TV White Space as a Rule Based Expert System

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Background

- Protection of incumbent users from interference within their service area is one of the greatest challenges in TV white spaces technology.
- The TV band has greater transmission range and better penetration property than the higher frequency bands.
- With no proper measure of handling the interference in place the proliferation of future wireless networks in the TV band could be hindered.

Background

- The use of geo-location Spectrum database for detecting TV white spaces for white space devices (WSDS) is one of the ways of fulfilling regulatory requirements for the use of white spaces.
- The approach gives a centralized spectrum usage control by protecting white space devices from interfering with TV transmitters.

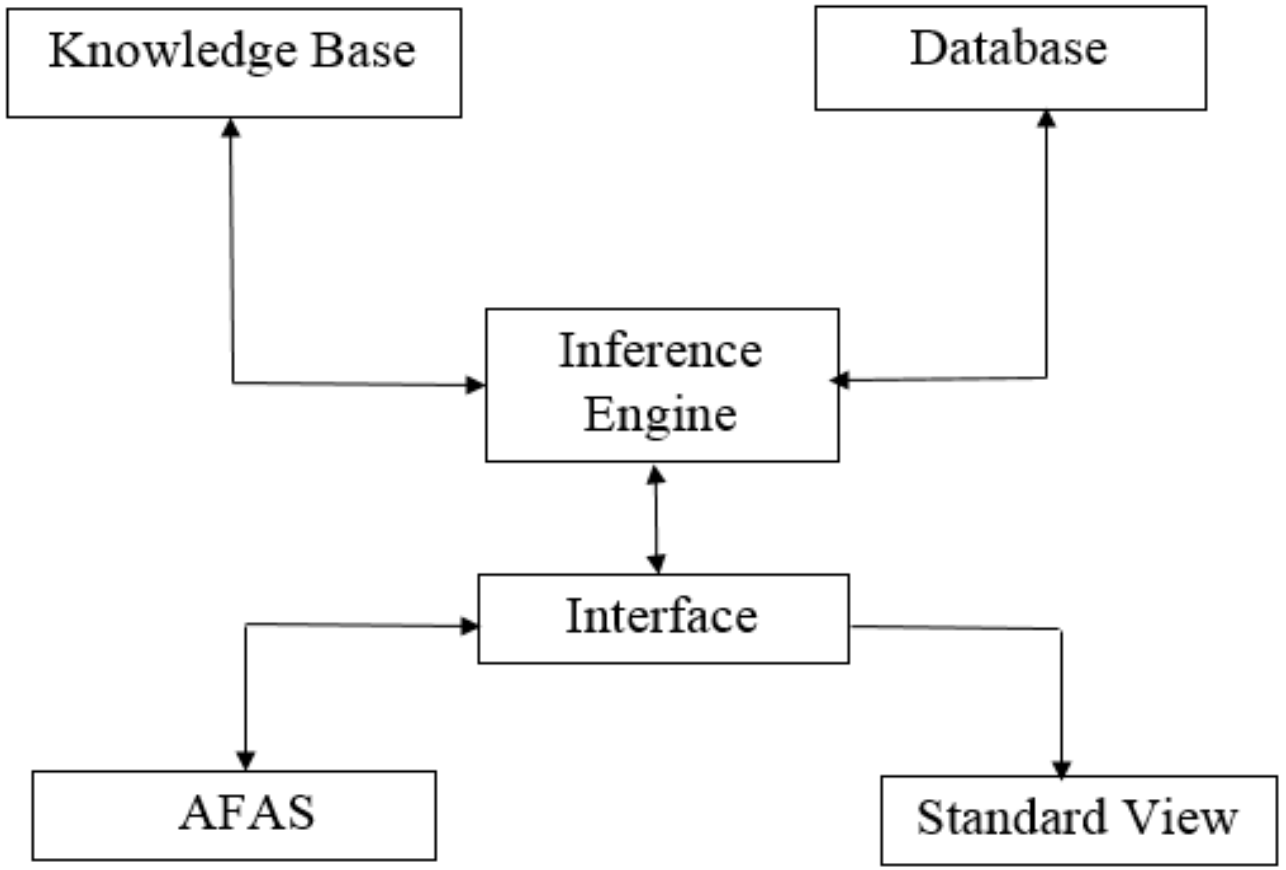
Introduction

- TV white spaces database has been implemented for the use of TV white space in Malawi and can be used elsewhere.
- The database has been implemented as a rule based expert system and has a capability to adapt to changing conditions of the spectrum.
- An expert system is any system that is able to apply expert knowledge, in this case the knowledge is TV white space rules.

System architecture

- The database has been implemented as rule based expert system with four main parts:
  - knowledge base
  - Database
  - inference engine
  - Interface
    - Advanced Frequency Allocation System (AFAS)
    - Standard view

System architecture diagram



Knowledge base

- Contains the TV white spaces domain knowledge.
- The knowledge is used when allocating a channel to a white space device and resolving frequency interferences.
- knowledge is represented as a set of rules “IF-THEN structured”.

Some of the rules

- Permissible Frequency of Operation by WSDs.
- White space device geo-location determination.
- Determination of available frequencies and maximum transmitting power.
- Accessing the database.
- Time validity and database re-check requirements.

[http://www.dynamicspectrumalliance.org]

Database (data storage)

- This part will include a set of facts used to match against the conditions parts of the rules in knowledge base when making decisions.
- A fact in this case may be channels occupied by incumbent users or white spaces at a specific location or the boundaries of operation of operators.

Categories of Information

- Locations and channels of protected facilities that are registered with a regulatory authority.
- Location and channels of protected facilities not registered with the regulatory authority.
- Information about location and identification of secondary White Space Devices (WSDs).
- Priority of the devices that are using the spectrum or are requesting to use a channel.

Inference Engine

- This part of the system carries out reasoning:
- By linking the rules in the knowledge base to the facts in the database using **forward chaining**.
- Reasoning starts from the known data and proceeds forward with that data.
- For example if a white space device requests a channel, the inference engine will first check the database for the facts.

Inference Engine

- Each time a new rule is fired, data is added to the database hence adaptive.
- At times, the knowledge base may not be searched for a rule because the database may have information enough to make a decision “**database learning capability.**”

Interface

- This is the part where the Expert System interacts with the users: WSDs and people.
- Has two parts:
  - Advance Frequency Allocation System
  - Standard view

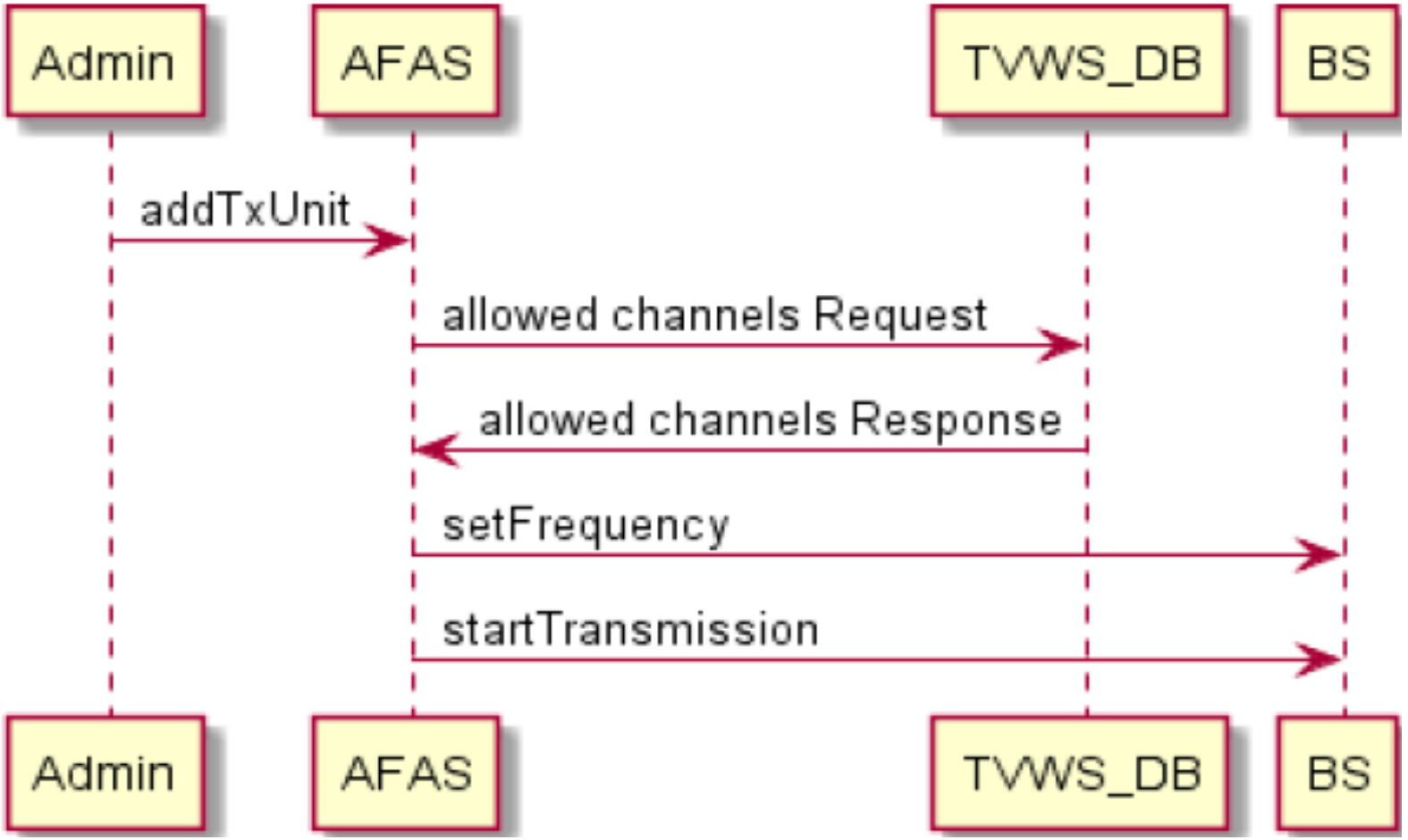
Advanced Frequency Allocation System (AFAS).

- This is the interface or the mediation device between the database and white space devices.
- The AFAS sits on a separate server implemented in node and python.
- When deploying a new base station, operator updates AFAS with the base station information, the installation location, the radio capabilities and the initial frequency which is selected from the database manually.

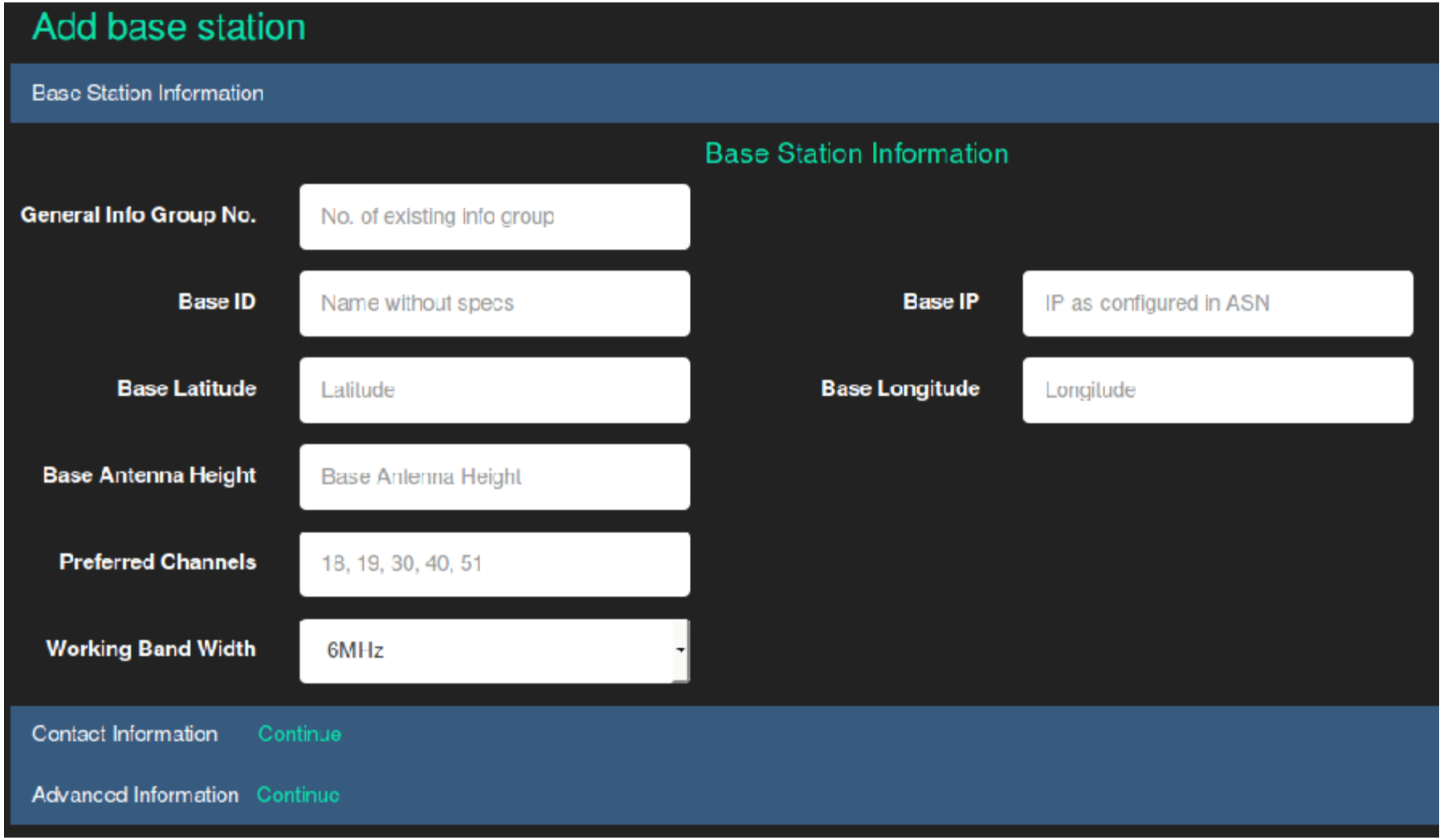
Advanced Frequency Allocation System (AFAS).

- Periodic update is done once in every 24 hours. The process is initiated in two ways:
  - Expiry of a timer using synced tasks in the AFAS management system.
  - System administrator using AFAS front-end web interface

AFAS position in the system



AFAS interface

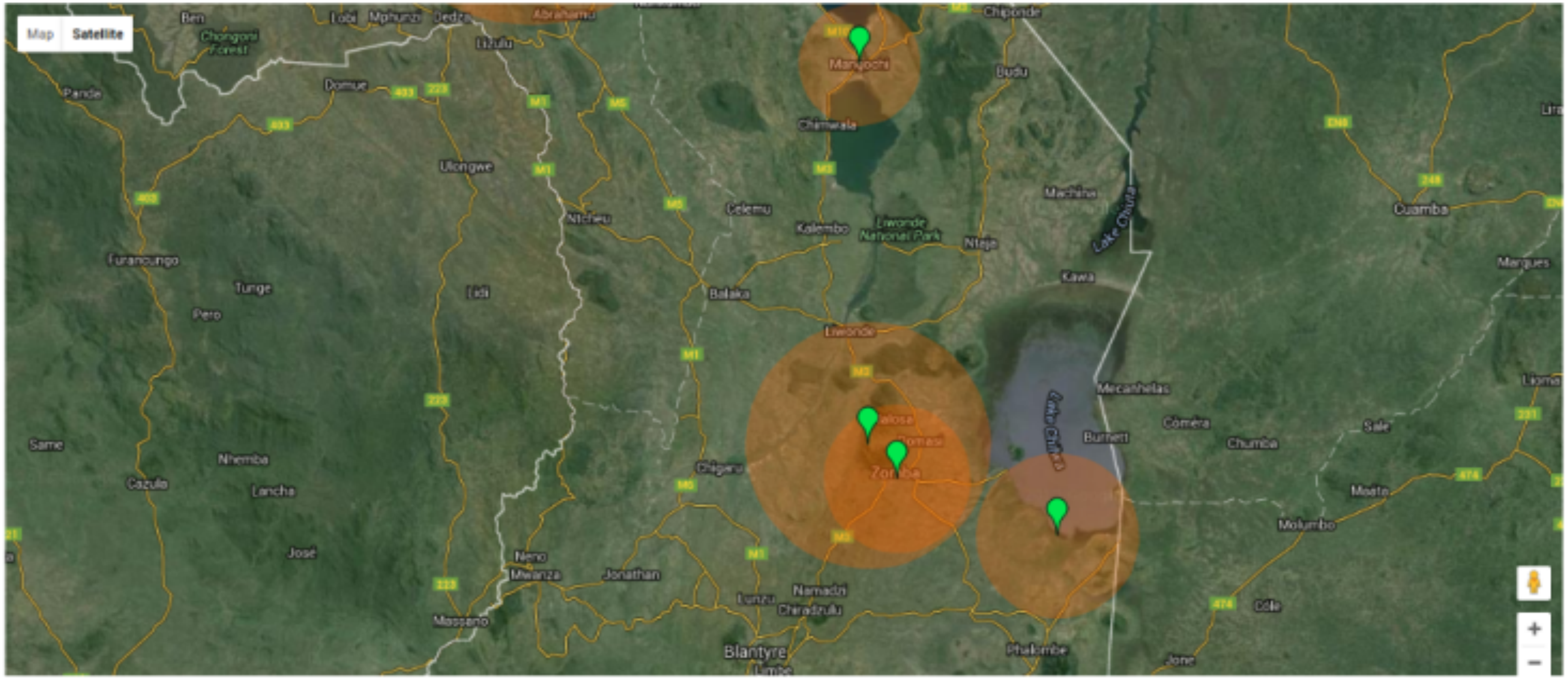


Standard View

- This is the part where the overall view of the white spaces and frequencies occupied by incumbent spectrum users can be viewed from a single machine.

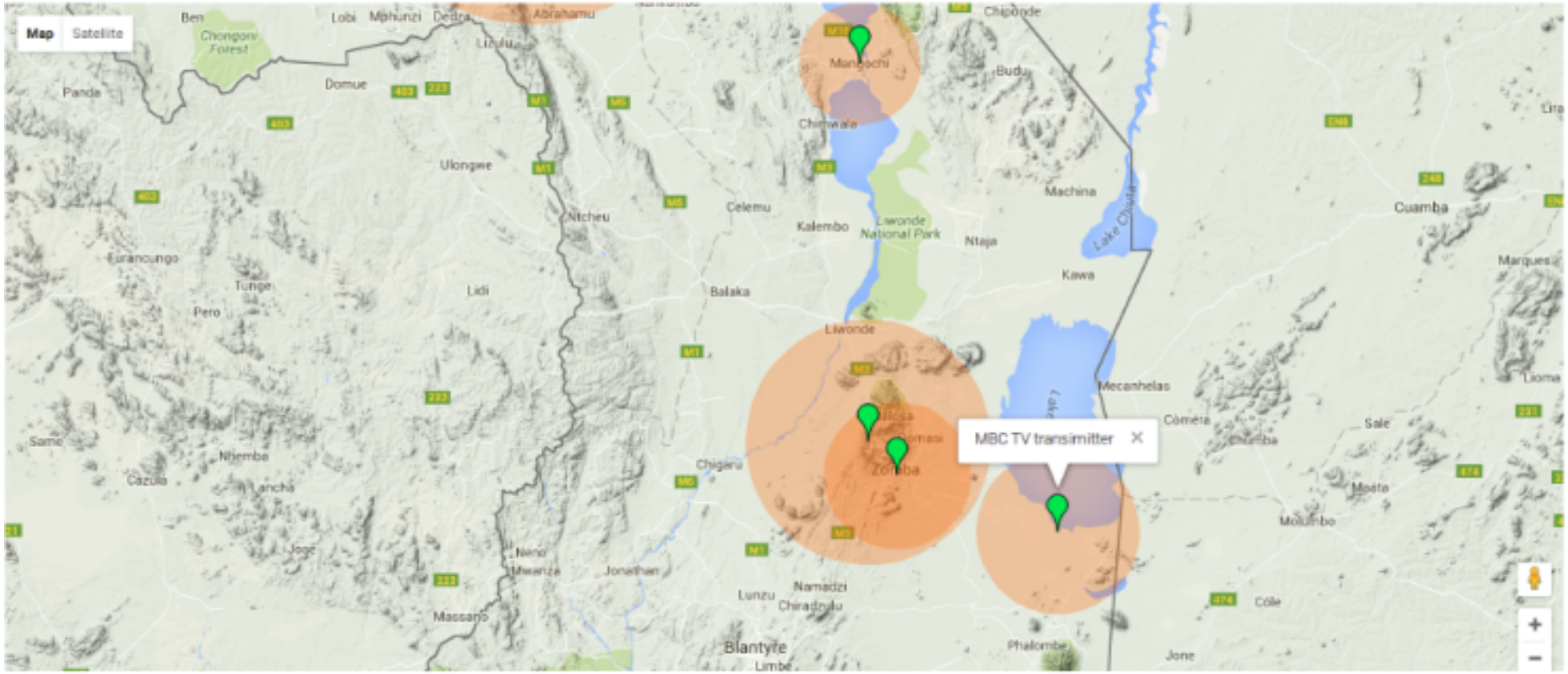
- This interface is available to be used by the regulator in monitoring the TV spectrum and other users which are recommended by the regulator.

View



Map
Satellite
Chiponde
Budu
Ulongwe
Ntcheu
Balaka
Liwonde
Liwonde National Park
Kalembo
Ntaje
Machinga
Lake Chiuta
Cuamba
Marrupa
Kawa
Mecanhelas
Burnett
Chumba
Molumbo
Cazula
Lancha
José
Neno
Mwanza
Jonathan
Namadzi
Chiradzulu
Blantyre
Limbe
Phalombe
Zomba
Lidi
Tunge
Pero
Nhemba
Furancungo
Pande
Domue
Lizulu
Massano
Chigaru
Cuamba

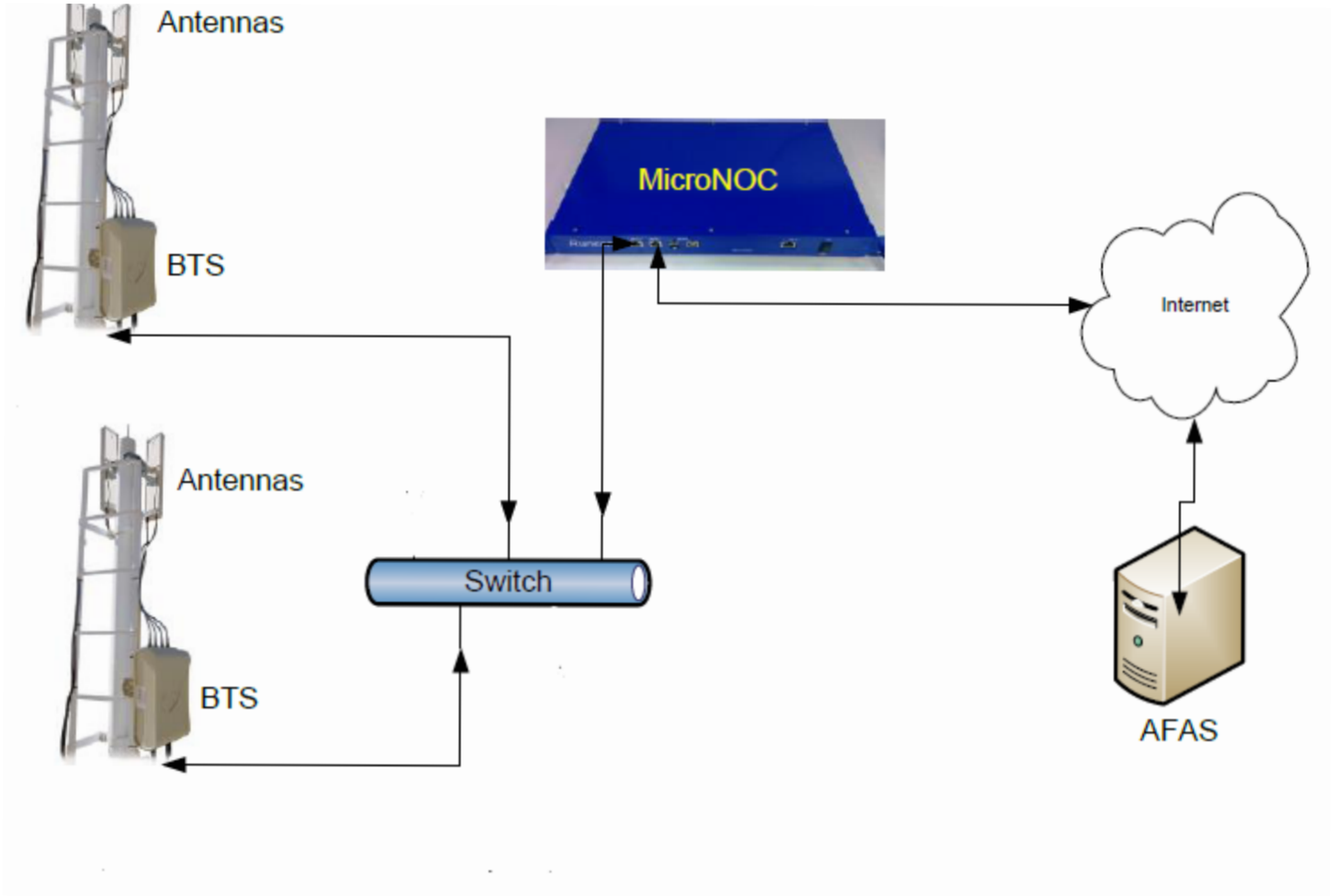
Standard View



Network structure and infrastructure (Tested)

- The interface used for testing implemented is a standard WIMAX 802.16e.
- This standard includes adaptations to support the TVWS spectrum and management requirements under FCC part 15 mandatory requirements.

Network structure and infrastructure (Tested)



Conclusion

- The structure of the system can allow easy modification of the rules for allocating frequencies.
- The interface for accessing the database can also be modified with no further change to the actual database since it has a separate implementation i.e. sit on a separate server.
- The database can be easily modified for use in another country.