

## FINAL REPORT

| PROJECT INFORMATION  |  |               |                      |
|--|--|---------------|----------------------|
| Project Title:   | Wireless Communications and Networking Research Cloud (WCNRC)<br>بيئة سحابية لأبحاث الاتصالات والشبكات اللاسلكية |               |                      |
| Project Code:  |  |               |                      |
| Start Date:  | October 2014   | End Date:     | September 2016       |
| Project Budget:  | 1,346,760  | Equipments:   | 653,000              |
| Milestone No.  | 4  | Project Type: | Applied              |
| Funded Cycle   |  |               |                      |
| PRINCIPLE INVESTIGATOR (PI) INFORMATION  |  |               |                      |
| Name:  | Mustafa ElNainay   |               |                      |
| Institute:   | Alexandria University  |               |                      |
| Faculty:   | Engineering  | Department:   | Computer and Systems |
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| <b>PROJECT DESCRIPTION</b>   |  |               |                      |
| <p>The long term goal of this proposal is to build a Wireless Communications and Networking Research Cloud (WCNRC) to enable a world-wide collaborative environment for wireless communications research in general, and cognitive radio research in particular, that eases the deployment and testing of protocols at different layers of the protocol stack. The focus of this proposal is to build a wireless testbed that has a scalable and modular architecture with full experimental protocol stack that enable web/remote access to the testbed to facilitate research experiments in the field of cognitive radio networks especially for Egyptian researchers and practitioners. During the first phase, USRP-based software defined radio nodes connected to wifi-enabled mini-desktops will be installed and integrated with our developed full stack testing framework. Powerful servers will be used to host different front-end and back-end testbed components. Different software and hardware components will be developed and installed to enable the testbed planned features and functionalities. Some components may be implemented using existing open source frameworks/tools/software for potential future integration with other worldwide testbeds. However, several research challenges still need to be addressed including optimal utilization of the testbed resources, non-conflict scheduling of parallel experiments, real-time measurements and control for dynamic experiments, multi-testbed inter-operability, realistic mobility emulation and management, malicious user detection, efficient operating system image swapping and transfer, among others will be investigated in this project. Such a testbed will allow a wide set of applications and will have a huge impact on different sectors of the society, not only in Egypt, but through the region and internationally.</p> |  |               |                      |

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### A. MARKET/NTRA IMPACT

The project can benefit the NTRA on multiple fronts including testing new policies and protocols on actual hardware (rather than through simulations, which leads to more accurate and reliable results that reflect reality better), investigating different technologies interoperability, evaluating other NTRA-funded research projects outcomes on the testbed for credible evaluation, and facilitating the engagement between NTRA with different IT sectors and International organizations on mutual development and testing of International standards. These can be used in policy determination and regulation as well as international spectrum co-existence studies. The proposed testbed can also speed the time-to prototype for specific protocols and prototypes, allowing for quicker decisions.

The testbed can also be used to support all funded projects through the NTRA Research and Development Division, reducing the cost and time of acquiring equipment, helping in solving one of the main challenges of research funds in Egypt (delay in acquiring equipment) increasing the success rate of the funded projects and sharing resources allowing for accommodating more projects with the same budget. This also applies for funded graduation projects.

The project will also enhance the students' understanding of key networking concepts at different layers of the protocol stack on actual hardware with its easy-to-use GUI. In addition, it will produce better-trained students that have exposure to real hardware. The planned training and competitions will add more positively to this aspect and will increase the interest of students in the networking and spectrum sharing work as well as research. This pool of talented graduates is a hiring gold mine for NTRA, universities, research labs, and industry.

Finally, the intellectual merit and broader impact generated by this project will give visibility to NTRA among the international regulatory authorities, allowing for a bigger impact in the ITU meetings.

### B. TECHNICAL STATUS

**BRIEF DESCRIPTION OF THE TECHNICAL PROGRESS, SIMULATION MODELS/ALGORITHMS, PROTOTYPES, TRIALS/IMPLEMENTATIONS, ...**

The CRC testbed is designed to serve both research and education. For researchers, it enables them to test their work either as a simulation or using real hardware. For education, it gives students the opportunity to gain a hands-on experience with the concepts they study in communications and networking courses. It also provides an intuitive interface that enables easy management of labs for instructors. The controller server runs all the software used for the administration of the testbed. The simulation server provides users with computational resources along with preinstalled simulation tools. Testbed nodes provide access to wireless interfaces. The web portal and the SSH (Secure shell) are used to provide access to users according to their permissions, whether they are researchers, instructors or students. The portal additionally provides interfaces for the scheduler which is used to grant or deny users' requests according to resource availability. An authentication module enforces the scheduler decisions by banning unauthorized users from accessing the testbed. Once a request has been granted, the user can use

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the existing tools; the experiment controller, disk imaging or topology control. Other features like mobile nodes and the mobility control software, the node emulation and the support of integration with other testbed will be added in later stages of the project.

In addition to building and integrating the testbed nodes and simulation server with testbed management framework and developed portal, several workshops have been organized to publicize the testbed, training sessions are planned to teams of 4 Universities and a competition will be held during August among those teams.

### C. DEVELOPED/MASTERED HW/SW TOOLS

**BRIEF DESCRIPTION OF ANY TOOLS THAT HAVE BEEN DEVELOPED OR PRACTICED BY THE TEAM MEMBERS (E.G., NS2, OPNET, DRIVER PROGRAMMING, USRP,... )**

- ORBIT MANAGEMENT FRAMEWORK (OMF) TESTBED FRAMEWORK
- OMF SCRIPT LANGUAGE
- USRP WITH GNURADIO AND LABVIEW
- MATLAB
- NS2 AND NS3

### D. QUANTITATIVE OUTCOMES

SUCH AS PAPERS, PATENTS, THESES,....

#### I. PAPERS

1. Arsany Guirguis, Raymond Guirguis, and Moustafa Youssef, "Primary User-aware Network Coding for Multi-hop Cognitive Radio Networks", *IEEE GlobeCom - Cognitive Radio and Networks Symposium*, Austin, TX, USA, 8-12 Dec. 2014.
2. Mariam Nabil, Mustafa ElNainay, and Mohamed Rizk, "TV Signal Classification using Fuzzy Inference Fusion," *IEEE International Conference on Computing, Networking and Communications 2015 (ICNC 2015), Workshop on Computing, Networking and Communications (CNC)*, Anaheim, California, USA, 16-19 February 2015.
3. Guirguis, Arsany, Mohamed Ibrahim, Karim Seddik, Khaled Harras, Fadel Digham, and Moustafa Youssef. "Primary User Aware k-Hop Routing for Cognitive Radio Networks." In *2015 IEEE Global Communications Conference (GLOBECOM)*, pp. 1-6. IEEE, 2015.
4. S. Hanna, M. Mahdi, Y. ElNakieb, A. Guirguis, R. Elbakly, M. Youssef, M ElNainay, A. ElSherif, and K Seddik, "CRC: Enabling a Collaborative Environment for Wireless Communication and Networking Research," *33<sup>rd</sup> National Radio Science Conference (NRSC 2016)*, Feb 22-25, 2016, Aswan, Egypt
5. Yaser El-Nakieb, Michael Azmy, Mustafa ElNainay, "Genetic Algorithm-based Mapper to Support Multiple Concurrent Users on Wireless Testbeds," *2016 IEEE WCNC*, Doha, Qatar, 3-6 April 2016, pp. 267-273.
6. Mariam Nabil and Mustafa ElNainay, "Fuzzy-based Assignment Algorithm for Channel Sensing Task in Cognitive Radio Networks," *IEEE ISCC 2016*, Messina, Italy, 27-30 June 2016, pp. 890-895.
7. Samer Hanna, Arsany Guirguis, Moustafa Youssef, Mustafa ElNainay, and others, "CRC:

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Collaborative Research and Teaching Testbed for Wireless Communications and Network," *The 10<sup>th</sup> ACM WiNTECH 2016*, New York City, USA, 3 Oct. 2016.

8. Samer Hanna, Amr Elsherif, and Karim Seddik, "Topology Realization using Gain Control for Testbeds," *The 10<sup>th</sup> ACM WiNTECH 2016*, New York City, USA, 3 Oct. 2016.
9. Samer Hanna, Amr El-Sherif, and Mustafa ElNainay, "Maximizing USRP N210 SDR Transfer Rate by Offloading Modulation to the On-board FPGA," *IEEE WINCOM 2016*, Dez, Morocco, 26-29 Oct. 2016.
10. Arsany Guirguis, Mohammed Karmoose, Karim Habak, Mustafa El-Nainay, Moustafa Youssef, "Cooperation-based Routing in Cognitive Radio Networks," *submitted to Elsevier Journal of Networks and Computer Applications*.

### III. PATENTS

### III. THESES

Arsany Guirguis, "Cooperation-based Routing Protocol for Cognitive Radio Networks", M.Sc. thesis, Alexandria University, 2016

### IV. REPORTS/STUDIES

### V. OFFERED TRAINING/INFORMATION DISSEMINATION PROGRAMS

- Two workshops/information dissemination sessions have been organized.
- Multiple training sessions have been given and planned for teams from 5 Universities.
- Teaching labs have been developed and will be published on the testbed to be used in Communication and Networking courses.

### VI. SUPERVISED GRADUATION PROJECTS RELATED TO THE RESEARCH PROJECT

### VII. OTHERS

A competition among Universities had been organized August 2016 on the testbed. Team from Cairo University has won the first place prize.

## E. HUMAN RESOURCES

ACTIVE TEAM MEMBERS (PROFESSORS, RAS, ENGINEERS) THROUGHOUT THE PROJECT WITH THEIR MAIN DUTIES AND GAINED EXPERTISE ACROSS THE COURSE OF THE PROJECT (E.G., SW DEVELOPER, EMBEDDED SYSTEMS EXPERT,...)

| TEAM MEMBER          | TASK/EXPERTISE   |
|----------------------|--|
| Dr. Mustafa ElNainay | Project PI supervising testbed framework and portal development    |
| Dr. Moustafa Youssef | Project Co-PI supervising testbed framework and portal development |

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|------------------|--|
| Dr. Karim Gomaa  | EE Co-PI supervising testbed node placement and all communication related tasks                          |
| Dr. Amr ElSherif | EE Co-PI supervising testbed node placement and all communication related tasks                          |
| Yaser El-Nakieb  | RA responsible of building testbed scheduler and experiment mapper                                       |
| Samer Sarwat     | RA responsible of node placement, USRP labs, training, and Challenge                                     |
| Arsany Hany      | RA responsible of Simulation server setup and integration with testbed framework and network course labs |
| Mahmoud Alaa     | RA responsible of communication course labs and user experiment isolation                                |
| Mahmoud Mahdi    | RA responsible of developing testbed portal  |
| Mariam Nabil     | RA responsible of spectrum sensing research  |

### F. LIST OF PURCHASED LAB EQUIPMENT/SOFTWARE PACKAGES

| ITEM           | QUANTITIES | DESCRIPTION  | COST (L.E) |
|----------------|------------|--|------------|
| SDK Kits       |            | 5 USRP B210+ 2 SDR starter kit from Agile SDR Solutions + 1 mini USRP + 8 SDR-RTL + 32 VERT 2450 | 139000     |
| Server         | 2          | Dell Servers + KVM + CISCO Switch  | 217980     |
| Tiny Desktops  | 8          | Lenovo M93P  | 71200      |
| Printer/copier | 1          | Kyocera 6530   | 20000      |