Hands-on experimentation with cognitive radio enabled systems

(Half Day Technical Tutorial)

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***Abstract*—Scarcity of spectrum is one of the factors limiting the increase of wireless access networks capacity. So, together with high interest in adopting new frequency bands, it is necessary that multiple networks will have to share large parts of the spectrum. Cognitive Radio (CR) principle is a promising way to open the doors for such sharing. While the research in this area is very active, there is an acknowledged issue that the design and execution of real experiments remains very labor and cost intensive. This tutorial will shortly present the existing experimentation facilities. It will show, through hands-on exercises, how to set up and execute simple CR experiments, which will be conducted remotely on the different testbeds during the tutorial.**

I. Tutorial Content

Scarcity of spectrum is one of the factors limiting the increase of wireless access networks capacity. So naturally - in parallel with attempts to go to higher frequencies (e.g. millimeter waves) - there is high interest in adopting new frequency bands to be used by low-cost and omnipresent technologies like WLAN or 4G femtocells. These frequency bands, however, must in many cases be shared with existing users. 5G envisions that multiple technologies and multiple networks will share large parts of the spectrum, not only todays ISM bands.

Cognitive radio principle is a promising way to open the doors for such usage. Still, cognitive wireless networking goes much further than that. The emerging wireless communication system will have to support, besides increasing volume of human generated data traffic, also machine generated traffic from the Internet of Things, the Industry 4.0, the Tactile Internet, the ambient assisted living, etc. Support of time critical as well as delay tolerant traffic, narrow band as well as wide band traffic will have to be assured. Highly dynamic and ad-hoc networks will have to be able to scale to sudden and temporal demand increases.

All these solutions will incorporate to a big extent adoption of cognitive principles. While the research in this area is very active, there is an acknowledged issue that the design and execution of real experiments remains very labor and cost intensive. To mitigate this obstacle we have - in the framework of the Cognitive Radio Experimentation World research project - created a set of testbeds that highly facilitate experimentation with cognitive radio based systems. A short presentation of the existing facilities is available on the project's portal[1].

The key feature of this infrastructure (besides of the availability of the proper equipment) is a carefully developed control plane allowing centralized - and even remote! - setting up of the experiments and measurements, and executing the experiments in an automated way. These facilities have been opened to experimenters from outside, and several successful experiments documented in research papers have already been executed[2]. The experimental cognitive radio community is growing, the testbeds supporting over 100 external users according to the available statistics.

While the usage of the facilities has proven to be very productive in the sense that the effort to set up and execute the experiment has been dramatically shortened, researchers and educators who are interested in experimentation with cognitive radio systems should have an understanding of:

- How experiments with cognitive radio systems should be designed?
- How to use the available testbed facilities?
- What are the typical mistakes made while setting up cognitive radio experiments?

The tutorial will address the above issues by set of presentations and hands-on exercises.

II. Structure of the Tutorial

The tutorial will start with the lecture style giving the introduction to the following topics:

- Problems and challenges in existing and next generation wireless networks
  - From spectrum scarcity to shared spectrum
- Dynamic Spectrum Access (DSA) models
  - From spectrum regulation to spectrum access models
  - From coexistence to cooperation
- Cognitive radio vs full-cognitive radio

[1] http://www.crew-project.eu/portal
[2] http://www.crew-project.eu/biblio

    - Examples of simple problem formulations
- Challenges in preparation of CR experiments
- What types of spectrum sharing experiments can be carried out in CREW testbeds?
    - Discussion of the steps: from the problem formulation to experiment results

Next the CREW experimentation facilities will be explained through **hands-on exercises** where attendees can set up their own simple CR experiments. These experiments illustrate different CR use cases and will be conducted remotely on the different CREW experimentation facilities. The following simple CR examples with audience interaction are targeted:

- GNU radio / IRIS on USRP in w-iLab.t
- TinyOS on TelosBs in TWIST
- VESNA in LOG-a-TEC

III. Instructors

The leading instructor will be supported by three other persons due to their deep familiarity with the details of the individual testbeds, and in order to assure more direct instructor - participants contact during the hands-on part.

Luiz A. DaSilva (lead instructor): holds the chair of Telecommunications at Trinity College Dublin, Ireland. He also holds a research appointment in the Bradley Department of Electrical and Computer Engineering at Virginia Tech, USA, where he was a tenured/tenure-track faculty member from 1998 to 2014. His research focuses on distributed and adaptive resource management in wireless networks, and in particular wireless resource sharing, dynamic spectrum access, and the application of game theory to wireless networks. Prof. DaSilva is currently a principal investigator on research projects funded by the National Science Foundation in the United States, the Science Foundation Ireland, and the European Commission under Horizon 2020 and Framework Programme 7. He is a co-principal investigator of CONNECT, the Telecommunications Research Centre in Ireland. He is an IEEE Communications Society Distinguished Lecturer (2015-2016).

Mikolaj Chwalisz: received his Master of Science degrees in electrical and computer engineering from the Warsaw University of Technology and in computer engineering from the Technische Universität Berlin in 2011 and is currently a senior PhD student at the Telecommunication Networks Group at Technische Universität Berlin, working in the area of the Cognitive Radio networks. His research focus is on coexistence and cooperation of heterogeneous wireless networks and is the lead architect behind the implementation of Connectivity Brokerage system. He is actively involved in European and German founded projects working on experimentally-driven solutions and testbed orchestration. He has experience in organizing award winning demonstrations and tutorials on conferences and for general public.

Wei Liu: received her master's degree of Electronic Engineering in 2010, and is currently a final year PhD student at Internet Based Communication Networks and Services research group of University Ghent - iMinds. She specializes in experimental-driven solutions of spectrum sensing for Cognitive Radio technology, and is familiar with several Software Defined Radio (SDR) platforms as well as some commercial off-the-shelf wireless devices. She is actively involved in European projects and has successfully organized two tutorials for using SDR devices on remote testbed and other network lab sessions for students.

Adnan Bekan: (B.Sc. ElecEng, University of Tuzla, 2012) is a visiting research assistant at the Department of Communication Systems at the Jožef Stefan Institute, Ljubljana, Slovenia since 2012 and he is a Master student at the Jožef Stefan International Postgraduate School. In his position he has actively participated in FP7 projects CREW and Fed4FIRE, focusing on activities based on low-power and lossy networks. His main research interests are network protocols and architecture of the wireless sensors networks and applications for the Internet of Things.

IV. Intended Audience

This tutorial is targeted at all researchers and educators interested in experimental, testbed-based work with cognitive radio systems. It does not require prior experience with particular hardware or software. It requires general familiarity with wireless communications systems.

Professional profiles expected to be interested in the topic are:

- Researchers and practitioners who are unfamiliar with the topic, and would like to understand the basics of either remote test facilities or the concept of cognitive radio.
- Researchers and practitioners who are experienced with CR technologies, but wish to find more inspiration of certain CR components (i.e. spectrum sensing modules) and explore more possibilities for CR implementation in both software and hardware aspects.
- Researchers and practitioners who wish to use the remote test facilities covered in this tutorial for any types of experiments.
- General audience interested in possibilities offered by remote test facilities, including the capability of large scale testing and the flexibilities of configuration.

V. Previous Editions

This is the first edition of the tutorial. Instructors have however organized already two editions of CREW (Cognitive Radio Experimentation World) training days[3] in which researchers who wanted to experiment on the emerging (not yet completely instrumented!) testbeds have been trained on how to get started and use the testbeds.

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[3] http://www.crew-project.eu/trainingdays2014