denkovski, Marko Angjelichinoski, Vladimir Atanasovski and Liljana Gavrilovska
{danield, markoang, vladimir, liljana}@feit.ukim.edu.mk

Scandinavian workshop on testbed based wireless research
Stockholm, November 27th, 2013

◇ Radio Environmental Maps – General Considerations

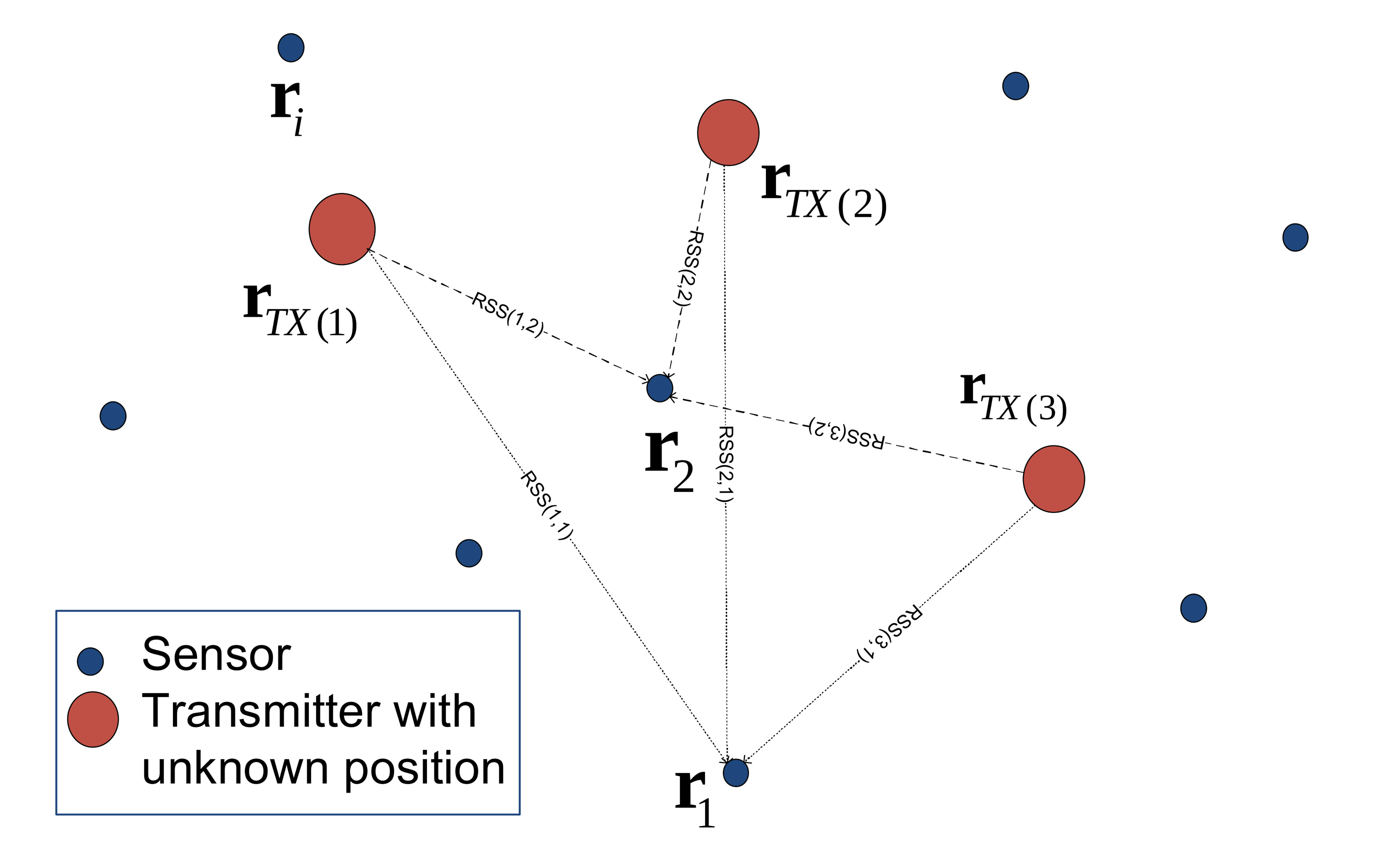
- ❑ Rich **hierarchical database or knowledge base** that stores various kinds of radio environmental information
- ❑ Powerful enabler and/or facilitator of:
  - **Dynamic Spectrum Access (DSA)**
  - Improved **environmental awareness** and **spectral efficiency** of wireless networks

◇ REM Architecture [1]



- ❑ **Measurement Capable Devices** (MCDs) – all network devices capable of performing spectrum measurements
- ❑ **REM Storage and Acquisition unit** (REM SA) – main REM storage entity capable of storing raw and processed data (both static and dynamic)
- ❑ **REM Manager** – responsible for requesting measurements and extracting and processing the data stored in the REM SA
- ❑ **REM Users**

◇ Transmitter Localization Background

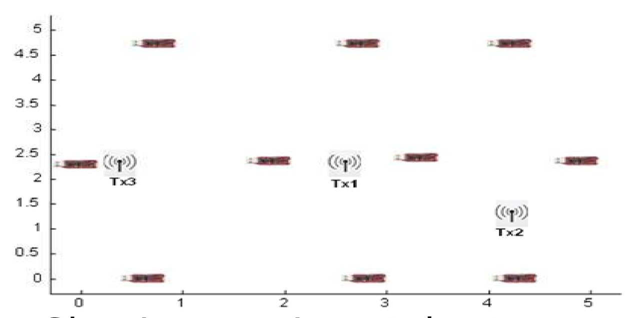


- ❑ Appropriate model for the Received Signal Strength (RSS) should be adopted
  - The model should be parameterized w.r.t. the unknown position(s) of the transmitter(s)
- ❑ **The localization technique should estimate the unknown position(s) of the transmitter(s) using the observed RSS values and the adopted RSS model**

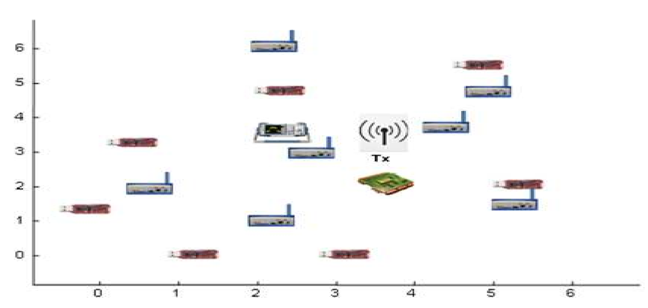
◇ Transmitter Localization Toolbox

REM Manager: Localization Toolbox	Single Transmitter Localization				Multiple Transmitters Localization
	Full Search		Grid Search		Full Search
	Maximum Likelihood	Least Squares [2]	Maximum Likelihood [3]	Least Squares [4]	Expectation Maximization with Gaussian Mixture Model [5]
Assumptions	- Simplified path loss model in log-normal shadowing	- Simplified path loss model	- Simplified path loss model in log-normal shadowing	- Simplified path loss model	- Simplified path loss model under log-normal shadowing - The number of transmitters is unknown - Gaussian Mixture Model (GMM, parameterized w.r.t. the unknown positions and Tx power) is used to model the distribution of received power
Operation	- Maximizes the log-likelihood of the RSS observation vector	- Minimizes the squared difference between the observed and predicted RSS values	- Searches through grid of points and chooses the point that maximizes the likelihood function	- Searches through a grid of points performing LS fitting of the model parameters and minimizes the squared error of the fit	- Estimates the parameters of the GMM by employing iterative Expectation Maximization (EM) approach - Uses Akaike Information Criterion (AIK) or Minimum Description Length (MDL) to determine the number of transmitters
Remarks	- Requires prior channel knowledge - Non-convex problem	- Best Linear Unbiased Estimator - Circumvents the non-convexity problem - Susceptible to the hostile propagation environment	- Complexity increases with the grid size - Simultaneously estimates the propagation model parameters	- Complexity increases with the grid size - Simultaneously estimates the propagation model parameters	- Assumes a dominant transmitter per sensor and achieves complexity that increases linearly with number of sources - Very susceptible to the hostile propagation environment

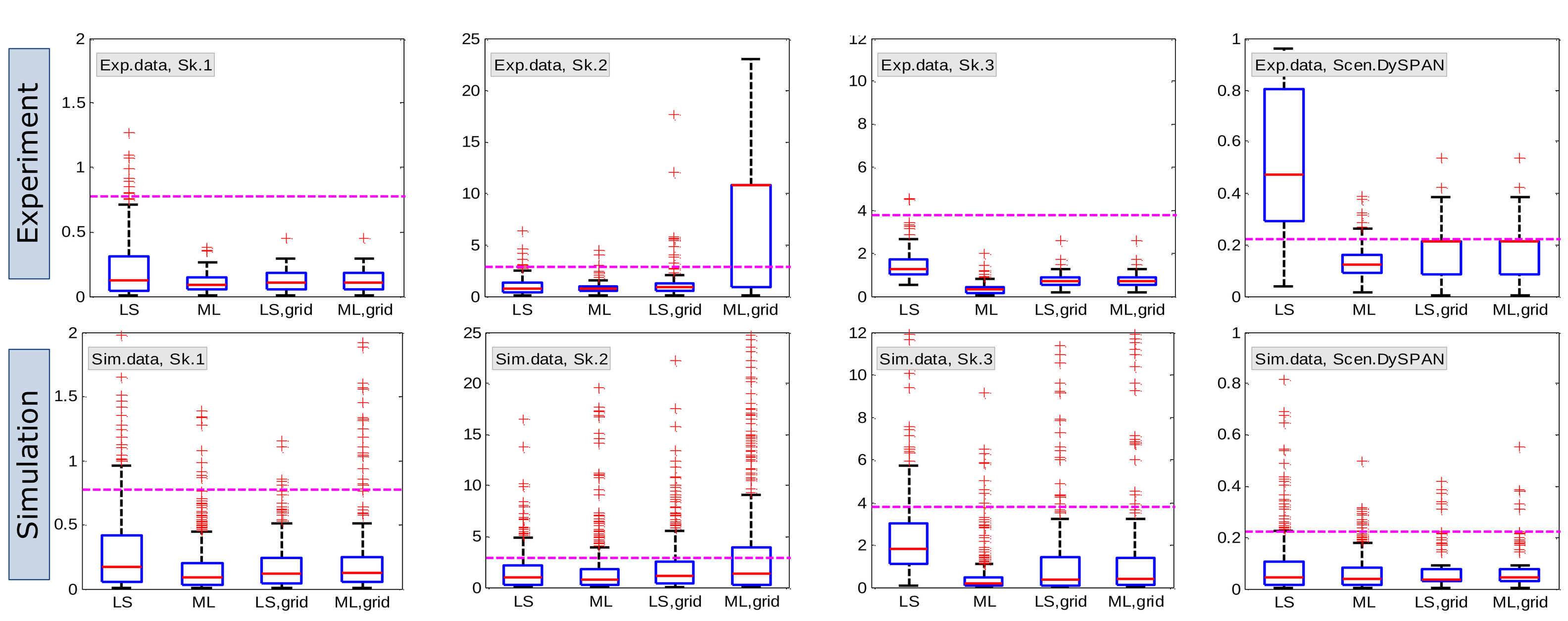
◇ Experimental and Simulation Results



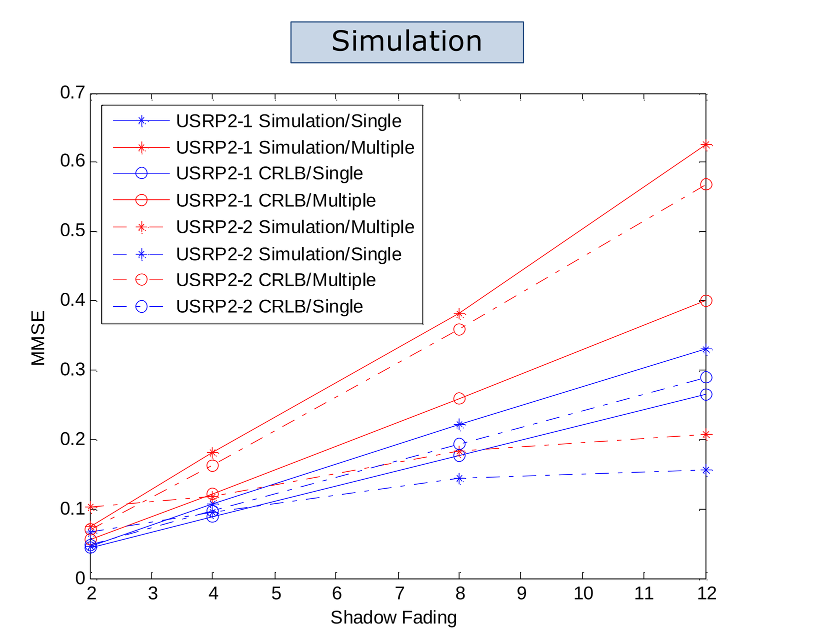
Skopje experimental setup



DySPAN 2011 experimental setup



- **Highest deviation** between simulation/experimental performances experienced in the DySPAN scenario due to the **heterogeneity of the used equipment**.
- The **Least Squares-Grid algorithm** proves to be a **viable solution**



- Performance of the **ML-FS single** transmitter localization and **EM-GMM multiple** transmitter localization algorithms (Skopje setup) and the respective **bounds**

◇ References

[1] V. Atanasovski et al., "Constructing Radio Environment Maps with Heterogeneous Spectrum Sensors," IEEE DySPAN 2011 demonstration, Aachen, Germany, May, 2011. (best demo award).
[2] L. Lin and H. C. So, "Best Linear Unbiased Estimator Algorithm for Received Signal Strength Based Localization," in 2011 Proc. EUSIPCO Conf. 2011, Barcelona, Spain, Sep. 2011.
[3] R. K. Martin, R. Thomas, "Algorithms and Bounds for Estimating Location, Directionality, and Environmental Parameters of Primary Spectrum Users," IEEE Trans. Wireless Comm., vol. 8, n0. 11, pp. 5692-5701, Nov. 2009.
[4] D. Denkovski, M. Angjelicinoski, V. Atanasovski and L. Gavrilovska, "Practical assessment of RSS-based localization in indoor environments," IEEE MILCOM 2012, Orlando, Florida, USA, Oct 29 – Nov 1, 2012.
[5] I. Dagres, A. Poydoros, D. Denkovski, M. Angjelicinoski, V. Atanasovski, and L. Gavrilovska, "Algorithms and Bounds for Energy-based Multi-source Localization in Log-normal Fading," IEEE GLOBECOM 2012 Workshop: Green Internet of Things, Anaheim, California, USA, December, 2012

Ss Cyril and Methodius University in Skopje
Faculty of Electrical Engineering and Information Technologies (FEEIT)

Institute of Telecommunications (ITK)
Wireless Networks Group
http://wingroup.feit.ukim.edu.mk