SAVANT – High Performance Dynamic Spectrum Access via Inter Network Collaboration*

Project Objectives:

This project is aimed at achieving significant spectrum efficiency gains through inter network collaboration in radio resource management. The proposed SAVANT (spectrum access via inter network collaboration) architecture is based on a new protocol interface for dissemination of spectrum usage information, policies and algorithms between neighboring networks to enable spectrum coexistence algorithms that reduce interference and improve spectrum packing efficiency. A new inter-domain spectrum coordination protocol (ISCP) is being developed to enable independent networks to negotiate radio resource management policies and optionally merge radio resource controllers for joint optimization. The proposed ISCP inter-network protocol has the potential for large gains in wireless spectrum utilization, and could thus influence future industry standards.

Technology Rationale:

The SAVANT architecture enables the sharing of spectrum usage information between collocated wireless networks, such as transmitter and receiver locations, transmit power, bandwidth of operation, channels being used, radio sensitivity, SNR vs. bit-rate, MAC schemes being employed, antenna properties, etc. This distributed sharing of spectrum information goes beyond the centralized spectrum database [1] approach mandated for white space systems [2], and may also be applied to emerging dynamic spectrum scenarios such as the 3.5 Ghz small cell band in FCC's recent NPRM [3]. Each network can use these parameters in autonomous distributed algorithms for spectrum sharing (such as bandwidth/rate backoff similar in spirit to TCP congestion control. In SAVANT, the sharing of spectrum use information, however, is just the first part of the solution – that of increasing the visibility of each transceiver much beyond what it can sense on its own. The second part comes from the ability to instantiate a higher-layer negotiation protocol between neighboring networks to support joint assignment/management of spectrum resources, negotiations between heterogeneous entities, and controller delegation.

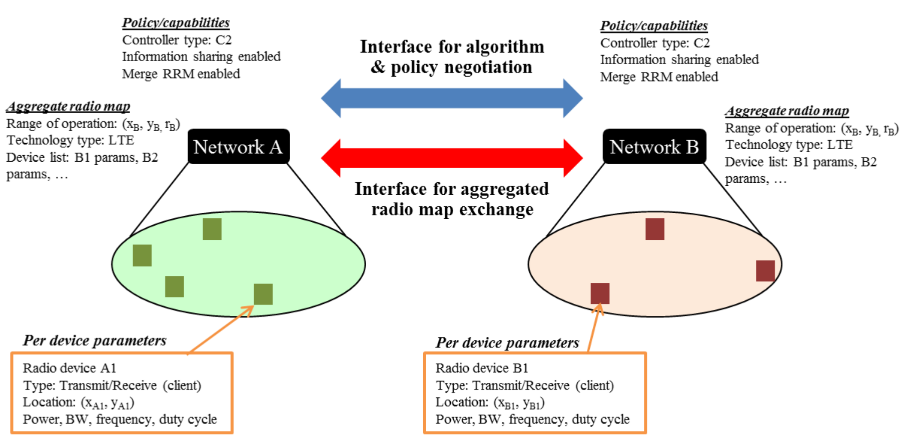

Fig. 1: Functional outline of the inter-network collaboration approach in SAVANT

Technical Approach:

Fig. 1 shows the functionality of the proposed SAVANT solution along with the two levels of interactions between two adjacent networks. As shown in the figure, each network collects radio parameters from each transceiver in its domain and then summarizes them into an "aggregate radio map" which is shared with neighboring networks (via the S-interface shown) with one or more radios within the interference region. There is also a second control interface ("M-interface") with higher-level semantics required to support policy expressiveness, global optimization algorithms, and controller delegation associated with management-level coordination of autonomous networks.

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Fig. 2 below shows a physical world view of the proposed SAVANT system [4]. Each wireless network has a local controller which collects radio device parameters as summarized in Fig 1, along with an RRM control interface for setting parameters for operation. The local controllers communicate with each other over the control plane designed to have two specific services – the first is a geographic multicast ("geocast") service which delivers the aggregate radio map to all networks in the region of interest (as calculated from the radio coverage parameters). This ensures that networks have information about spectrum use by other networks in the region, thus enabling each RRM controller to execute an appropriate distributed spectrum coordination algorithm to avoid excessive interference and achieve good spectrum use efficiency. With increasing spectrum packing, it may also be desirable for interfering networks to negotiate directly with each other using the management control interface shown – for example two overlapping WiFi networks in an urban area can use the M-interface to agree on a common radio resource management algorithm and merge their controllers to run a single more global scope algorithm – this has the effect of creating a unified virtual wireless network with a single logical controller delegated to one of the networks involved.

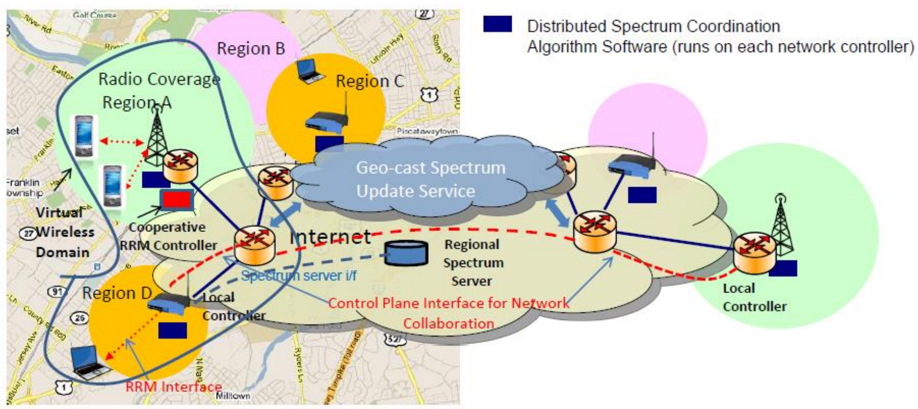

Fig 2: SAVANT System Architecture

Results to date and future work plan:

During the first phase of this project, the research team has focused on defining details of the SAVANT system architecture and on initial simulation-based studies for evaluating the performance of cooperative spectrum assignment algorithms. A preliminary design has been developed for the protocol required to exchange spectrum map information between adjacent networks, identifying necessary radio and geo-location parameters necessary to support coordination algorithms. One of the design goals is to identify a set of radio-technology independent parameters for describing alternative wireless standards such as WiFi, LTE and WiMax within the same protocol framework. The project team has also worked on simulation models for evaluating inter-system coordination in dense deployment scenarios, and has obtained initial numerical results for co-located dense WiFi networks showing significant gains from collaboration [5]. Further work on experimental validation of these simulation results is currently in progress using the ORBIT testbed at WINLAB. In parallel to this, the group at Princeton has been working on implementation aspects using software-defined network (SDN) technology. In particular, extensions to the OpenFlow standard necessary for supporting control of radio systems are being considered, and initial results were obtained for SoftCell, a scalable architecture that supports fine-grained policies for mobile devices in cellular core networks, using commodity switches and servers. Joint work is currently in progress on prototyping of a multi-network SDN prototype with two or more independent controllers with the ability to exchange spectrum maps and carry out simple joint optimizations of radio parameters.

The SAVANT inter-network coordination model is particularly relevant now in view of FCC's recent NPRM (notice of proposed rule-making) for shared small-cell operation in the 3.5 Ghz band. Future results from this project are expected to provide guidance for the design and specification of efficient shared spectrum access procedures for the proposed 3.5 Ghz small-cell band.

References:

[1] V. Chen, D. S., L. Zhu, J. Malyar, and P. McCann, *Protocol to Access Spectrum Database*, IETF Internet Draft, draft-ietf-paws-protocol-06.txt, June 2013.
[2] Federal Communications Commission, "In the Matter of Unlicensed Operation in the TV Broadcast Bands: Third Memorandum Opinion and Order," Apr. 2012.
[3] Federal Communications Commission, "FCC Notice of Proposed Rulemaking and Order 12-148, Enabling Innovative Small Cell Use In 3.5 GHz Band," Dec. 2012.
[4] "NASCOR: Network Assisted Spectrum Coordination Service for Coexistence between Heterogeneous Radio Systems", Dipankar Raychaudhuri, Akash Baid, IEICE Trans. Communications 2013.
[5] Network Cooperation for Client-AP Association Optimization, Akash Baid, Michael Schapira, Ivan Seskar, Jennifer Rexford, Dipankar Raychaudhuri, RAWNET 2012 - The 8th International Workshop on Resource Allocation and Cooperation in Wireless Networks.

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