Cognitive Radio Experimentation World

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Promotion and Dissemination Report of CABIN-CREW Experiments

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Abstract: This deliverable summarizes all the promotion and dissemination activity related to the CABIN-CREW experiments on MAC layer cognitive adaptations. We promoted i) the use of the Wireless MAC Processor by explaining how to implement, load and activate different MAC programs, and ii) the use of the OMF control architecture by demonstrating how to define network observation and decision logics for implementing MAC layer cognitive adaptations. These activities have been supported by scientific papers, talks and demonstrations.

Keywords: dissemination, presentations, publications, demonstrations, network testbeds, MAC layer, wireless networks, cognitive radio, cognitive network.

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Executive Summary

This document provides an overview of all WP8 promotion and dissemination activities relevant to the CABIN-CREW experiments. The document compiles all the publications and dissemination activities that were undertaken by CNIT, a partner that joined the CREW Consortium as a result of the second open call. The content is offered in the same way as was done for the other dissemination deliverables: scientific publications are often linked to a presentation, a poster, or a demonstration. We also explicitly mentioned the invited talks and the scientific cooperation activities that have been organized for promoting the usage of the CREW testbed.

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1 Introduction

CABIN-CREW experiments are focused on the possibility to implement MAC protocol adaptations on the basis of a cognitive cycle. In order to enable this type of experiments on the CREW testbed, we integrated some programmable WiFi nodes (equipped with the so called Wireless MAC Processor) on the federated testbed, and we exploited the OMF control architecture for collecting measurements and propagating decision signals, and the OEDL language for implementing a network-wide decision logic. The programmable nodes and the control architecture has been exploited for several different scientific activities dealing with the optimization of very different network contexts (from mesh networks, hidden links, WiFi/ZigBee inter-technology interfered networks, etc.).

Our dissemination activities have been consequently organized into two main directions. On one side, we promoted i) the use of the Wireless MAC Processor by explaining how to implement, load and activate different MAC programs, and ii) the use of the OMF control architecture by demonstrating how to define network observation and decision logics. These activities have been mainly supported by talks, demonstrations and tutorials. On the other side, we divulgated the results of our experiments in scientific publications in which we experimentally validated the performance of non-standard MAC protocols.

2 Scientific publications

1 Gallo P, Garlisi D., Giuliano F, Gringoli F, Tinnirello I, Bianchi G. (2013). Wireless MAC Processor Networking: a control architecture for expressing and implementing high-level adaptation policies in WLANs. IEEE VEHICULAR TECHNOLOGY MAGAZINE, ISSN: 1556-6072, doi: 10.1109/MVT.2013.2281652
Published, no abstract available**.**

2 Gallo P, Garlisi D, Giuliano F, Gringoli F, Tinnirello I, Bianchi G. (2013). Control Architecture for Wireless MAC Processor Networking. In: Proc. of Future Network and Mobile Summit 2013. Lisbon, Portugal , 3 – 5 July 2013.
Published – *Best paper award FuNeMs 2013*
Abstract. In these years, the proliferation of unplanned WLANs is creating the need of implementing different adaptation strategies for improving the network performance under mutating and evolving interference scenarios. Many vendors propose undisclosed MAC/PHY optimization solutions, such as ambient noise immunity schemes, dynamic tuning of operating channels and contention parameters, etc., relying on low-level implementations in the card hardware/firmware. In this paper we envision a new solution for expressing and implementing high-level adaptation policies in WLANs, in contrast to the current approaches based on vendorvendor specific implementations. We exploit the hardware abstraction interface recently proposed by the Wireless MAC Processor (WMP) architecture, and some flow-control concepts similar to the Openflow model for defining MAC adaptation policies. A simple control architecture for disseminating and activating new policies among multiple nodes is validated in an experimental testbed.

3 Tinnirello I, Gallo, P (2013). Supporting a Pseudo-TDMA Access Scheme in Mesh Wireless Networks. In: Proc. Of International Workshop on Wireless Access Flexibility (WiFlex) 2013. Kaliningrad, Russia, 4-6 Sept. 2013.
Published. *Best paper award WiFlex 2013*
Abstract. Wireless mesh networks appear a promising solution for providing ubiquitous low-cost wireless access, but cannot rely on simple CSMA access protocols because of the critical inefficiencies that arise in topologies with hidden nodes. To overcome these limitations, some important protocol extensions based on synchronization and reservation mechanisms have been ratified. In this paper we show that an alternative approach to the standardization of new features and signaling messages for mesh networks can be the utilization of programmable nodes able to execute different MAC protocols programmed on the fly. Signaling messages are used only for disseminating the new protocol among the nodes. The scheme, that we call pseudo-TDMA, can be optimized as a function of the node density in the network. Apart from the numerical evaluations, we also run some experiments by exploiting our prototype of wireless programmable node called Wireless MAC Processor.

4 Bianchi G, Gallo P, Garlisi D, Giuliano F, Gringoli F, Tinnirello I (2013). Deploying Virtual MAC Protocols Over a Shared Access Infrastructure Using MAClets. In: Proc. of IEEE INFOCOM 2013 (Demo Session). Torino, Italy, April 2013.
Published.
Abstract. Network virtualization has been extensively researched in the last years as a key enabler for improving the network performance. However, virtualization in wireless networks pose some unique challenges: first, the usual over-provisioning approach for providing isolation between multiple virtual entities is not viable; second, the partitioning criteria are often ambiguous, since the actual resources perceived by each entity depend on many external (and time-varying) factors. In this demo, we show an effective virtualization solution for wireless local area networks, solving the problem of isolation and flexible resource partitioning, based on the concept of MAClets. MAClets are software programs uploaded and

executed on-demand over wireless cards, and devised to change the card's real-time medium access operation. MAClets can be directly conveyed within data packets and executed on hard-coded devices acting as virtual MAC machines. A multi-operator virtualization experiment involving the distribution of MAClets within data packets, and their execution over commodity WLAN cards, shows the flexibility and viability of the proposed concept.

5 Bianchi G, Tinnirello I (2013). One Size Hardly Fits All: Towards Context-Specific Wireless MAC Protocol Deployment. In: Prof. of ACM Wintech 2013. Miami, September 2013.
Published.
Abstract. This paper casts recent accomplishments in the field of Wireless MAC programmability into the emerging Software Defined Networking perspective. We argue that an abstract (but formal) description of the MAC protocol logic in terms of extensible finite state machines appears a convenient and viable data-plane programming compromise for modeling and deploying realistic MAC protocol logics. Our approach is shown to comply with existing control frameworks, and entails the ability to dynamically change the MAC protocol operation based on context and scenario conditions; in essence, move from the traditional idea of ``one-size-fits-all'' MAC protocol stack to the innovative paradigm of opportunistically on-the-fly deployed context-specific MAC stacks. With the help of selected and currently developed use cases, we report on preliminary integration activities within the CREW federated wireless testbed, and its OMF experiment control framework.

6 F. Gringoli, P. Gallo, N. Facchi, D. Garlisi, F. Giuliano, G. Bianchi. Enabling Cognitive-Radio paradigm on commercial off-the-shelf 802.11 hardware, in Proc. of ACM Wintech 2013 (Demo session), Miami, September 2013.
Published.
Abstract. Cognitive Radio paradigm (CR) is recognized as key enabler for next generation wireless networking: accessing the limited radio spectrum in an opportunistic manner allows secondary users to boost their transmission performance without interfering with existing primary networks. Full testing and experimenting with this paradigm, however, is still a tough task, given either the i) limited capabilities above the PHY layer of cheap SDR solutions, or the ii) heavy investment required for setting up multi-node testbeds powered by FPGAs. In this demo we show how we leveraged our Wireless MAC Processor architecture to tackle the two issues at the same time, providing a highly reconfigurable cognitive solution for wireless local area networks on top of commercial off-the-shelf (COTS) 802.11 devices. We demonstrate a typical CR use case where local and network-wide cognitive loops interact for configuring secondary users real time channel switching in reaction to channel state mutation. We also prove the flexibility of our Wireless MAC Processor (WMP) architecture for extensive testing of the CR paradigm.

7 D. Croce, P. Gallo, D. Garlisi, F. Giuliano, S. Mangione, I. Tinnirello. ErrorSense: Characterizing WiFi Error Patterns for Detecting ZigBee Interference.
Accepted to 5th IEEE International Workshop on TRaffic Analysis and Characterization, TRAC 2014, August 2014
Abstract. Recent years have witnessed the increasing adoption of heterogeneous wireless networks working in unlicensed ISM bands, thus creating serious problems of spectrum overcrowding. Although ZigBee, Bluetooth and WiFi networks have been natively designed for working in presence of interference, it has been observed that several performance impairments may occur because of heterogeneous sensitivity to detect or react to the presence of other technologies. In this paper we focus on the WiFi capability to detect interfering ZigBee links. Despite of the narrowband transmissions performed by ZigBee, in emerging scenarios ZigBee interference can have a significant impact on WiFi performance. Therefore, interference detection is essential for improving coexistence strategies in heterogeneous networks. In our work we show how such detection can be performed on commodity cards working on time and frequency domain and also analyzing data in the "error domain". Errors are monitored and classified into error patterns observed in the network in terms of occurrence

probability and temporal clustering of different error events. Through statistical analysis we are able to detect the presence of ZigBee transmissions measuring the errors raised by the WiFi card.

8 P- De Valck, I. Moerman, D. Croce, F. Giuliano, I. Tinnirello, D. Garlisi, E. De Poorter, B. Jooris, Exploiting Programmable Architectures for WiFi/ZigBee Inter-Technology Cooperation
Submitted to Eurasip Journal on Wireless Communications and Networking
Abstract: The increasing complexity of wireless standards has shown that protocols cannot be designed once for all possible deployments, especially when unpredictable and mutating interference situations are present due to the coexistence of heterogeneous technologies. As such, flexibility and (re)programmability of wireless devices is crucial in the emerging scenarios of technology proliferation and unpredictable interference conditions.
In this paper we focus on the possibility to improve coexistence performance of WiFi and ZigBee networks by exploiting novel programmable architectures of wireless devices able to support run-time modifications of medium access operations. Differently from SDR platforms, in which every function is programmed from scratch, our programmable architectures are based on a clear decoupling between elementary commands (hard-coded into the devices) and programmable protocol logic (injected into the devices) according to which the commands execution is scheduled. Our contribution is two-fold: first, we designed and implemented a cross-technology TDMA scheme devised to provide a global synchronization signal and allocate alternating channel intervals to WiFi and ZigBee programmable nodes; second, we used the OMF control framework to define an interference detection and adaptation strategy that in principle could work in independent and autonomous networks. Experimental results prove the benefits of the envisioned solution.

9 Pablo Salvador, Luca Cominardi, Francesco Gringoli, Pablo Serrano, A First Implementation and Evaluation of the IEEE 802.11aa Group Addressed Transmission Service, ACM Computer Communication Review, 44 (1). pp. 35-41, 2014.
Published.
Abstract. The IEEE 802.11aa Task Group has recently standardized a set of mechanisms to efficiently support video multicasting, namely, the Group Addressed Transmission Service (GATS). In this article, we report the implementation of these mechanisms over commodity hardware, which we make publicly available, and conduct a study to assess their performance under a variety of real-life scenarios. To the best of our knowledge, this is the first experimental assessment of GATS, which is performed along three axes: we report their complexity in terms of lines of code, their effectiveness when delivering video traffic, and their efficiency when utilizing wireless resources. Our results provide key insights on the resulting trade-offs when using each mechanism, and paves the way for new enhancements to deliver video over 802.11 Wireless LANs.

3 Other presentations

Some of the presentations below are presentations on invitation, not linked to any peer-reviewed publication. Nevertheless, these presentations contributed to the dissemination of the CREW project and are therefore important to list.

1 I. Tinnirello, “The Wireless MAC Processor” invited talk at Università la Sapienza di Roma, May 2013
Presentation.
Abstract: This talk introduces the notion of wireless MAC processors (WMP). Instead of implementing a specific MAC protocol stack, Wireless MAC processors do support a set of Medium Access Control ”commands” which can be run-time composed (programmed) through software-defined state machines, thus providing the desired MAC protocol operation. We prove the feasibility of the wireless MAC processor concept over a commodity WLAN hardware card. The flexibility of the proposed approach is analyzed through three use-case implementation examples. We also show how to remotely run experiments on the WMP-enabled nodes available in the CREW testbed.

2 G. Bianchi, Wireless MAC layer reconfigurability (from a software-defined networking perspective), Mobile Computing Conference (IWCMC 2013), Cagliari, 4 July 2013.
Keynote Speech at:
- Mobile Computing Conference (IWCMC 2013), Cagliari, 4 July 2013;
- WiFlex Conference, 4 September 2013;

Presentations at:
- Eidgenössische Technische Hochschule Zürich (ETH) Zurich, 28 October 2013.
- InterDigital, Melville, NY, USA, November 2013

Abstract: Wireless MAC protocols have been traditionally deployed as monolithic, one-size-fits-all, standards. In contrast, flexibility and programmability of wireless devices appear crucial to foster innovation and customization, so as to accommodate the need of customers (and applications) for personalized delivery and quality of experience, and overcome performance limitations by smartly exploiting opportunistically available spectrum and resources in dense environments. Moreover, wireless protocols originally designed for general scenarios are now stretched so as to fit the very diverse needs of niche contexts and deployments (industrial automation, domotics, military, emergency, machine to machine, etc). In this talk, we revisit very recent advances in the field of wireless MAC programmability. We specifically focus on programming approaches which do not require open source network interface cards, but still permit dynamic MAC protocol stack reconfiguration in negligible (sub-microsecond) time. This is accomplished by decoupling a set of ``dumb'' (hard-coded) primitives, from a third-party provided ``smart'' MAC protocol logic, provided in the form of (extensible) finite state machines which formally specify how such primitives shall be executed. We argue that such ideas and approaches, although technically different and relying on different abstractions, appear to enrich the wireless access domain with software-defined networking concepts that are today leading the data centers and wired networks innovation.

3 G. Bianchi, I. Tinnirello. Wireless MAC layer reconfigurability (from a software-defined networking perspective)
Presentation and Demonstration at:
- Networking Summer School organized by Prof. Bjorn Scheurmann, 22 July 2013.
- Technische Universität Berlin, invited by Prof. Adam Wolisz, 23 July 2013.

4 I. Tinnirello, “Wireless MAC layer Reconfigurability: General concepts and Implementation details” invited talk at the University of Electronic Science and Technology of China (UESTC) ChengDu, China, 2 September 2013
Presentation.

Abstract: In this talk, we revisit very recent advances in the field of wireless MAC programmability and software defined networking. We specifically focus on programming approaches which do not require open source network interface cards, but still permit dynamic MAC protocol stack reconfiguration in negligible (sub-microsecond) time. This is accomplished by decoupling a set of ``dumb'' (hard-coded) primitives, from a third-party provided ``smart'' MAC protocol logic, provided in the form of (extensible) finite state machines which formally specify how such primitives shall be executed. We argue that such ideas and approaches, although technically different and relying on different abstractions, appear to enrich the wireless access domain with software-defined networking concepts that are today leading the data centers and wired networks innovation.

4 Demonstrations & posters

The "scientific publication" section of this document already indicated that several demonstrations were given as a result of the acceptance of a peer-reviewed publication. In this section, additional CREW posters and demonstrations –those that are not attached to peer-reviewed publications– are listed:

1 Gallo, P. and Tinnirello, I., "The Wireless MAC Processor over CREW: enabling Cognitive Access BenchmarkINg (CABIN-CREW)" *Hands-on-FIRE! Demo session* organized at the *Future Internet Assembly (FIA)* in Dublin, Ireland, May 2013.

½ poster; no abstract available

2 Pierluigi, G., "The Wireless MAC Processor over CREW: enabling Cognitive Access BenchmarkINg (CABIN-CREW)", *Future Network & Mobile Summit 2013*, Lisbon, Portugal, July 2013.

Demonstration & ½ poster
Video: http://www.youtube.com/watch?v=Cr4K4_mCBJ8

3 D. Garlisi, M. Gucciardo, et al. "The Wireless MAC Processor over CREW: enabling Cognitive Access BenchmarkINg", *Demo session* organized at the ICT 2013 event in Vilinius, November 2013

Demonstration & ½ poster

4 F. Giuliano, et. al, "Cross-technology interference avoidance", *Demo session* at the *Future Internet Assembly (FIA)* in Athens, Greece, March 2014.

Demonstration & ½ poster

5 Workshops & Tutorials

1 G. Bianchi, “Wireless MAC Processor”, 16 July 2013, at Polytechnic NY, invited by Prof. George Kesidis, Brooklyn
Tutorial.

2 I. Tinnirello “Wireless MAC Processor Demonstration and Integration with a Control Architecture”, University of Electronic Science and Technology of China, ChengDu, China, 4-5 September 2013.
Tutorial and Demonstration Examples.
Abstract. This tutorial will present, demonstrate and provide a hands-on experience on the concept of Wireless MAC Processors (WMP). WMPs are programmable devices which i) provide a set of stateless Medium Access Control commands, and ii) embed a MAC protocol engine in charge of executing a finite state machine able to exploit and compose the sequence of commands forming a desired protocol. Wireless MAC processor commands can be considered analogous to the instruction set of an ordinary CPU. They are meant to implement elementary actions, namely MAC operations such as transmit a frame, set timers, etc, which may be then executed in the appropriate sequence and/or under the occurrence of specific events and conditions mandated by a protocol logic. Based on the WMP, a MAC protocol engine can be defined in charge of executing a user-developed software program implementing a desired MAC protocol operation in the form of an extended finite state machine. Flexibility and ease of programmability is thus a consequence of the clear architecture-level decoupling made between what the device is able to do (the pre-installed MAC commands), and what it is instructed - at run time - to do (the injected state machine). We also present the possibility to remotely run experiments with WMP-enabled nodes on the European testbed CREW, by discussing some simple examples of experiment configuration scripts.

6 Further Promotion and Dissemination

As a further promotion and dissemination action, the CNIT team has submitted a GENI-FIRE cooperation proposal that has been approved for supporting mobility between our researchers and the research group lead by Prof. Violet Syrotiuk, School of Computing, Informatics and Decision Systems Engineering, Arizona State University. The cooperation is targeted to the experimental validation of a novel medium access scheme for wireless mesh networks, called REACT. In the following we briefly summarize the cooperation program described in the proposal.

Project summary. In any network whose basis is a broadcast channel, the fundamental issue is how to determine who gets to use the channel when there is competition among users for it. This determination is made by the medium access control (MAC) protocol, and is especially important in, e.g., local area networks (LANs), wireless LANs, and wireless mesh networks. It is challenging to develop MAC protocols that are adaptive to changes in network conditions. REACT is a distributed algorithm that each user runs to compute its topology- and load-aware (TLA) persistence, the fraction of time a user is permitted to transmit that depends on the current wireless connectivity and traffic. The TLA persistence has been integrated into ATLAS, a scheduled MAC protocol, and evaluated in simulation. ATLAS achieves predictable throughput and delay characteristics — of particular interest, variance in delay — compared to IEEE 802.11, the de facto standard MAC protocol. The strong simulation results warrant their validation in a wireless testbed.

The foreign collaborator, Dr. Ilenia Tinnirello, is an Assistant Professor in the Department of Electrical Engineering at the University of Palermo in Italy. Her team developed a wireless MAC processor (WMP) that allows the programming of MAC protocols on commodity hardware, making it uniquely suited for this validation. For this purpose a contention-based protocol is implemented, removing synchronization requirements. Fortunately, the application of TLA persistence is not limited to scheduled MAC protocols. The activities that would result if this Catalyzing New International Collaborations (CNIC) proposal were funded include: (1) Designing a variant of the IEEE 802.11 MAC protocol that accesses the channel according to a user's TLA persistence; (2) Implementing REACT, and the TLA persistence based IEEE 802.11 protocol in the Italian testbed; (3) Evaluating the performance of the proposed protocol in the testbed.

The role of Dr. Tinnirello in the proposed activities is: (1) Using her expertise on the AirForce54G chipset from Broadcom, and the programming interface to the WMP, to inform the design and implementation of the proposed TLA persistence based variant of IEEE 802.11; (2) Providing the testbed for validation. The planning visit to Italy provides an opportunity for the domestic students to program the WMP, set up experiments in the local testbed and remote testbed CREW, instrument the data collection, and analyze the results. The characteristics and information about localized capacity at the MAC layer observed in simulation may be used to inform higher layers, while end-to-end characteristics at higher layers may be used to inform the MAC protocol. If the simulation results are validated in the testbed, the goal is to develop a follow-on full research proposal expected to be submitted to the NSF Computer and Network Systems (CNS), Networking Technology and Systems (NeTS) core program to support the development of an agile protocol stack with higher performance.

7 Conclusion

From the list of presentations, demonstrations and publications above, it can be seen that CNIT actively participated to the CREW project dissemination activities.

Our dissemination activities were mainly targeted to guarantee the sustainability of experiments about MAC layer re-programmability on the CREW testbed. To this purpose, apart from the scientific activities on cognitive MAC adaptations, we provided: i) guidelines on the layered configurations of the experiments; ii) reference MAC programs not specifically built for internal experiments, but available for other tests; iii) examples of MAC controller logic for helping in the definition of new adaptation strategies.