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# Rule-based dynamic TV white space spectrum sharing services composition framework

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ABSTRACT

When developing a TV White Space (TVWS) system with the available TV spectrum after digital switchover, the smooth introduction of new technologies and components has to be supported because the requirements of users change frequently in a new system. We need to provide a modular, extensible and easy to implement framework rather than building highly integrated systems. According to environment, rules, polices and users' requirements, advanced intelligent management functionalities that can guarantee the proper configuration of devices in TVWS networks and proper load balance, have to be developed. According to different requests from users, different algorithms and components have to be used to meet the needs of the users. How, when and which algorithms and components should be combined in order to meet the requests from the users become essential problems. Based on Service Oriented Architecture, all things in the proposed system including algorithms and components can be defined as services. This paper presents a framework of rule-based dynamic TVWS services composition that can meet the above needs and combine different TVWS services to fulfil users' requirements dynamically.



## 1. Introduction

Wireless data networking technology is ideal for many environments, including homes, airports, and shopping malls because it is inexpensive, easy to install, and supports mobile users. As a result, and a tremendous growth in mobile broadband, we have seen a sharp increase in the use of wireless over the past few years [1,2], and this has in turn resulted in a sharp increase in demand for radio frequency (RF) spectrum resources. There is currently great interest in cognitive wireless network strategies to find new solutions for Spectrum Resource Management [3].

In particular both in the United States and the UK a significant portion of spatially unused RF spectrum within the existing TV band are becoming available for secondary sharing for devices with cognitive capabilities [3]. This spectrum is known as TV White Spaces (TVWS). Initially cognitive radios with sensing capabilities were considered as prime contenders for access to TVWS. In sensing-based cognitive radios sophisticated algorithms are used in order to detect the presence of TV signals and avoid harmful interference to the primary TV band users. However, sensing-based cognitive radios suffer from a number of issues, including uncertainty and the CPU, time and energy cost associated with detection. Consequently, a different approach based on the use of geolocation databases has emerged as the most pragmatic and robust approach for access to TVWS, and is also endorsed by the US and UK regulators [4].

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In a Geolocation system, prior to accessing the TVWS spectrum, a white space device has to register its location and, possibly, other characteristics with a designated database provider. The database then uses this information to determine, via a set of propagation modelling computations, a list of available TVWS channels at the location of the device along with the maximum transmit power to be used per channel. This information is then sent to the device, which selects from this list one or more vacant channels for its transmission [5]. However, an intelligent system is required on top of the simple geolocation service that can integrate TVWS devices and networking technologies, management functionalities, algorithms and cognitive, reconfigurable and cooperative schemes and can allow quick development and deployment of new algorithms and applications. The removal and replacement of existing algorithms and applications and the introduction of new modules and technologies are required. This means the low level applications and algorithms have to be abstracted through high level interfaces.

There has been considerable research in recent years on resource management systems in the context of cognitive radio. In [6] the authors propose the concept of a Cognitive Radio Manager, as an evolution of the classical Radio Resource Manager in cellular networks. They aim at enabling a dynamic and distributed cross-layer approach to resource management, and the authors also attempt to implement a system with flexibility and modularity. In [7] development of a case-based reasoning cognitive engine is discussed in the context of the IEEE 802.22 WRAN applications. In [8] the authors investigate the applicability fuzzy logic and case-based reasoning methods as the core reasoning engine for a cognitive radio WiMAX system. In [9,10] an innovative and generic approach to developing cognitive radios is based on the radio environment map. The researchers in [6–10] present important advances in the development of resource management systems for cognitive radios. However, the majority of previous systems are highly integrated ones which are not very flexible.

Many researchers have attempted to provide modular, extensible and easier to implement frameworks rather than building highly integrated systems. In particular we believe that a system based on Service Oriented Architecture (SOA) can satisfy the requirements of modularity and flexibility very well. In an SOA system, everything is defined as a service. Services can be defined, registered, published, found and invoked respectively or combined with other services to constitute composite services. However, there is very little research which is focusing on SOA-based radio resource management systems. The authors in [11], for example, present the design and implementation of a service-oriented platform, and also introduce a large number of services.

Much more research, however, needs to be carried out in order to understand how to dynamically combine various services which are required to respond to requests from users. For example, different algorithms and components have to be used when different requests arrive. Some users send requests with one objective function while others send requests with more than one. Obviously, the algorithm handling requests with one objective is different from that handling requests with more than one. In this system, all algorithms and components are developed as services. How and when to combine which algorithms and components become essential problems. This paper presents the framework of rule based dynamic TVWS services composition that can combine different services to fulfil users' requirements dynamically. In the framework, when a request arrives, the requirements, the information of the device and environment will be analysed. Based on the analysis result, rules will be exacted from rules database to construct a composite service. At last, the composite service will be executed to satisfy the requirements of the users and result will be sent back.

This paper is organized as follows. In Section 2, details of TV White Space Database (WSD) are introduced. All applications of TVWS are based on this database. In Section 3 the system model and a detailed problem are given. In Section 4 we present the architecture of the framework. In Section 5 the performance of the proposed framework is presented. Conclusions are given in the final section.

## 2. White space database

Although potentially a large portion of spatially unused TV spectrum could be used by cognitive radios, the availability varies as a function of location and transmit power of devices. In this work we have made use of a tool developed at BT Research which quantifies the availability and variability of TVWS spectrum across the UK for low-power devices. These make use of publicly available coverage maps of digital terrestrial TV (DTT), which were generated via computer simulations from Ofcom's database of location, transmit power, antenna height, and transmit frequencies of the UK's DTT transmitters [12]. It combines these coverage maps with simplified propagation modelling calculations to obtain estimates of the vacant TVWS frequencies at any given location in the UK.

Fig. 1(a) shows a coverage map of channel 21, in which there are $800 \times 1600$ pixels and each pixel is coloured or white. For each different channel, there is a different corresponding coverage map. The coloured pixel indicates a location where a channel is occupied while a white pixel indicates a location where a channel is available. The tool was implemented with Python. The location coordinates encoded in the UK National Grid format (Easting and Northing) [13] are used as inputs. The National Grid is the map projection used on Ordnance Survey Great Britain maps. The 'false origin' (f.o.) is just south-west of the Scilly Isles to ensure that all coordinates in Britain are positive. The 'true origin' (t.o.) is 400 km east and 100 km south of f.o. The grid is divided into 100 km squares which each have a two-letter code. The area of one square is 100 square km. Hence, one square which has a two-letter code, such as SV, SW as shown in Fig. 1(c), is a square with sides of 100 km.

When a request with location arrives, the location coordinates are transformed into the corresponding pixel in coverage maps. Then the model can know whether the