Microsoft

NTIA Response to Notice of Inquiry

Establishing a Spectrum Monitoring Pilot Program

Submitted by

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1 Executive Summary

Microsoft has been running a Spectrum Observatory Program with the purpose of providing an intuitive presentation of the usage of the wireless spectrum. The project is sponsored by Microsoft's Technical Policy Group and the data is made freely available to the public. Data is recorded through measurement units and is stored and processed for visualization through the Windows Azure cloud.

Microsoft Spectrum Observatory collects and presents frequency spectrum usage data in a way that interested parties can have an open discussion about current and future uses of allocated frequency spectrum. The data collected on with this program has been used to inform research and discussion in instances such as the following:

Characterizing Spectrum Goodness for Dynamic Spectrum Access

http://research.microsoft.com/apps/pubs/default.aspx?id=174795

MS Spectrum Observatory: Seeing Things NTIA Doesn't Want to See

http://www.marcus-spectrum.com/Blog/files/MSO913.html

Microsoft believes that the data gathered on spectrum utilization will help inform policy discussions and decisions implicating various forms of spectrum management – ranging from reallocation of spectrum for exclusive use licensing or unlicensed access to dynamic access to allocated but unassigned spectrum.

To support this effort by collecting spectrum usage data, measurement units have been installed by Microsoft in various locations around the world. Microsoft philosophy in developing this program has been to keep costs low and to keep the solution flexible and open to others. We are of the opinion that any solution that the NTIA develops should also have these philosophies and should be collaborative in the approach that is taken. Using this experience, the following document is a response to the NITA’s inquiry on spectrum monitoring.

2 Overall Response

The NTIA's stated goals are very well aligned with the current goals of Microsoft's Spectrum Observatory.

- *The system would be designed and intended to interoperate with other third-party measurement units and spectrum databases to enable academic and industry researchers, commercial and government spectrum managers, and independent database managers to implement and deploy their own data collection and dissemination systems.*
- *Make available to interested parties criteria, requirements, parameters, designs, interfaces, software, data sets, and other information generated at each phase of the project.*
- *Prototype monitoring unit would be designed to run continuously at remote sites with system control and data uploads performed over the Internet.*
- *Standardized data sets would be accumulated and analyzed within the unit and uploaded to a centralized database.*
- *Based on the fully developed and tested prototype unit and subject to available funds, ten or more identical spectrum measurement units would be built and deployed in up to ten major metropolitan areas throughout the United States.*
- *Once deployed, they would continuously monitor the spectrum and collect data in predetermined frequency bands and upload them to the database.*

Our experience in this space has led us to believe that it is a logistical and financial challenge for a single party to install all new measurement units and continue to support the ongoing operations of those units. Additionally, Microsoft sees benefits in making this a collaborative effort involving parties in different locations, presenting different perspectives on data collection, and potentially arriving at different conclusions about spectrum allocation and use based on the data collected. These are benefits that can be derived from an open and collaborative approach. As a result, Microsoft has started to look for partners within various communities to aid in the installation and support of new measurement units. The installation and support efforts over a calendar year are usually small, but are necessary in the case of hardware or infrastructure failures. For normal operation, all of the monitoring and storage of collected data to the cloud is completely automated. The benefits to partners are the following:

- Free storage of measurement unit data in the cloud.
- Additional data processing on the spectrum observatory data.
- Different ways to visualize the spectrum data that has been measured and processed such as power density, utilization, and spectrogram, with the potential for future expansion and customization by partners.

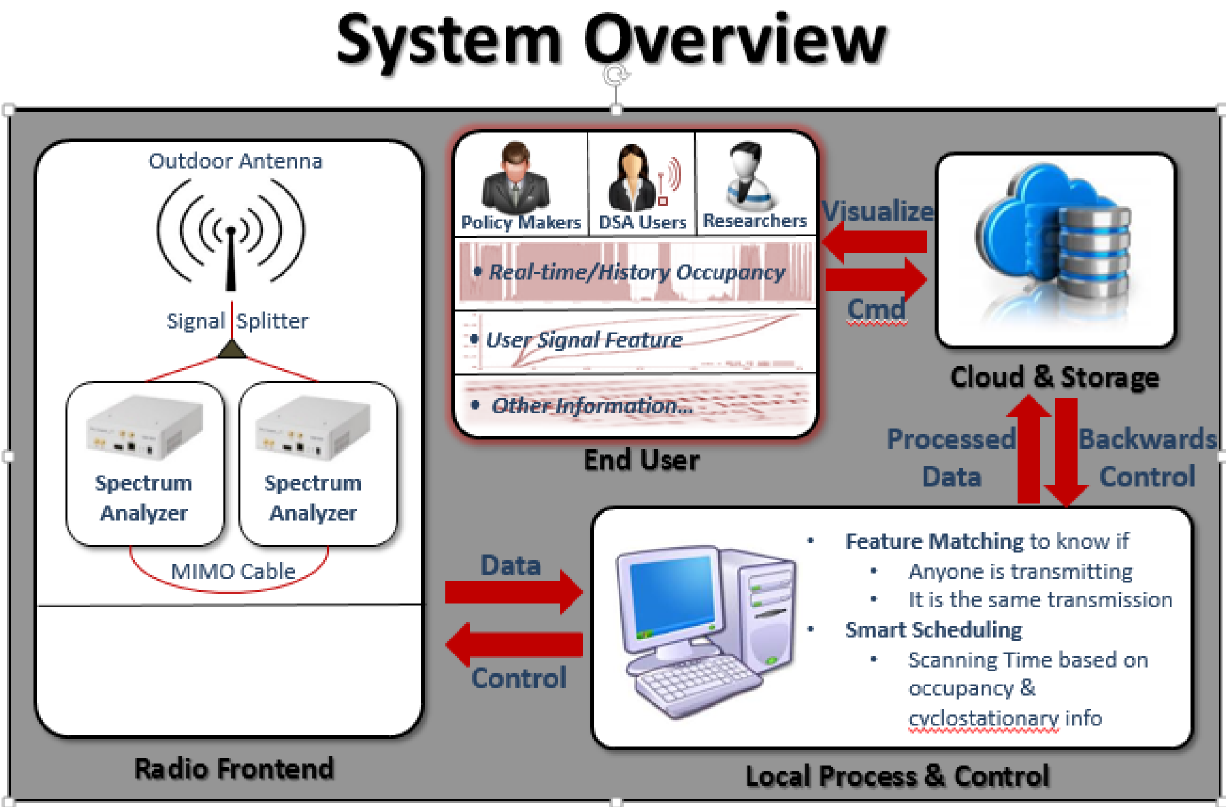
- Access to data from other measurement units
- Free updates to the software and website

Microsoft's architecture allows partners to integrate other radio types, and future additions will also allow partners to add other types of analysis and visualizations. Additionally, we would like to make this a tool that researchers, regulators, and other parties around the world can use by allowing those that are participating to have finer grained control of the spectrum sensing that is occurring at various sites, and then have the data available to them on the web. Eventually, the vision is that the entire Spectrum Observatory solution would become a project that is owned and managed by the community of partners that are established, with Microsoft being a single voice in that partnership.

Microsoft

3 Microsoft Spectrum Observatory Design

The following diagrams illustrate the architectural approach that Microsoft took in developing our Spectrum Observatory solution, which can be found here: http://spectrum-observatory.cloudapp.net/



Home Page


Microsoft Spectrum Observatory
Sign In
HOME
STATIONS
CHARTS
ABOUT
Browse Spectrum Stations
Discover all the spectrum observatory stations and measurements (eg., Frequency Bands).
Create New Charts
Create charts of your choice, save them and browse through built-in charts.
About
Learn more about Spectrum Observatory, User Manual, FAQs etc.
Technology Policy Group
The Microsoft Technology Policy Group is currently collecting frequency usage data from a number of sensor base stations. Select a sensor location to view more detailed reports and graphs about the spectrum usage.
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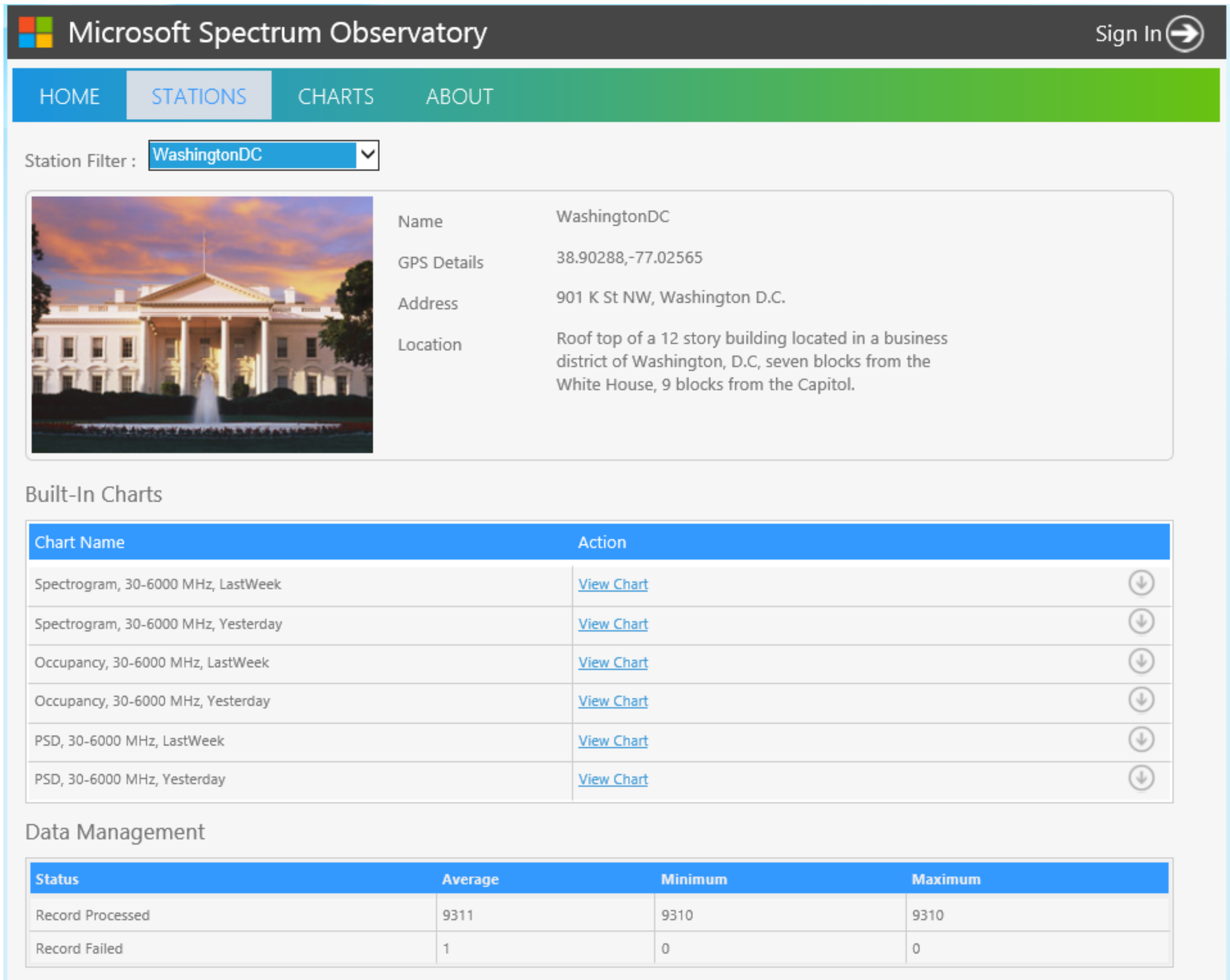
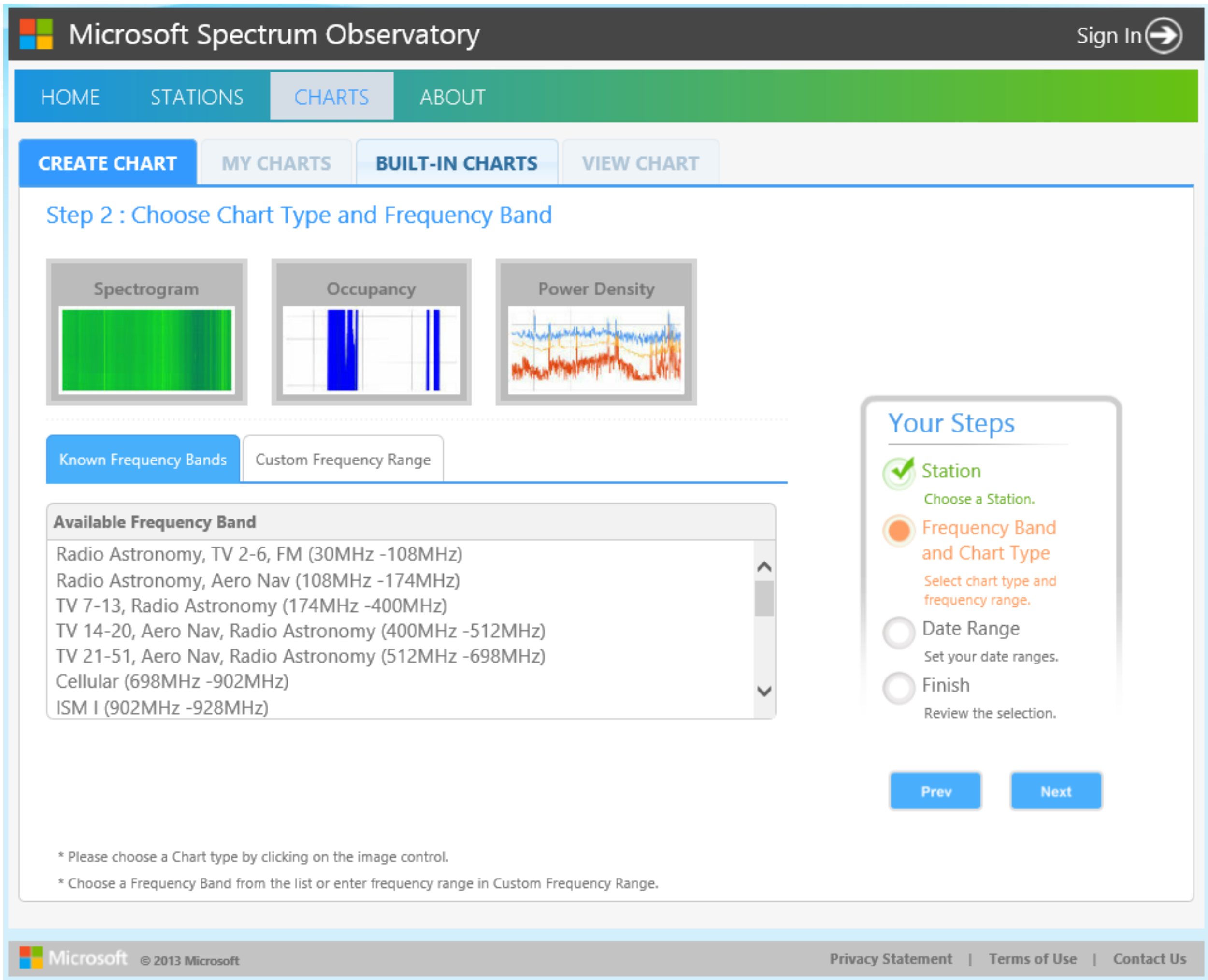
Measurement Unit Details



Charts



Microsoft Spectrum Observatory
Sign In
HOME
STATIONS
CHARTS
ABOUT
CREATE CHART
MY CHARTS
BUILT-IN CHARTS
VIEW CHART
Step 2 : Choose Chart Type and Frequency Band
Spectrogram
Occupancy
Power Density
Known Frequency Bands
Custom Frequency Range
Available Frequency Band
Radio Astronomy, TV 2-6, FM (30MHz -108MHz)
Radio Astronomy, Aero Nav (108MHz -174MHz)
TV 7-13, Radio Astronomy (174MHz -400MHz)
TV 14-20, Aero Nav, Radio Astronomy (400MHz -512MHz)
TV 21-51, Aero Nav, Radio Astronomy (512MHz -698MHz)
Cellular (698MHz -902MHz)
ISM I (902MHz -928MHz)
Your Steps
Station
Choose a Station.
Frequency Band and Chart Type
Select chart type and frequency range.
Date Range
Set your date ranges.
Finish
Review the selection.
Prev
Next
* Please choose a Chart type by clicking on the image control.
* Choose a Frequency Band from the list or enter frequency range in Custom Frequency Range.
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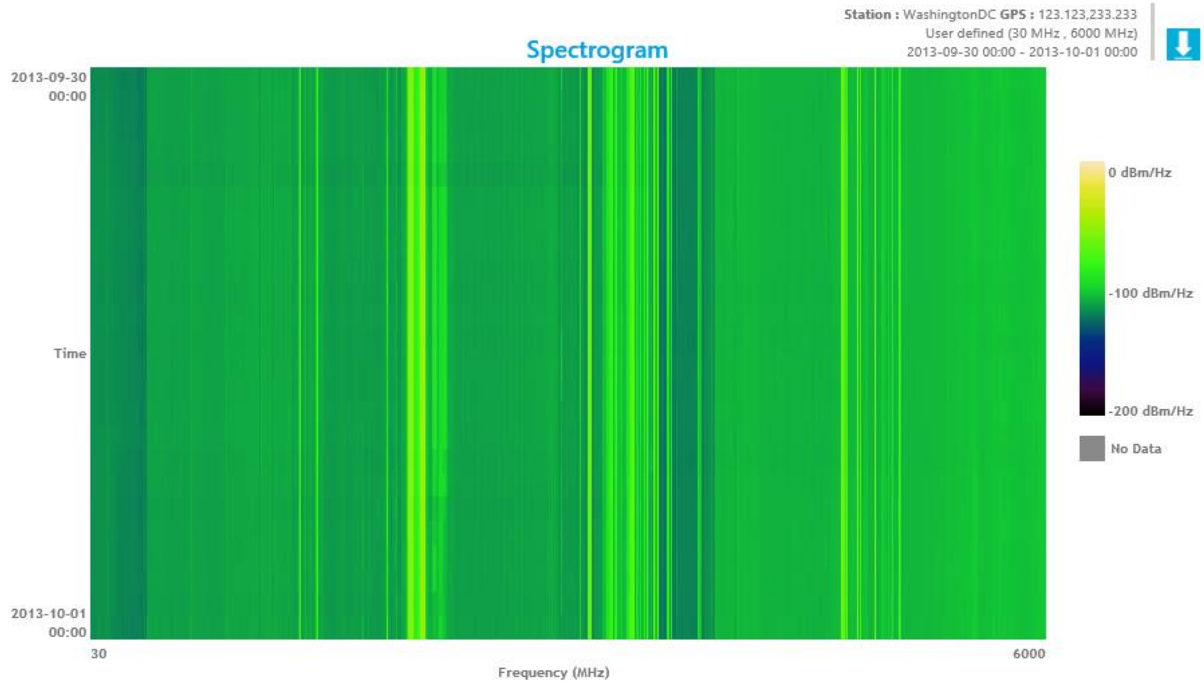
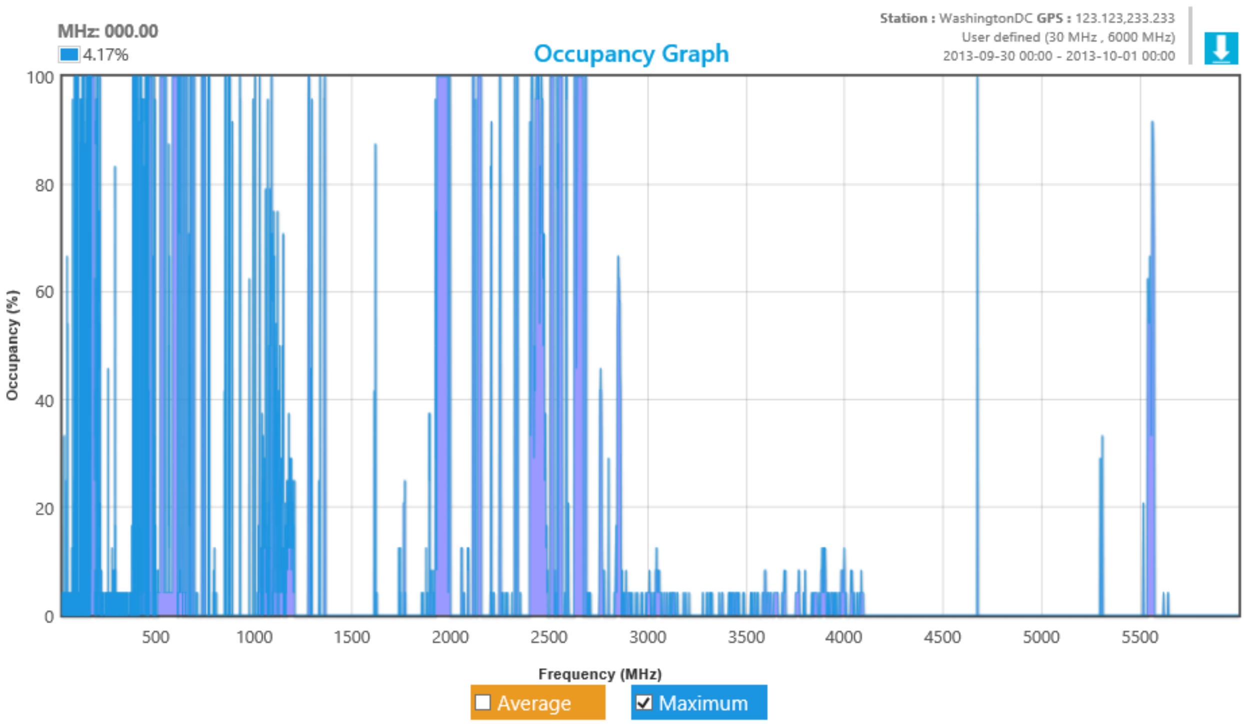
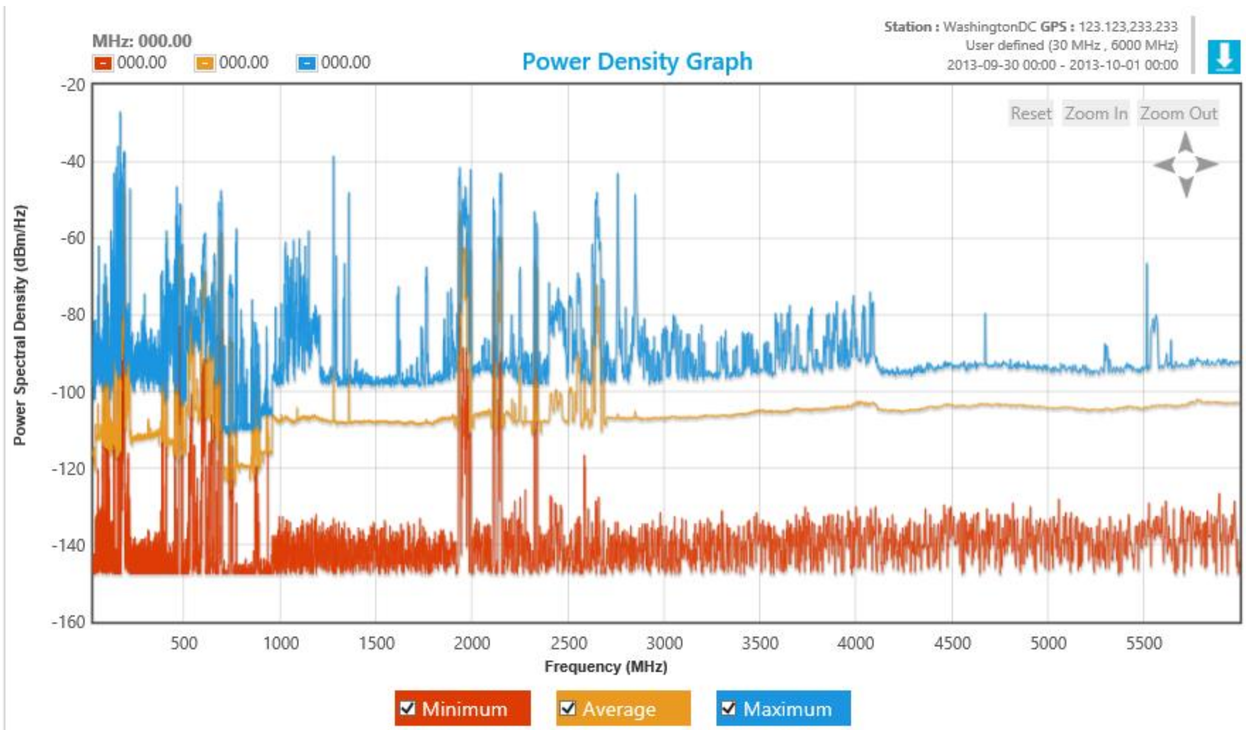
Spectrogram



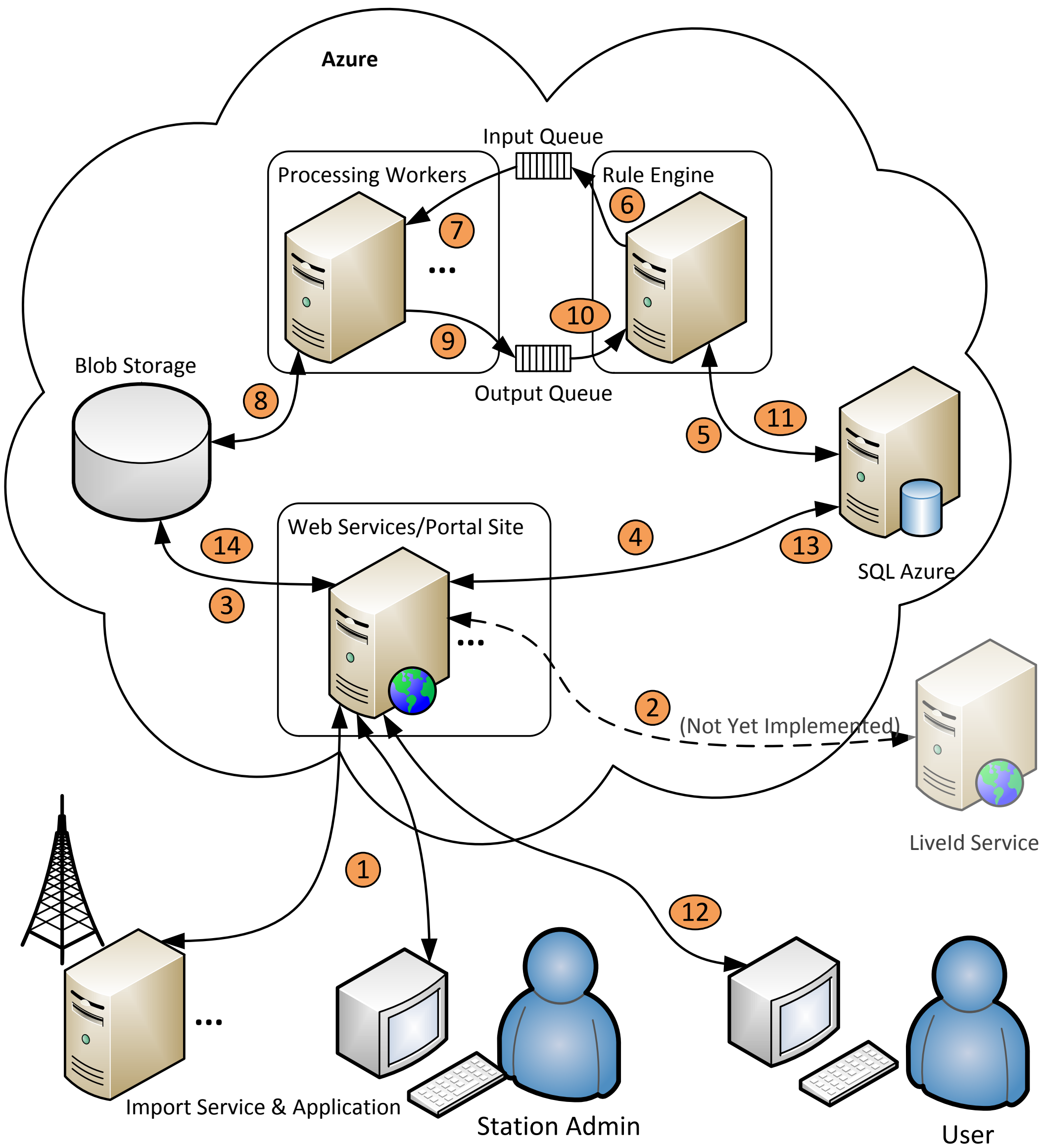
Occupancy



Power Density



System Design Details



4 Monitoring Unit Infrastructure Requirements

Here is a list of the current hardware required for a Microsoft Spectrum Observatory monitoring unit. The total costs of all of the initial hardware when using USRP radios comes to under $6,000 and this could be brought down significantly with newer hardware, by buying in larger volumes, or by changing the parts of the spectrum being measured.

Component Type	Specification
RF Sensors	• Ettus Research USRP radio with daughter cards
Antenna	• Omni-directional outdoor wideband antenna
Solution Software	• Spectrum Observatory Measurement Unit software
Server	• Minimum 1.8 GHz, 1 MB L2 Cache • Minimum 1 500 GB 7200 RPM drive • Minimum 4 GB PC3-10600 RAM • 3 Gigabit NICs
Operating System	• Windows Server 2012, but others could be supported
Network Switch	• Minimum 1 Gigabit Network Switch • At least 2 open ports
Clean Power	• Minimum of at least four outlets available • Outlets will have to conform to the correct amps and voltage of the hardware being provided • Power should be clean and surge protected • Any power outlet adapters for differing plug types
Cabling	• LMR-400 cabling between antenna and location where RF sensors are stored • SMA cabling between splitter and antenna cable, and between splitter and RF sensor
Connectors and Splitters	• SMA splitter

	• Connector/Convertor between type N and SMA
Internet Connection	• The connection must be able to support 0.22 megabits upload speed per second.

5 Specific Questions Response

5.1.1 How should a measurement system be designed to measure a variety of emissions, including weak or intermittent signals, airborne platforms, and radar systems, while keeping incremental costs in check?

Microsoft believes that any spectrum monitoring solution should be flexible so that it can be applied to the largest number of areas.

We believe the design of the system should be relatively agnostic to the hardware and the specific monitoring techniques that are doing the actual sensing. Microsoft accomplishes this by splitting the overall data gather process into four different tiers.

- Raw data capture by the RF sensor
- Feature extraction
- Upload to storage
- Processing and bucketing

Since the raw data capture is the key to being able to measure different types of signals and we are flexible with the types of hardware and the algorithm that is used to collect the raw data, we are able to measure even weak signals. Intermittent signals are handled by revisiting each spectrum band frequently to make sure that any transmission greater than a few seconds is captured. Airborne and radar systems are often point to point which is a little more challenging, but these can be handled by within our solution by deploying many sensors so that the likelihood of capturing these point to point transmissions is increased. Additionally, by using hardware to measure these specific signal types only when needed we are able to keep overall costs low. In total the average Microsoft Spectrum Observatory measurement units' hardware costs under $6000 to monitor between 30 MHz and 4400 MHz and this number could be brought down significantly if hardware was purchased in greater volumes or if the required area of spectrum coverage is altered.

5.1.2 What types of measurement/monitoring techniques should be used for the different types of radio services?

It is Microsoft's belief that any monitoring system should allow for various different techniques to be used so that improvements can be made over time and to take advantage of various techniques for different uses. Microsoft has currently developed two different monitoring techniques, but the solution that we have is open to other techniques to be integrated into the solution over time. This is possible because the design that we created is flexible and splits the monitoring/data capture from the rest of the solution. As a result, if the data capture technique is changed, as long as the format of the data remains the same, the rest of the solution is able to operate without additional changes. Additionally, the system is cognizant of different radio services by integrating with systems like the FCC dashboard or its regional equivalent. Depending on the use case the RBW and other parameters can be changes.

5.1.3 What frequency bands should initially be measured during the pilot phase of the program?

The Microsoft Spectrum Observatory currently measures from 30 MHz to 6000 MHz because it is a range that covers the frequency ranges commonly used today, to provide consumers with wireless broadband connectivity – for all the commonly used fixed and mobile wireless air interfaces. The solution itself also support other hardware types. Since we wanted to remain hardware agnostic, we found that allowing for flexibility in the frequency bands that are measured was the correct route for our purposes. By doing this, we are able to accommodate more measurement units with specialized hardware for different frequency bands.

5.1.4 How should measurement and monitoring parameters (e.g., resolution and video bandwidths, sampling rate, dwell time, detector selection, antennas, pre-selector filtering, dynamic range) be specified?

Again, the key goals that Microsoft had around developing a Spectrum Observatory was flexibility. As a result, all of the parameters are configurable. Currently, these are set up on the local measurement unit's monitoring system, but to allow for even easier changes and to centralize the management of observatory measurement units, Microsoft plans on storing these settings in the cloud, which the measurement units can then access.

5.1.5 Which geographic locations within major metropolitan areas or other communities throughout the country would provide the greatest value for the pilot?

Microsoft has no comments on specific areas or communities that should be considered. We would suggest that the selection process should include the following criteria:

- Locations with high usage of available spectrum such as the top metropolitan areas in the United States should be included.
- Locations should be included within range of current federal and others users which are currently under consideration for spectrum sharing and reallocation – such as users of 1.75-1.85 GHz and 3.5-3.65 GHz, as well as some of the 5 GHz users.

5.1.6 How should individual measurement units be deployed in each community?

Microsoft has no comments on the specific deployment of the measurement units in each community.

5.1.7 How could the long- or short-term placement of multiple fixed units within the same general geographic area improve the accuracy and reliability of the data collected in each community and at what incremental cost?

There are potential advantages of placing multiple units in the same general geographic area. By doing this, the data between two different observatories could be compared to verify results. Also, additional conclusions could be reached by combining the data from two or more units. The incremental costs should be no higher than the total costs of the hardware for the unit, installation of the unit, costs for connectivity to backend services, and costs for processing and storing the data. Some benefits of multiple sensors was shown in a recent ACM MobiCom paper, and the associated blog.

5.1.8 How could mobile or portable units be utilized to supplement data collected at fixed sites within a community and at what incremental cost?

Mobile or portable units could be used to supplement data by temporarily acting as a secondary site in a community. If it is considered a secondary site, the benefits are the same as a fixed secondary site for the period of time that it is in the community. The incremental costs should be no higher than the total costs of the hardware for the mobile or portable unit, transport of the unit, costs for connectivity to backend services, and costs for processing and storing the data.

5.1.9 How long should measurement data be collected to provide statistically relevant results, particularly for intermittent operations, at each geographic location?

The period of time required to collect statistically relevant results highly depends on the use of the data that is collected. Generally speaking, longer periods of time are better than shorter, and Microsoft has chosen to store one year's worth of data in our Spectrum Observatory with flexibility in the design of the solution to allow us to increase or decrease the period of data stored. This could also be set up per monitoring unit, so that for specific locations data is stored for much longer or much shorter periods of time. The data beyond these time frames is automatically deleted to reduce maintenance costs. Additionally, the raw data in Microsoft's Spectrum Observatory can be downloaded by end users so that they can maintain a copy for longer periods of time outside the system if there is a need.

5.1.10 How should the measurement system design take into account variations in population densities, buildings, terrain and other factors within or surrounding selected measurement locations (i.e., in urban, suburban, and rural parts of a metropolitan area)?

Microsoft has chosen to be somewhat agnostic to the particulars of the area surrounding the measurement units during the collection of data. The exact location of the data collection should be recorded as well as the specifics of the equipment performing the data capture, but analysis of the data and the effects of items like population densities, buildings, terrain and other factors is something that we have left to the analysis of the data after it has been captured.

5.1.11 What steps can be taken to eliminate or minimize the possibility of ''hidden nodes'' when conducting measurements?

Microsoft uses a few techniques to minimize the presence of hidden nodes. The measurement units use a low resolution bandwidth to detect low signals, or the ones that are not received by the sensor due to obstructions. Furthermore, to reduce the presence of obstructions, some measurement unit antennas are placed on buildings that do not have obstructions nearby. Density of measurement units will also help reduce the presence of hidden terminals.

5.1.12 What kind of spectrum utilization and occupancy information (e.g., precise received field strength levels, time-of day occupancy percentages, times that signals are measured above specified thresholds) would be most useful to spectrum stakeholders?

Microsoft believes that any monitoring solution should simply allow for collection and presentation of data to users. Currently the Microsoft Spectrum Observatory has the following chart types:

- Spectrogram in a specific date range and at a specific location
- Occupancy over various time scales and at a specific location
- Power Density in a specific date range and at a specific location

Microsoft also provides the raw data behind these charts, so that any calculations that are provided within our user interface can be independently verified. Over time, Microsoft plans on giving end users the ability to add their own chart types by providing interfaces for them to implement.

5.1.13 What detection thresholds should be used to measure and characterize the usage patterns of incumbent systems?

Microsoft suggests looking at exiting research that has already been conducted in this space to determine these thresholds, the following is an example:

Characterizing Spectrum Goodness for Dynamic Spectrum Access

http://research.microsoft.com/apps/pubs/default.aspx?id=174795

5.1.14 What data and information would be useful in evaluating potential sharing compatibility with wireless broadband devices?

While the following are useful, there may be other data and information that is useful in evaluating potential sharing compatibility with wireless broadband devices. It is important that the raw monitoring data is made available so that this other information can be determined and analyzed.

- Occupancy percentage – This is the overall percentage of time that a specific area of the spectrum is occupied.

- Occupancy pattern – If a specific pattern for occupancy can be determined, then the times when that area of the spectrum is not likely to be used is potentially a good candidate for sharing. For example, if a specific area of the spectrum is only used for the first 10 minutes of the hour, then the other 50 minutes could potentially be used for sharing.

5.1.15 How can the gathered data and analysis better inform spectrum policy decisions, enhance research and development of advanced wireless technologies and services?

With more accurate and more up-to-date data about spectrum usage, researchers, analysts, regulators, and industry can have better informed discussions about how to use spectrum more efficiently – whether as a result of reallocation for exclusive use or through various forms of spectrum sharing (or both). Also, all of these parties can also study the results of any policy decisions to ensure that the intended results actually occurred, which can then inform and improve future policy decisions in this space.

5.1.16 What data formats and evaluation tools should be employed?

Microsoft suggests that the data formats should be discussed and agreed upon by the industry. By having a common data format, various monitoring solutions could be made to be interoperable. This format should be extensible to allow new data to be added such as new feature vectors. Additionally, the data format should be efficient in terms of the size so that a minimum amount of storage is required to store the data, and a minimum amount of bandwidth is required to transmit it.

Interoperability also aids in allowing new evaluation tools to be developed over time and at a quicker pace since users can use the platform that suits them best, while having access to the most data.

5.1.17 How can the large amounts of measurement data be effectively managed, stored, and distributed?

Microsoft takes the approach of centralizing the measurement data in the cloud. Data storage is relatively cheap in the cloud. The link below is a simple way of calculating monthly storage costs in Windows Azure:

http://www.windowsazure.com/en-us/pricing/calculator/?scenario=data-management

Each measurement unit within Microsoft's Spectrum Observatory is responsible for uploading both the raw data as well as feature vectors like the min, max and average power within an area of the spectrum for a specific time period. As a result, the workload is distributed, but all of the data is available in one central place in the end. By storing the data in one central location, Microsoft is able to provide access to either visualizations of the data or the raw data itself to users of Microsoft's Spectrum Observatory website.

5.1.18 What steps can be taken to ensure that sensitive or classified information will not be revealed to unauthorized parties?

Security and access to the raw data are items that could be integrated into the solution that is created. Microsoft Spectrum Observatory project allows users specific functionality based on their current role which is determined by standard authentication and authorization techniques. If they are viewing the data as a guest, they get only the basic functionality available on the site, but if they sign into the site, then new functionality is revealed. Similar approaches could be taken with any sensitive or classified information.

6 Response Criteria

- Evaluate whether the proposed collection of information is necessary for the proper performance of the functions of the agency, including whether the information will have practical utility;
- Evaluate the accuracy of the agency's estimate of the burden of the proposed collection of information, including the validity of the methodology and assumptions used;
- Enhance the quality, utility, and clarity of the information to be collected; and
- Minimize the burden of the collection of information on those who are expected to respond, including the use of appropriate automated, electronic, mechanical, or other technological collection techniques or other forms of information technology (e.g., permitting electronic submissions of responses).