On the Exploitation of Dynamic Spectrum Allocation & Control (DSAC) for Assured Military Communications

Extended Abstract

Military communications are embracing a period of dramatic changes in the next several years. Their dependence on new ways to access the RF spectrum has been increased by the competition of civilian and government spectrum users in each country in which they operate.

The ability of the military to start operations in other countries in friendly or hostile scenarios is subject to the host nation sovereignty and regional spectrum usage patterns. Deployment of new generation weapons systems become on an extensive, frequency by frequency, system by system coordination.

This lengthy process is inconsistent with the high tempo and quick reaction timeline that is needed for modern operations. Coalition and allied operations are more complex to manage, and spectrum assignment issues may severely limit the U.S.'s ability to fully exploit its superiority and investment in information technology. The problem is aggravated by the current static approach to spectrum management that is not able to optimally, or even effectively, pack the spectrum, resulting in difficulty in obtaining frequencies for many systems, and potential conflict between military and civil users. The need for higher and more complex data services coupled with the explosion of the commercial wireless market strain the current limits of military spectrum allocations both domestically and abroad.

A commonly held perception within the private sector is that there is not enough available spectrum for new applications; however, the real problem is not a spectrum shortage, but developing reliable spectrum methods that enable new system to co-exist with non-cooperative existing users.

According to the Spectrum Task Force in [1], preliminary data and general observations indicate that portions of the radio spectrum are not in use for significant periods of time. Measurements of the spectrum below 1 GHz in several cities in the United States in July 2002 indicate that, while some bands are heavily used, many other bands are not in used or are used only part of the time. A key challenge, therefore, is to develop new on-demand spectrum access technologies capable of dynamically allocating and controlling the access to the spectrum based on instantaneous environmental conditions. Simultaneously, new flexible policies have to be developed in a general framework so those devices can coexist with legacy communication technologies.

Ongoing work is developed in both aspects. [2] announces the review of the governmental sector spectrum use. The general idea is to produce recommendations for improving government spectrum management policies and procedures while finding ways to increase the efficiency and beneficial use of spectrum by the government itself. In parallel to the Federal Communications Commission (FCC) conducts its own review of spectrum policy. In their initial report in November 2002 [1], FCC characterizes the current policy as inflexible, intolerant to non-destructive interference and not receptive to the apparition of new technologies.

On the other hand, the Defense Advanced Research Projects Agency (DARPA) is developing the neXt Generation (XG) program to develop a new generation of spectrum access technology to increase the ability of military to access the spectrum. A series of public available RFCs [3] and [4] have been presented in which the vision, approaches and functionalities of XG are presented. XG devices are envisioned as policy enabled devices that can sense environmental conditions and opportunistically share frequency band without causing interference to incumbent devices in friendly or hostile scenarios. With an appropriate technology development to identify such frequency spectrum opportunities, an optimization of frequency use of 10x hoped to be reached. In a higher level of description, the RFCs and in [5], is presented as an abstract set of behaviors that could be broadly applied to many of the existing and likely future Media Access Control (MAC) and Physical (PHY) layers.

Foreseeing the upcoming changes in policy regulations, inquires [6] show their interest on receiving comments on the feasibility of allowing unlicensed devices to operate in TV broadcast spectrum at locations and times when spectrum is not being in used, and on the technical requirements that would be necessary to ensure that such devices do not cause interference to authorized services operating within the TV broadcast bands.

Our work consists on a specific instantiation of Dynamic Spectrum Allocation and Control Architecture for and multihop Adhoc Network.

We have chosen Adhoc Networks because their high applicability and potential in military operations. Coordinated

deployment of troops where infrastructure is not available makes Adhoc networks the right communication system for the future battlefield.

While dynamically frequency management appears as a solution for the frequency scarcity problem and new smart devices can optimize the use of frequencies, several questions arise. What is the trade-off between interference and throughput? Are there policies that can enhance throughput and reduce interference? Where should DSAC be implemented in networking standards? Are DSAC enabled nodes capable of starting a communication without interfering with incumbent nodes? Should local DSAC information be disseminated among all nodes in a network? How wide is the spectrum that DSAC enabled nodes should handle? Is it necessary to distinguish between incumbent nodes and DSAC nodes transmission? Which existing Adhoc networks enhancements helpful for a good DSAC mechanism performance?

These questions are addressed in total for the first time in this paper. This paper presents ideas and issues that have been discussed as well as the architecture implementation of an evaluation a DSAC platform in OPNET that can test a proposed protocol for DSAC control information dissemination and dynamic frequency allocation. Our first contribution is a complete system implementation of dynamic spectrum techniques. We implement a mechanism in the MAC layer capable of coordinating the selection of frequency opportunities. At the same time, to guarantee frequency allocation coordination with legacy link and physical layers we implement a set of APIs that will transfer carrier presence signaling, frequency opportunity presence, topology changes, etc. A number of enhancements to a traditional Adhoc networking protocol stack are also implemented, they include link power control, frequency neighbor discovery as well as the channel allocation mechanisms. Link power control will be strongly related to each DSAC enabled node's sensing capabilities. It cannot only enhance connectivity in an Adhoc network but also will enable dynamic frequency reuse by avoiding interference with incumbent nodes.

Neighbor discovery and channel allocation are tasks not only related to topology but also dependent on the frequency opportunities availability on each nodes local environment which will push current static confined bandwidth utilizations beyond its limits. Because of the importance of non-interference with incumbent devices, sensing capabilities are extremely important; hence, for a node to communicate with its neighbors, nodes should be aware of their neighbor's frequency opportunities. This coordination is essential because we need to both ensure that the selected frequency is usable at the receiver, and it is not likely to jam signals from the environment of the transmitter. A sufficient condition is the assumption of the existence of a small reserved coordination channel not assigned to any legacy communication device; it will be for exclusive use of DSAC enabled nodes.

Among the most important tasks of our DSAC mechanism, we consider the following functionalities:

- Discover other DSAC enabled nodes in the neighborhood and disseminate local information among the network. The pre-assigned coordination channel will be used for this function. In this work, we implement a dissemination protocol for Adhoc networks. Nodes will exchange information with all DSAC enabled nodes in the network. By doing so, nodes can at some point discover a common available channel in a wider area either to form clusters or to establish a free trading zone of information (data or control packets). To avoid the saturation of the coordination channel, control information can also be sent through a frequency opportunity already allocated whenever the contained information comes from nodes more than one hop away.
- Estimate the frequency availability in the node's neighborhood. Presence of a incumbent node in a determined channel will null it; however, presence of DSAC enabled nodes will not. The differentiation of nodes will avoid any possible deadlock when competing for the available media. That is, DSAC nodes could be competing with their peers for the available media with a contention or any other mechanism.
- Allocate a default set of frequency intervals to become the idle channel of this node. The idle channel is defined as the frequency band and waveform that the node is tuned to when it is not transmitting for receiving a data packet. Advertising this selection, nodes should be able to start communicating with their peers occupying a free set of frequencies. This characteristic makes more difficult tasks such as scheduling since the transmission rate in a single communication.
- Serve as a front end to the MAC and the Physical layer. The interface between both layers and our DSAC module is defined by the opportunity API and the transceiver API respectively. With the first, the DSAC module will be able to send carrier signaling information, opportunity frequency availability, transmit power rate settings, topology control, etc. The latter will provide the control of the transceiver to the module; therefore, the new MAC layer will be able to tune its transceiver to any frequency channel.

Consequently, our DSAC mechanism will act as a new added constraint for transmission for any kind of present legacy MAC. In Our implementation we use a CSMA/CA based MAC.

In this paper, we present the benefits of DSAC and the issues that it originates when implementing it. To provide a better understanding of the challenges anticipated in the design of a real life on demand frequency system as well as to validate the correctness of our proposed mechanism, a simulation platform was developed. Issues inherited to Adhoc networks will be analyzed. For example, different factors can be taken into account to decide the size of the communication channel. If the communication channel is set without controlling the possible overlapping in frequency between to neighbors, already described problems characteristic in wireless communications will appear (i.e. Hidden and exposed terminals problems). To find an optimum manner to find a right size of an Idle channel, we show two different approaches. The first one is by using a greedy algorithm and allocating as much as bandwidth is available for all transmissions. The second approach is a set of experiments in which set different size thresholds where we find an optimal size value according to different scenarios of load and density.

Our objective is not only to show its benefit on finding more available bandwidth for faster or more transmissions, but also on examining the relative improvement on network throughput without causing interference to incumbent devices. The throughput vs. interference trade off result will be valuable for policy making when deciding the rules governing sensing transmissions in DSAC systems. Finally, statistics showing the frequency reuse factor, will indicate the how useful is DSAC on guaranteeing a solution for the frequency scarcity problem.

References

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