COORDINATED DYNAMIC SPECTRUM MANAGEMENT IN LEGACY MILITARY COMMUNICATION SYSTEMS

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ABSTRACT

The rapid development of systems using wireless technologies causes increasing problem of spectrum shortage. That is why a concept of dynamic access to the spectrum (DSA) has appeared. The most advanced form of DSA is the opportunistic access (OSA), which will find its implementation in the future solution of the cognitive radio.

Nowadays, the rationalization of spectrum efficiency in legacy communication systems can be obtained by implementation of the so called coordinated dynamic spectrum access (CDSA), based on certain infrastructure, including a spectrum broker as a principal component of tactical radio networks. This kind of DSA can be used in systems based on the radios enabling remote reconfiguration mechanism. In the Polish army, such capabilities have VHF PR4G radio, VHF/UHF R-450C radio and HF RF-5800H radio. This presentation describes a concept of these radio networks remotely controlled by the frequency broker. The results of experimental validation of such system efficiency are described as well as the planned future actions.

1. INTRODUCTION

Communication systems used on the contemporary battlefield encounter more and more rigorous requirements related to a set of implemented services, because such services as transmission of images, video transmission and the like, became a standard presently. It causes the increase of signals bandwidths, and in the effect, greater spectral needs generated by these systems. This phenomenon, together with violently increasing number of systems using wireless technologies on the battlefield, leads to the excessive load, and in the effect to the shortage of spectrum – particularly in coalition operations. Such situation, in connection with inefficient spectrum use, being a result of static management and assigning frequencies (channels) for exclusive use, have become the inspiration to create the paradigm of spectrum sharing and – in the consequence – the dynamic access to the spectrum.

Taxonomy for various „philosophies” of the access to the spectrum presented in [1] introduces their classification in the form of the three following states:

- static methods of the access to the spectrum (present state),
- coordinated dynamic access to the spectrum (with the infrastructure in the form of frequency broker - FB),
- opportunistic access to the spectrum (executed by the cognitive radio).

Methods of the coordinated and opportunistic accesses are a realisation of the spectrum sharing philosophy by various users, which leads to considerable increase the of its usage efficiency.

A “road map” of the evolutionary modification for spectrum management in tactical communication systems was presented in the report of the NATO – IST104/RTG-050 task group works [2], enabling transition from present static methods, changing them progressively to the state when the radio spectrum is shared by introducing cognitive radio systems for operation.

The starting stage of modification (“baby step”) was proposed in the formulated road map, adequate to the present condition, depending on adaptation of presently used spectrum management procedures intended to achieve considerable shortening of the frequency assignment time.

This paper presents the results of work, to achieve the efficient spectrum use by automation of frequency assignments – using remote reconfiguration mechanisms. A possibility of shortening frequency assignment time was enabled by introducing the frequency broker directly connected with radio networks, and achieving the coordinated dynamic access to the spectrum.

The feasibility test results of such scenario and frequency change times within radios controlled by the broker generating undisturbed frequency plans are presented in the paper.

2. CHARACTERISTIC OF FREQUENCY BROKER

A frequency broker generating and distributing radio data to subordinated (managed) radio networks and links is the main component of the coordinated dynamic spectrum management mode. Within the radio data generation process providing operation of radio networks and links without collisions, the broker acquires accessible frequency files from the unit responsible for frequency administration, which in the Polish Armed Forces is NARFA PL. In order to define the organisational structure of a radio communication system the broker should cooperate with automated command systems, delivering the information on locations and types of all radio resources grouped into radio networks and links. Continuous verification of the interferences level on the frequencies assigned from the files can be executed by cooperation with electronic warfare systems.

Fig. 1 presents the location of a frequency broker within a command system (from the operational to subunit levels).

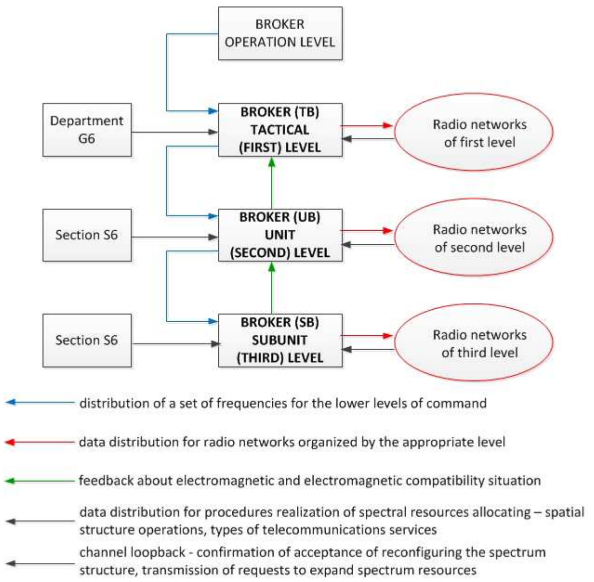

Fig. 1 Frequency broker in spectrum management system

The broker at any level is connected to the corresponding cell responsible for managing communication networks (G6, S6). Radio data from the broker is passed to radio networks that confirm receiving of them or generate the demand for new spectrum resources. The broker is also connected to higher and lower levels brokers in order to distribute data about spectrum resources assignment to the lower level and collecting data on electromagnetic situation within the responsibility area of this broker.

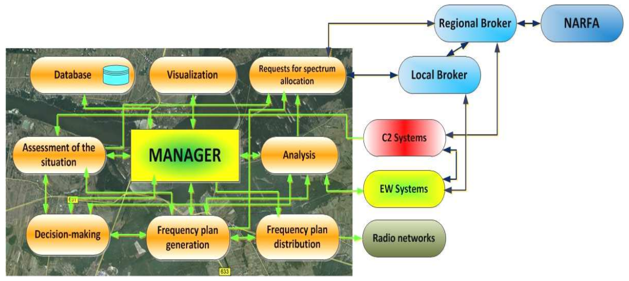

Fig. 2 Broker's architecture and its functional connections

Fig. 2 presents the structural relations scheme between NARFA PL and local brokers. Also, the functional scheme of the frequency broker is presented in this Figure to illustrate its modular structure.

Basically, a frequency broker realize two functions:

- preparing radio data for networks in the operation planning phase – Phase 1,
- dynamic spectrum management in the operation executing phase – Phase 2.

The original (initial) frequency assignment plan is prepared in the Phase 1 (Primary Frequency Assignment plan). At the beginning, the regional level broker sends demands for frequencies to NARFA to support the operation. In the case of the Polish Armed Forces, NARFA uses the SPECTRUM XXI planning software, and therefore the electronic version of the formalised demand document and data exchange protocols between broker and NARFA were developed. Next, based on the operational data including the information about the completion, spatial structure, location and tasks of military units as well as spectrum resources achieved, the broker develops frequency plans for operating subunits and transfers them to the cells responsible for spectrum management and to local brokers, which distribute the data to subordinated radio networks.

Within the Phase 2 the broker realizes the function of Frequency Assignment on Demand according to the monitoring results of own networks operation as well as data achieved from external reconnaissance EW systems. The main element of the broker is the planning module to allow generation of frequency plans without conflicts based on measures and interference criteria adequate for radios creating radio communication system. To evaluate interference and usable signals levels suitable radio waves attenuation models are used.

Radio data distribution to managed radios is provided by the distribution module, which executes the functions allowing automation of the radio data remote exchanging process both in a single network and also in the whole radio communication system.

3. RADIOS USED BY POLISH ARMED FORCES SUSCEPTIBLE TO AUTOMATIC REKEYING

The Polish Armed Forces use many types of radio communication media, such as narrowband radios operating in HF, VHF and UHF frequency bands, multiband radios (mostly with the frequency band up to 512 MHz) as well as broadband radios. Among them there are three radio families susceptible to automatic changes of radio data. They are VHF radios of PR4G family produced by Radmor, HF RF-5800H radios produced by Harris as well as R-450C radio produced by Transbit.

These radios, cooperating with the frequency broker, create the possibility to build radio networks using the philosophy of the coordinated dynamic spectrum management mode, because they have the capability to change their configuration over the air. The OTAR (*Over The Air Rekeying*) function make such a function possible within the PR4G radios family. In the case of Harris radios the application RPA (*Radio Programming Application*) is used in the process of automatic radio data exchange. In turn, the remote control protocol AMI (*Advanced Manager Interface*) is used for configuration the R-450C radios. In the OTAR procedure of the PR4G radios, the data are sent by radio between a radio connected to the frequency broker and other radios belonging to the radio network (see Fig. 3). To initialise the OTAR procedure, the following data should be defined in the frequency broker:

- access code to the program component or to the file;
- radio networks number, numbers of destination radios;
- number of backup networks.

The execution of the OTAR procedure is performed in the three following phases:

- initial data verification;
- set-up loading into the radio connected to the broker;
- transmission of set-up files to managed radios.

The RPA application in HF Harris radios offers a graphical interface and enables to define the following parameters of the radio:

- operational modes of the radios (FIX, FHOP, ALE - 3G RF-5800H);
- operational channels and groups of channels (numbers of channels, basic and reserve transmitting and receiving frequencies, modes of modulations, channel bandwidth, grouping channels (ALE, 3G);
- certificates of radios (names of radios, types of radios, modem type, configuration of IP mode);
- defining networks (grouping radios in radio networks, defining names of networks, networks parameters, mode of IP for networks, and the like);
- parameters of modems.

The RPA application provides storing all radio data in the form of suitable text file and sending it to a radio. The file created in this way is stored in the memory of the radio connected to the frequency broker, and then it is transmitted to other correspondents of the radio network. Change of the radio data is done automatically in the addressed radios.

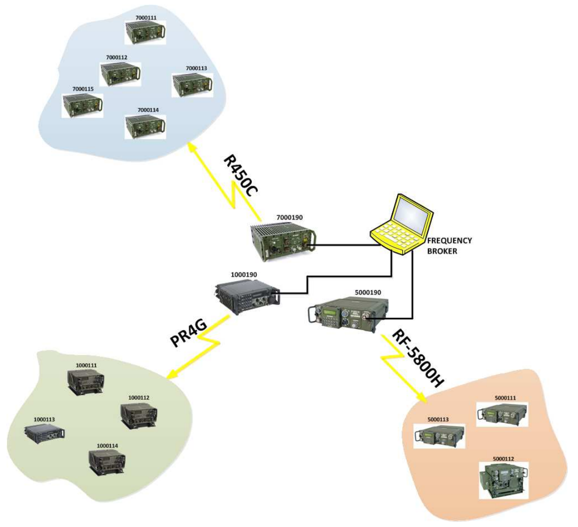

Fig. 3 Functional scheme of the radio communication system with dynamic spectrum management

In R-450C radios the remote control protocol AMI is the text one, using the TELNET session between the radio connected to the broker and other radios of the system. In order to initiate the OTAR procedure for a R-450C radio, the remote session should be started in the broker with the selected radio introducing its IP address and TTY port number.

4. TEST RESULTS

The tests were done in the measurement circuit presented in the Fig. 4.

Fig. 4 PR4G test set

Process of changing radio data using the radio PR4G is based on creating a complete file including radio data for the PR4G radio (7 operational channels) and distributing it to a selected radio in the network (the operation mode of selective calling of a correspondent) or to all radios in the network.

Four PR4G radios were used in the tests. In the first step the new data was transmitted by the radio connected to FB, either to all radios in the network (broadcast) or to the selected one (unicast).

The results of radio data change time measurements are presented in the table below.

Tab. 1 Results of data change time measurements for PR4G

Mode of PR4G radio	No. of trials	Av. time [sec.]	Std dev. [sec.]	Min. [sec.]	Max. [sec.]
unicast	10	57	2	54	61
broadcast	10	72	2	69	77

In the case of using high frequency RF-5800H radios the process of radio data change is based on selecting the radio communication plan defined earlier in the radio memory. In HF communications several radio communication plans are used, that take into account the specificity of operation in this frequency range (time of the day, ionospheric predictions, and the like). The radio itself has the possibility to store several radio communication plans that later may be activated using a defined command. Mostly, each communication plan has a defined date to be automatically activated at but there is the possibility to activate a plan by sending a given command to the whole radio network. The measurements lead to the conclusion, that the activation process of a selected radio communication plan lasts not longer than 5 seconds.

R-450C radios data change time was measured in the network of four radios. The change of radio data was based on establishing the TELNET session by the radio connected to FB with all radios and sending the command to change radio data. The process of changing radio data was done automatically. The test result are presented in the table below.

Tab. 2 Results of R-450C radio data change time measurements

No. of trials	Av. time [sec.]	Std dev. [sec.]	Min. [sec.]	Max. [sec.]
10	0.809	0.050	0.172	2.7

5. CONCLUSIONS

The working Group IST-104/RTG-050 “Cognitive Radio in NATO II” has developed a evolutionary plan of introducing to NATO more effective ways of spectrum use. The technical report includes recommendations related to the way of implementing spectrum sharing mechanisms, at the beginning by the managed systems, and then by autonomic cognitive solutions. At the present stage of implementation, the first phase of the development of military spectrum management systems is essential. It anticipates the progressive increase in flexibility of using spectrum resources by making several steps such as:

1. shortening time of waiting for the frequency assignment;
2. shortening minimal time of the frequency assignment being valid;
3. allowing assignment of frequency sub bands for whole systems (without defining other parameters, e.g. modulation) instead of nominal values for given radio resources, what makes possible optimisation of frequency usage within a given system;
4. taking into account the real frequency usage during the resources assignment (except analytic-simulation tools), preceded by achieving “the spectrum consciousness” based on the performed sensing.

In this phase the frequency sharing is not anticipated (at the level of assignment) by users of various categories, however Step 3 – the assignment of frequency sub bands for the whole systems – enables introducing such solutions at a lower level by the communication system organiser, what was done by the authors of this publication.

The presented work is an example of using technical capabilities that could be created by implementing the organisational changes recommended by IST-104/RTG-050. Legacy systems of the HF, VHF and UHF frequency range make possible to change radio data dynamically, but the time for reprogramming radio networks is so long that such actions should be taken not often to avoid disorganisation of the communication systems. Analogical times in the case of radios operating at higher frequency ranges are short enough, so the possibilities created by organisational changes recommended can be fully used.

Implementation of Dynamic Spectrum Management for heterogenic radio networks, which use legacy radios as well as the radios using cognitive solutions, needs further regulations and research works concerning policies related to the networks and nodes behaviour in given conditions, creation and use of radio environment maps REM, and development of procedures enabling efficient use of multi-range radios as well as principles of spectrum sharing with other systems.

6. REFERENCES

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