Dynamic Spectrum Sharing Algorithm for Combined Mobile Networks

Minho Jo
Department of Computer and Information Science
Korea University
Seoul, South Korea
minhojo@korea.ac.kr

Mykhailo Klymash
Department of Telecommunication
Lviv Polytechnic National University
Lviv, Ukraine
mklimash@polynet.lviv.ua

Taras Maksymyuk
Department of Telecommunication
Lviv Polytechnic National University
Lviv, Ukraine
taras_maksymyuk@lp.edu.ua

Ruslan Kozlovskiy
Department of Telecommunication
Lviv Polytechnic National University
Lviv, Ukraine
ruslan0kozlovskiy@gmail.com

Abstract— **This paper proposes a new dynamic spectrum-sharing algorithm for combined cellular networks which can allow users to access both networks simultaneously using the same spectrum resource. This article proposes an algorithm to save spectrum resources due to the limited and costly bands. The proposed method for enhancing the spectrum utilization of combined radio interface (CRI) is called the dynamic spectrum sharing algorithm (DSSA). The proposed algorithm dynamically reallocates the occupied channels to meet the quality of service (QoS) requirements for each user. This is a different idea from traditional static spectrum sharing algorithms (SSSA). In the proposed DSSA, spectrum utilization is enhanced by dividing the entire spectrum into three separate zones: determination zone, which is occupied concurrently by GSM or LTE users, and fixed zones just for GSM and LTE users, respectively.**

Index Terms— **GSM, LTE, Cognitive Radio, Spectrum Sharing.**

I. INTRODUCTION

Modern mobile networks technologies rapidly developed towards higher performance, better energy efficiency and low cost per bit transmission. Current research interests is Advanced Long Term Evolution (LTE-A) networks, which able to provide throughput up to 1 Gbit/s [1]. Some research groups already started work on 5G networks development [2]. Deployment the next generation mobile network always meet a problem of additional spectrum resources. Due to market inertia, previous generation networks usually used simultaneously with just deployed new network. Thus, implementing next generation networks, providers should choose between two directions: purchasing a license for additional spectrum resources or implementing new standard network in combination with the existing network. The combined implementation assumes that both standards will utilize single spectrum band concurrently. This conception is known as Cognitive Radio [3].

CR is an opportunistic technology designed in order to utilization the maximum available bandwidth for current transmission. Wireless communication devices rapidly spreads and thus the problem of available spectrum limitation becomes even more urgent. Recently, the infrastructure-based CR, were developed for increasing the spectral efficiency cellular networks [4] and Spectrum Sharing Algorithms (SSA) been developed for this CR type [5]. Because in some countries, the additional spectrum resources are quite expensive, the new conception of cellular networks assumes joint spectrum utilization by different technologies.

In this paper, a new Dynamic Spectrum Sharing Algorithm (DSSA) proposed for joint spectrum utilization by existing GSM and new LTE (LTE-A) radio access networks. Existing Static Spectrum Sharing Algorithm (SSSA) divides the entire spectrum resources into three separate zones:

- GSM fixed zone – a part of the spectrum resource that provides service only through a GSM/EDGE radio access network. LTE technology is not allowed;
- LTE fixed zone – part of the spectrum resource that provides service only through the Evolved UMTS radio access network (E-UTRAN). GSM technology is not allowed;
- determination float zone – part of the spectrum resource, which can provide service through both GSM and LTE (LTE-A).

SSSA uses the static division of the spectrum between GSM and LTE, according to the average utilization during the day. Sometimes, however, the network loading conditions become very different from the average, which causes an overload of the spectrum resources and a denial of service. Applying the determination zone allows a change in the balance between both technologies using Cognitive Radio approaches. Base station equipment automatically detects the available spectrum resources, and changes the transmission or reception parameters providing service for GSM or LTE subscribers.

II. PRINCIPLES OF LTE AND GSM RADIO RESOURCES ALLOCATION

The main technique for the LTE PHY level is orthogonal frequency division multiplexing (OFDM) [6]. According to the OFDM principles, the entire wideband channel is divided into many narrow band subcarriers with a 15 kHz bandwidth. In contrast to UMTS, which uses a continuous spectrum 5 MHz with code division multiple access, OFDM divides the data stream into many slower data streams, which are transported over many carriers simultaneously. The advantage of many slow parallel data streams is that a pulse can be sufficiently long to avoid the issues of multipath transmission on the fast data streams. To save the total bandwidth, the subcarriers are spaced in such a way that the side lobes of each subcarrier wave are exactly zero at the center of the neighboring subcarrier. This property is called – orthogonality.

In the time domain, 10 users occupy a 10 ms frame, which divides into 1 ms subframes for each user. One subframe consists of two 0.5 ms time slots. Each time slot is divided into 7 time interval with a 66.7 µs duration. At least 12 subcarriers are scheduled for one user because of the small throughput of each subcarrier. The part of the time-frequency resources contain a single 0.5 ms time slot and 12 consecutive subcarriers called the Resource Block (RB). The RB consists of 84 Resource Elements with 66.7 µs intervals and a 15 kHz bandwidth. Each RE transmits a symbol modulated by BPSK/QPSK or 16/64 QAM modulation of the users data or signaling information. Therefore, OFDMA forms a time-frequency resource grid [7, 8] (Fig.1).

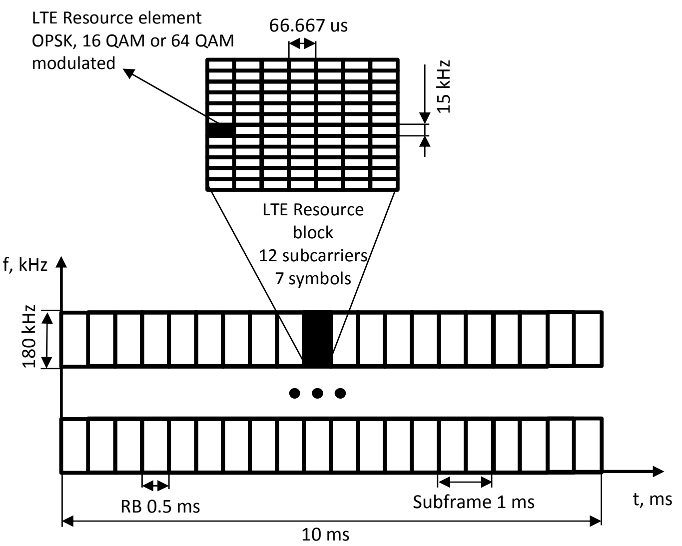

Fig.1. Radio resources grid of LTE network

Consider the GSM radio interface [7]. The frequency domain spectrum is divided into 384 channels in the 1800 MHz range. The bandwidth of each channel is 200 kHz. In the time domain, 8 users occupy a single frame with a 4618 µs duration. The time division multiple access frame (TDMA) consists of 8 time channels, 577 ms each (Fig.2).

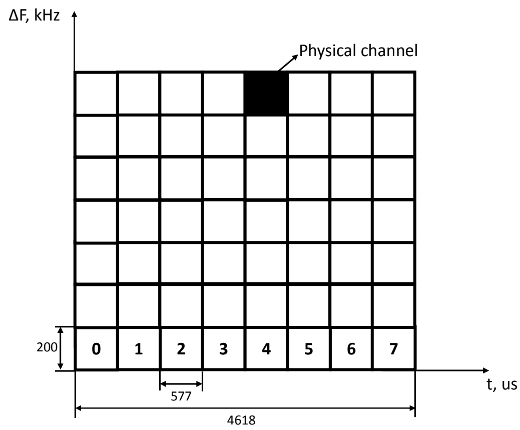

Fig. 2. Radio resources grid of the GSM network

III. DYNAMIC SPECTRUM SHARING ALGORITHM

In [9] scenario, each GSM carrier can allocate 8 or 16 subscribers using the full rate (FR) and half rate (HR) channel mode was considered. The orthogonal sub channel technique, developed by Nokia-Siemens Network, which is capable of duplicating the voice capacity of the GSM channel, was used to improve the spectrum sharing performance [10]. Therefore, up to 16 or 32 users can occupy a single carrier by the double full rate (DFR) or double half rate (DHR), respectively (Fig.3).

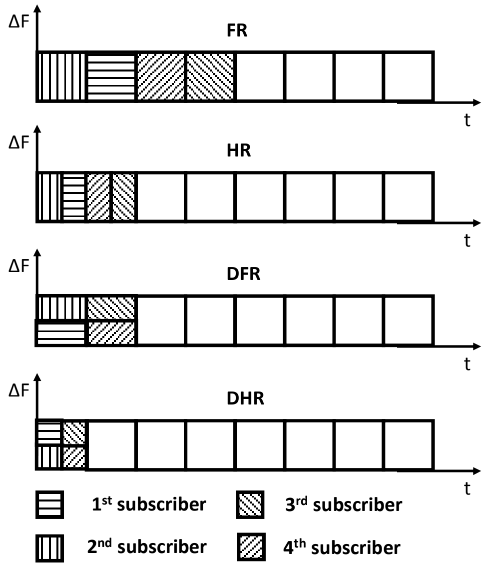

Fig.3. Comparison of physical channels utilization for different channel modes

According to the parentage of GSM, the time-frequency resource grid of the radio access network was considered as the following matrix:

$$\mathbf{RS} = \begin{bmatrix} t_{11} & \cdots & t_{18} \\ \vdots & \ddots & \vdots \\ t_{n1} & \cdots & t_{n8} \end{bmatrix}, \quad (1)$$

where n is the index of the GSM carrier (200 kHz).

Each element of matrix (1) represents a single byte, which contains information on the channel current condition:

$$t_{nm} = Q_{nm} \cup A_{nm} = \{q_3, q_2, q_1, q_0\} \cup \{a_3, a_2, a_1, a_0\}, \quad (2)$$

where Q_{nm} denotes 4 bits of the channel quality identifier (CQI) value and A_{nm} denotes the current channel utilization status [11].

The CQI values varies from 1 to 15 and are directly proportional to the signal/noise ratio in the current channel if the channel is allocated, and zero if the channels is free [12].

DSSA looks for zero elements in matrix RS, and calculates the total number of unused channels. If the number of free channels is more than 8, the matrix RS rearranges due to the established free carrier. If LTE subscribers require additional spectrum resources, DSSA performs a request to the network control center regarding the priority of current users. The control center returns the following matrix:

$$\mathbf{S} = \begin{bmatrix} s_{11} & \cdots & s_{18} \\ \vdots & \ddots & \vdots \\ s_{n1} & \cdots & s_{n8} \end{bmatrix}, \quad (3)$$

where snm denotes the necessary Quality of Service for a user allocated on the m^{th} time channel of the n^{th} carrier (0 – free, 1 – DHR, 2 – DFR or HR, 3 – FR only).

By analyzing the matrices, RS and S, DSSA knows which user can be reallocated to the HR, DFR or DHR channels. By default, the users are allocated to the FR channel. If a current circumstance requires compression of the spectrum channels, the DSSA checks for users that can be reallocated to the DHR channel (S=1), and then reallocate them to the HR channels. The algorithm stops if there are sufficient spectrum resources for all GSM and LTE subscribers. Otherwise, the orthogonal sub channel algorithm applies for users with S= 2, 3.

Furthermore, if there are users with equal values of S and A, the dynamic frequency and channel allocation algorithm (DFCA) applies [13]. DSSA obtains information from the DFCA regarding the channel conditions and checks the matrix RS for the CQI values. Therefore, users with better SNR conditions are reallocated primarily. Fig. 4 presents the time-frequency resource grid of CRI.

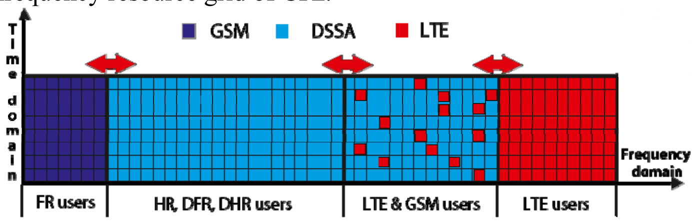

Fig.4. Radio Resources grid of the Convergent Radio Interface

IV. Conclusion

This paper proposes a new Dynamic Spectrum Sharing Algorithm for infrastructure based cognitive radio network. The combined radio interface of GSM and LTE networks was studied and advantages of the joint spectrum utilization was proved. Proposed algorithm takes into account different spectrum utilization by each users category, and channel quality identifier status for each connection. Moreover, spectrum utilization scheme is enhanced by establishing an additional zone for spectrum sharing and state-of-the-art techniques implemented in DSSA considering the quality of users experience for each GSM and LTE subscribers.

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