COMMERCE SPECTRUM MANAGEMENT ADVISORY COMMITTEE (CSMAC)

SPECTRUM SHARING WORKING GROUP (SSWG)

Feburary 3, 2012
Working Notes

TABLE OF CONTENTS

I. SPECTRUM SHARING WORKING GROUP WORKING RECOMMENDATIONS

The CSMAC recommends that the NTIA:

1. **Develop a set of spectrum sharing system requirements.** The requirements are used to develop and to analyze spectrum sharing approaches. The requirements include general requirements for most spectrum bands and requirements for specific bands. The requirements include estimated limits on the changes in incumbent use (waveforms, locations, occupancy, etc). The NTIA should develop both incumbent and entrant requirements, assuming that in some cases the entrant systems maybe other federal systems. The requirements should be made public and open for comment. Currently the requirements are not well known, which makes it difficult for incumbents and entrants to develop or analyze spectrum sharing approaches.

2. **Require that a management and control (e.g. an interactive database) feature be used in all spectrum sharing approaches.** The management and control feature is needed to supervise and reconfigure the entrant system. The management and control feature would have a defined reaction time (not necessarily continuously connected). The management and control feature would apply to geographic-based, to sensing-based, or to any other spectrum sharing approach.

3. **Not select a certain spectrum sharing approach at this time.** There are many potential spectrum sharing approaches that are capable of meeting the spectrum sharing requirements. The different approaches have their own costs, advantages and disadvantages that depend on the entrant and incumbent system details. Once the NTIA releases: (a) The requirements, and (b) More detailed information on the incumbent systems and the incumbent CONOPS, then these different sharing approaches can be evaluated by industry, and then specific proposals can be made to the NTIA. When analyzing alternate approaches, both the entrant and incumbent factors need to be considered in selecting the spectrum sharing approaches. It is likely that multiple spectrum sharing approaches will be used in a band to most economically accommodate the incumbent and entrant requirements. Selecting a spectrum sharing approach now is likely to result in a costly or an ineffective approach that will not ultimately be successful.

II. SPECTRUM SHARING REQUIREMENTS

These are the incumbent's and the entrant's requirements that different spectrum sharing approaches must meet.

1. Requirements of Incumbent

- Do No Harm to incumbent
- Accommodate Changes in Incumbent Use – Waveform types, occupancy, locations, etc
- Backup Band for entrant – Able reclaim the spectrum
- Enforcement – Track down interference events economically and quickly
- Safeguards/security – Protect against unauthorized and accidental use, avoid hackers
- DSA system diversity causing complexity – Many DSA types and entrants is too hard to manage
- Trust – Need assurance that agreement points will not change
- Security – Don't want to reveal classified information

2. Requirements of Entrant

- Do No Harm to entrant – Concerns that incumbent will have unreasonable interference criteria. Concerns that the incumbent system receiver and other equipment characteristics are different than originally planned for.
- Safeguards/security – Protect against unauthorized and accidental use, avoid hackers
- Support current architecture (i.e. frequency duplex)
- Minimal changes to standards – Want to purchase standardized, non-proprietary equipment from multiple vendors
- Low prime power
- Minimal software integration costs
- Capacity – Minimal capacity lost with 'Do No Harm' or with fair use rules
- High reliability and assured access
- Reduce operator workload
- Trust – Need assurance that agreement points will not change
- Fair use policy

III. WHAT KINDS OF SHARING ARE WORKABLE FOR INDUSTRY IN THE LONG TERM?

1. Spectrum Sharing Method Alternatives

a. Spectrum Sharing Mechanism

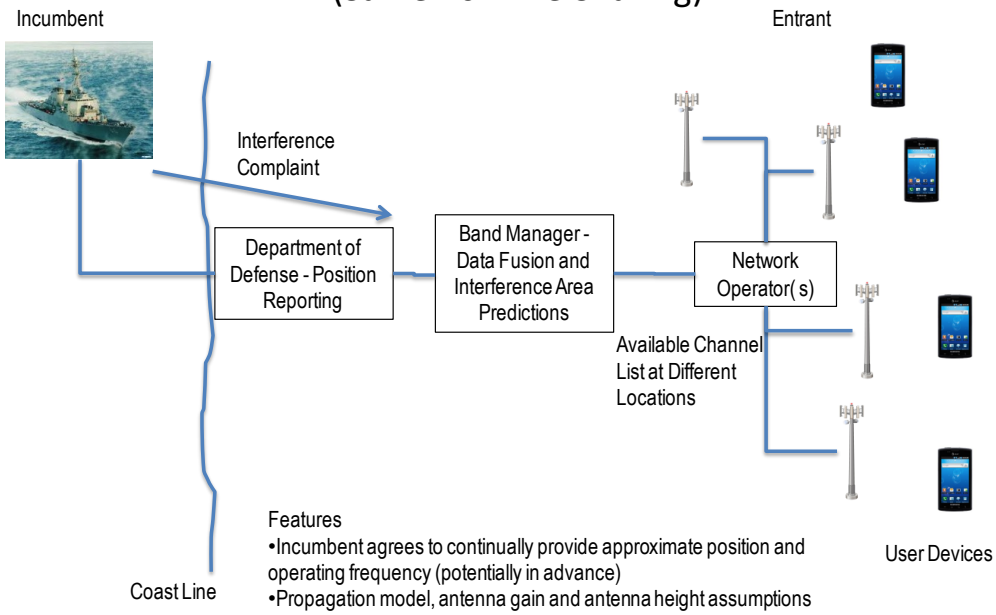
- Geo-Location method used to determine the transceiver parameters/capabilities (e.g., transmits frequency and power level, bandwidth, receiver capabilities).
    - Exact position vs. approximate position
    - User entered position versus GPS position versus trusted source for position

- Sensing-based method used to determine the transceiver parameters/capabilities.
    - Sensing on all entrant radios
    - Sensing on some entrant radios
    - Sensing at certain locations
    - External sensing network
    - Collaborative entrant sensing

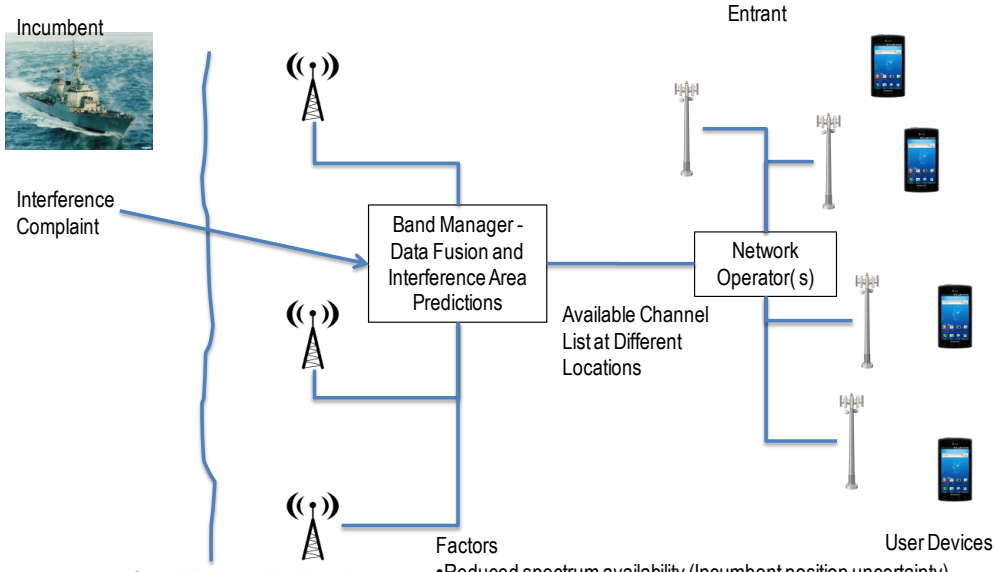
- Combined sensing and geo-location methods used to determine the transmitted transceiver parameters/capabilities.
- Physical layer
    - Receiver ignores interference
    - Transmit modulation (UWB)
- Timesharing
    - Entrant and Incumbent share information to share spectrum in time
    - Entrant senses channel and stops transmitting rapidly when the Incumbent begins transmitting, so as not to interfere with Incumbent communication

Example spectrum sharing architectures are shown below:

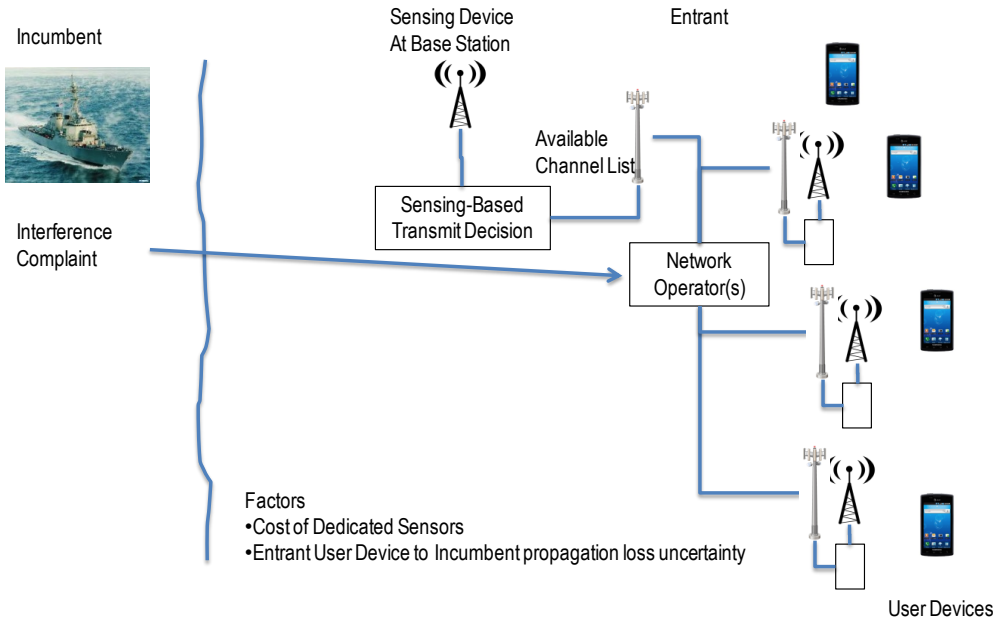
System #1 - Geo-location System (Same As Time Sharing)



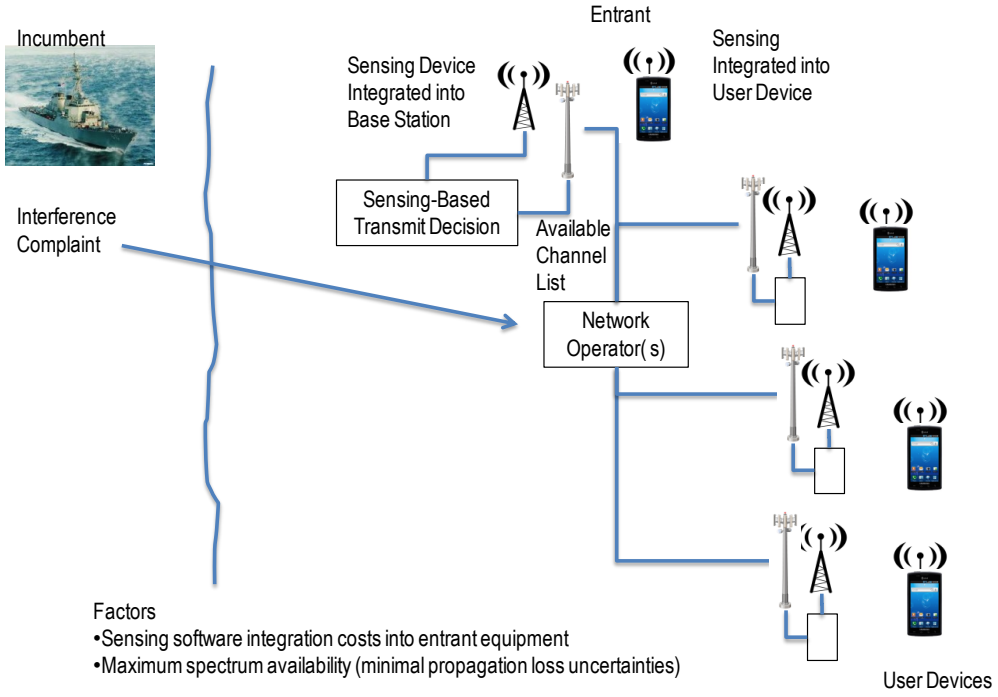
Features
- Incumbent agrees to continually provide approximate position and operating frequency (potentially in advance)
- Propagation model, antenna gain and antenna height assumptions
- Incumbent and entrant location accuracy
- Moderate spectrum availability (due to parameter uncertainties)



Factors
- Reduced spectrum availability (Incumbent position uncertainty)
- Number and cost of Dedicated Sensors (own operates and pays?)
- Propagation model, antenna gain and antenna height assumptions
- Entrant location accuracy
- Incumbent views system the same as geo-location system approach



System #4 – Sensing on All Entrant Radios System



b. Method Features

- Database connected or un-tethered method used to manage the spectrum sharing method.
  - Applied to either geographic or sensing-based methods
  - Continuous connection
  - Occasional connection (i.e. like the FCC TV whitespace Geo-Location/Database approach)
  - Periodic connection (annual)
  - Provide rule set or provide list of operating frequencies or provide operating frequency

- Interference Basis
  - Entrant/incumbent isolation determined by interference to entrant
  - Entrant/incumbent isolation determined by interference to incumbent
  - Entrant/incumbent isolation determined by interference to entrant or incumbent

IV. SPECTRUM SHARING COSTS

Table 1 shows the different spectrum sharing requirements and the approach used to meet the requirement. Also shown are the costs for the incumbent, the entrant, and for either party to meet the requirement.

Table 1 Spectrum Sharing requirements and Costs

Requirement	Approach Description	Cost		
		Incumbent	Entrant	Incumbent andEntrant
Do No Harm	Certain frequencies at certain locations/times are unavailable for entrant use.[1]	None	Implement dynamic network management	None
Do No Harm	Implement sensing-based sharing approach	Provide waveform information and equipment description.	Modify equipment to implement sensing.	
Do No Harm	Implement geographic-based sharing approach	Provide and update location information and equipment description.	Modify equipment to implement position location and connection to database.	Build and operate database system.
Do No Harm	Implement physical layer-based sharing approach	None	Reduced link distance performance.	None
Do No Harm	Implement cooperative time sharing-based sharing approach	Provide and update location and schedule information and equipment description.	Modification to equipment to implement position location and connection to database.	Build and operate database system.
Do No Harm	Implement opportunistic time sharing-based sharing approach	None	Modification to equipment to allow rapid sensing and response to avoid interference	None
Accommodate Changes in Incumbent Use	Entrant equipment connected to a database.[2]	Provide information on usage (locations, waveform types, etc).	All equipment must be periodically connected to a database.	Build and operate database system.
Accommodate Changes in Incumbent Use	Sensing-based approaches must have a programmable detector/classifier	Reduced flexibility in waveform design and must provide sensitive waveform information	Implement flexible, re-programmable detector/classifier.	None
Enforcement	Implement mechanism to detect and mitigate interference cause.	Provide information on interference event (locations, waveform types, etc).	Centralized method to locate and control equipment.	Operate interference management service.
Backup Band	Entrant hardware must cover multiple spectrum bands.	None	Additional hardware cost to cover additional spectrum bands.	None
Backup Band	Extra entrant spectrum must be	Potentially need to provide	Potentially need to acquire	None

[1] Changes to the available frequencies are potentially dynamic ("cooperative time-sharing," and "opportunistic time-sharing"). The changes may be pre-planned (i.e.24 hours notice by incumbent and then managed with a database) or may be sudden (i.e. no notice via unplanned incumbent usage change and then managed by a spectrum sensing mechanism).
[2] Used for all spectrum sharing mechanisms (geolocation, sensing, physical layer and time sharing).

	provided by incumbent or entrant	additional spectrum to entrant.	additional spectrum.	
Safeguards / Security	Implement secure method to manage entrant spectrum.	None	Minimal cost, COTS solutions.	None

V. ACCOMMODATING CHANGES IN INCUMBENT USE

Table 2 shows how different incumbent changes in use impact geo-location and sensing-based spectrum sharing mechanisms. Also shown are methods that could be used to reduce this impact and to provide certainty to the entrant. Relative difficulty to implement is shown (1-easy to 3-hard).

Table 2 Incumbent Change in Use Impacts to Geo-location and Sensing-based Spectrum Sharing

Incumbent Change in Use	Impact to Geolocation-Based Entrant Only	Impact to Sensing-Based Entrant Only	Impact to Both Entrant Types	Method to Provide Certainty to Entrant
Waveform Type - modulation type, signal bandwidth or MAC (	None	Must have enough waveform information to design classifier(3)	None	To enable sensing approach classifier design relative to entrant waveform, incumbent provides waveform information to limit waveform parameters.
Mix Waveform Types Within a Band	Adjust exclusion zone(1)	Implement multi-detector/classifier system(2)	None	Incumbent provides waveform types in the band
Withhold Transceiver Location Information	Approach not feasible(3)	None	None	Incumbent agrees to not change Transceiver Location Information policy
Provide Entrant Advanced Warning of Transceiver Operation	Assume 100% duty cycle and reduces amount of available of spectrum, (2)	None	None	Incumbent agrees to not change advanced warning plan.
Mobility - Fixed to mobile to airborne transmitters	Obtain real-time transceiver location information, use large exclusion zones, or approach not feasible(3)	None	None	Incumbent agrees to not change mobility, or to provide transceivers info in real-time to enable geolocation approach.
Link Type – Duplex vs telemetry vs f1/f2	Adjust exclusion zone size(1)	Telemetry links require lower detection thresholds and reduces amount of available of spectrum. f1/f2 requires frequency plan information.(3)	None	Incumbent agrees to provide link type information.
Transmit Power Level	None	Change detection thresholds(1)	Decreases amount of available spectrum if sharing based on interference to entrant.	Incumbent agrees to limiting min and max transmit power level.
Transmit Mask Shape	Adjust exclusion zone if based on entrant interference(1)	Change detection thresholds(1)	Decreases amount of available spectrum if sharing based on interference to entrant.	Incumbent agrees to limiting min and max transmit mask.
Desired Interference To Noise Level	Adjust exclusion zone size(1)	Change detection thresholds (1)	Decreases amount of available spectrum.	Incumbent agrees to limiting interference level.
Number of transceivers or TX duty cycle	Provide waveform information and equipment description.(1)	None	Decreases amount of available spectrum	Incumbent agrees to limiting number of TX duty cycle within each operating area.
Receiver	Adjust exclusion	Change detection	Decreases amount of available	Incumbent agrees to limiting

Selectivity	zone size(1)	thresholds(1)	spectrum	adjacent channel rejection level.
Antenna heights or antenna gain values	Adjust exclusion zone size(1)	None	Decreases amount of available spectrum	Incumbent agrees to limiting antenna height.