Coexistence as Value Added Service in the TV White Space

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Outline

- **What is Coexistence?**
- **Why is it needed?**
- **Air Traffic Control Paradigm for Coexistence**
- **Coexistence Service Examples**
- **Business Model for Coexistence Services**
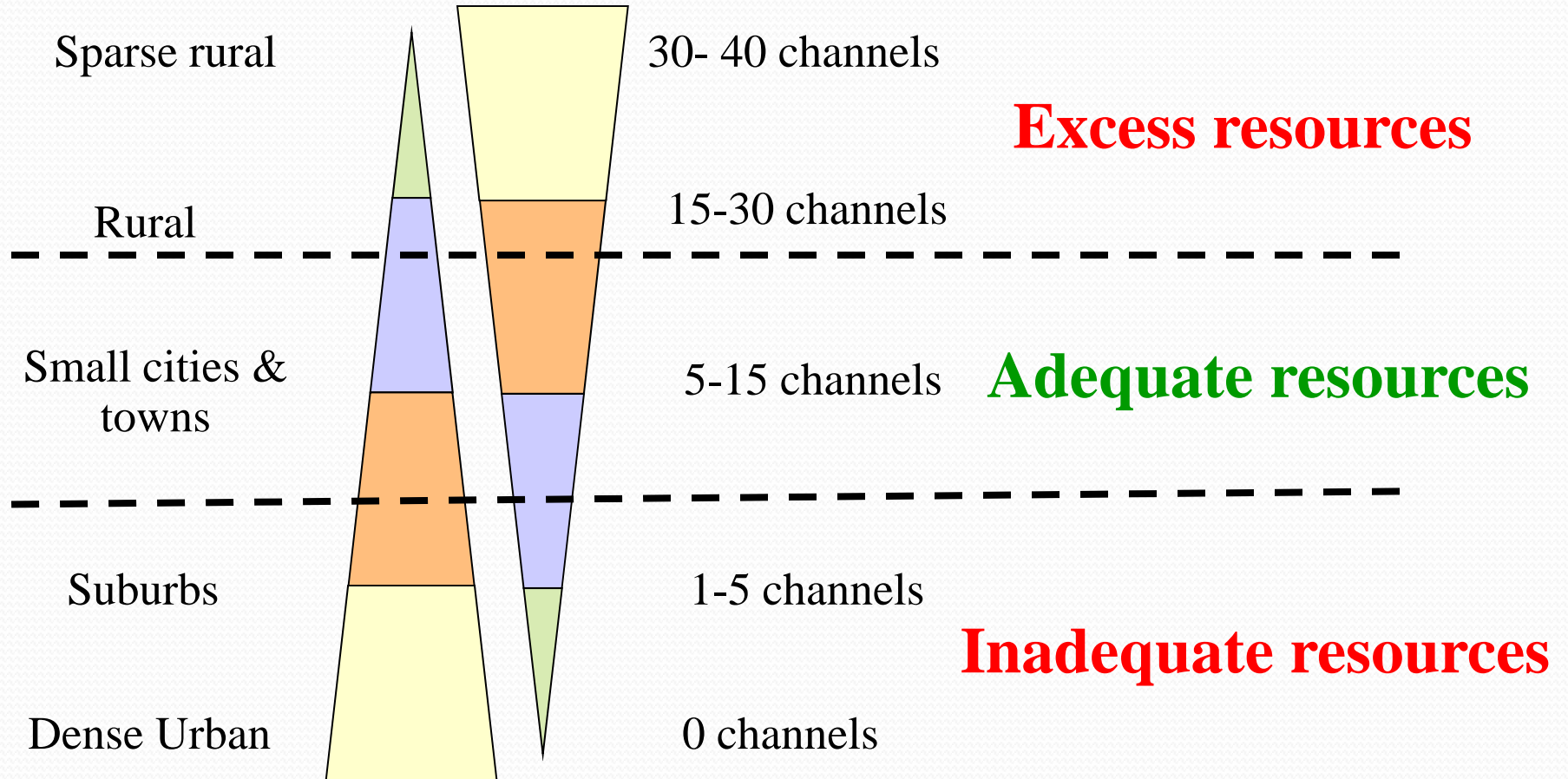- **Conclusions**

Coexistence: What is it?

- Two or more devices or networks existing together at the same time, in the same place, and in the same spectrum.

- Coexistence has quality, and can have metrics for good and poor coexistence.

- Coexistence Quality may be defined by operational examples:
    - **Good** Coexistence: Radio users or networks operating efficiently in same spectrum without causing each other harmful interference.
    - **Poor** Coexistence: Radio Users or networks operating so as to cause interference with resulting inefficiencies, errors, and retransmissions for the other users or networks.

    - So why is coexistence important in the TV White Space?

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Muskateer Method of Resource Allocation
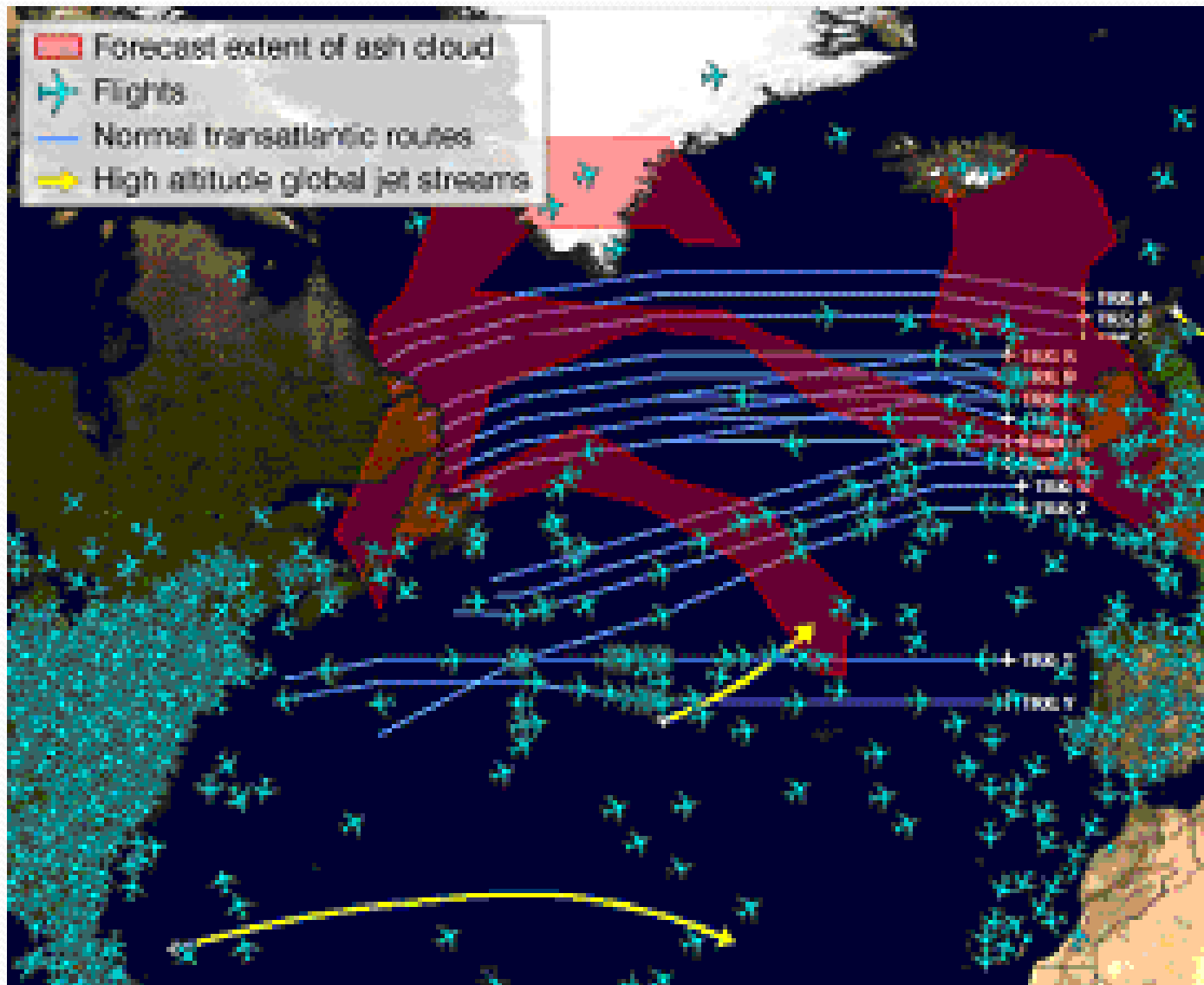
Users   **TV WS Resources**

Sparse rural   30- 40 channels

Excess resources

Rural   15-30 channels

Small cities & towns   5-15 channels   **Adequate resources**

Suburbs   1-5 channels

Inadequate resources

Dense Urban   0 channels

"All for one and one for all"

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TVWS Spectrum will be Crowded

Coexistence System Services

- 802.19.1 is tasked with specifying a Coexistence system which:

  1. Permits discovery, registration and use of the system
  2. Facilitates communications for collaboration to improve coexistence.
  3. Collects information about the RF environment and users
     - TVBD ID, location, NetID, terminal type and characteristics, operating frequency and bandwidth, transmit power, etc
     - Measurement and sensing data from all users
     - Interference event reports.
  4. Shares information about the environment
  5. Identifies coexistence problems
  6. Provides coexistence solutions

- **These are Coexistence Services**

How can these services help?

Air Traffic Control (ATC) Example

- ATC advises pilot and guides aircraft safely through crowded skies.
- Pilot remains in sole command of his aircraft.
- ATC has view of airway environment and traffic not available to pilot.
- ATC is valued service paid for by fuel taxes and user fees.

- Coex System advises user and guides network safely through crowded spectrum.
- User remains in sole command of his network operations.
- Coex System has view of RF environment and neighbors not available to user.
- Coex Service is valued and paid for by (?) TBD.

Air Traffic Control (ATC) Model for Coexistence (Coex) Services

- ATC system manages safe flights in crowded airspace as a location based service.

- ATC is optional for general aviation aircraft.

- Pilot chooses to submit to ATC procedures.

- ATC system provides "clearances" for flight path ahead.

- Decision to follow ATC clearance is pilots continuing decision.

- ATC system has traffic radar with view not seen by pilot.

- ATC radar tracks all nearby aircraft as they enter/leave airspace

- ATC guides aircraft to altitudes avoiding terrain and obstacles.

- Coex system manages effective operation in crowded spectrum as a location based service.

- Coex services are optional for TVWS users.

- TVBD subscribes to Coex services.

- Coexistence system provides clearances for useable channels.

- Decision to use cleared channels is TVBD's continuing decision.

- Coex system has dbase of users with view unavailable to TVBD.

- Coex database tracks all nearby TVBDs who enter/leave spectrum

- Coex System guides TVBDs to channels which avoid interference.

Command Service Protocol

- ATC: N12U, UA14 at 12 oclock your altitude and closing, climb to 11kft.

- P: Roger, N12U

- ATC: N12U, climb to 12kft to clear mountain top obstacle ahead.

- P: Roger, N12U

- ATC: N12U, maintain course 2 miles east of Airway V18, overtaking aircraft behind you will be 2 miles west of V18.

- P: Roger, N12U

- ATC: N12U, unidentified traffic ahead, climb to 17Kft.

- P: Negative. N12U will go VFR (visual) and maintain this altitude.

- ATC: Roger, N12U. Services terminated. G'day.

- CS: Net12, known user on your channel, switch to chan 17.

- U: Net12 ACK.

- CS: Net12, protected mic scheduled on chan 17,switch to18,

- U: Net12 ACK.

- CS: Net12, share channel 18 with new user, maintain ops in top 50% of frame, new user on other 50%.

- U: Net12 ACK.

- CS: Net12, unidentified network on channel, switch to channel 26.

- U: Negative. Net12 will contend and remain on this channel.

- CS: ACK Net12. Coex Command services terminated.

Value Added by Command Service

- Command service confirms that new channel is "clear" for Network prior to channel switch.
- Coex System "clears" channel by analyzing all possible interference paths with known neighboring TVBDs.
- TVBD and Network monitoring any new channel cannot confirm the channel is clear:
  - Can't sense idle transmitters or receivers
  - Can't determine impact of transmissions on neighbors.
- Monitoring or sensing only provides measure of channel use or interference levels.
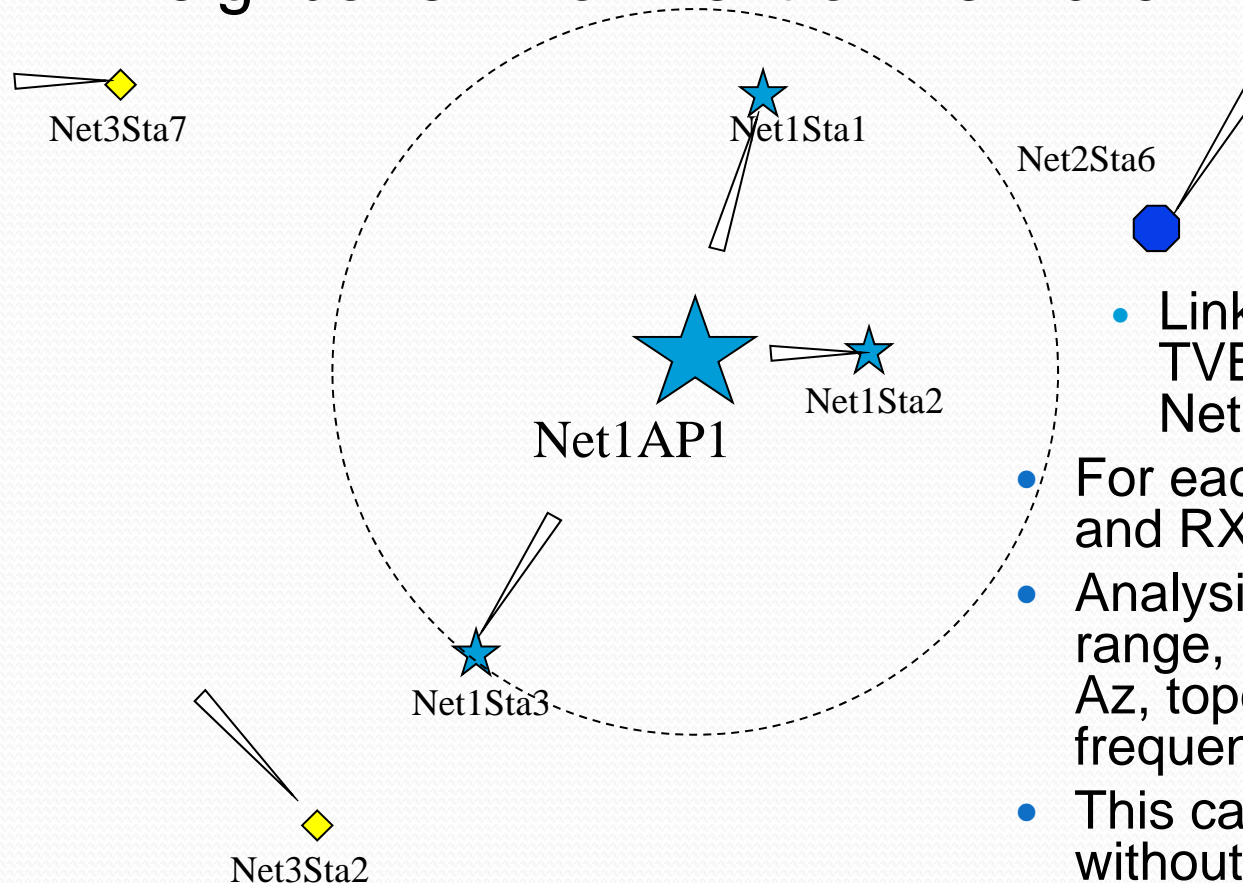- Clearing a channel is more complex.

Example follows.

Clearing New Channel for Switch

- Coex Server analyzes network topology and RF neighbor environment on new channel

Net3Sta7

Net1Sta1

Net2Sta6

Net1AP1

Net1Sta2

Net1Sta3

Net3Sta2

- Link Analysis from each Net1 TVBD to each Net2 and Net3 TVBD.
- For each link, analyze TX$\rightarrow$Rx and RX$\leftarrow$Tx.
- Analysis includes: STA locations, range, Ptx, Rx Sense, Ant G and Az, topology, prop model for frequency, etc.
- This cannot be done by Net1 without complete knowledge of RF environment including all neighbor TVBD locations and characteristics

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Information Service Protocol

- ATC: N12U, Flight Following service initiated at position 40 miles east of ABQ.

- P: Roger, N12U is westbound to ABQ.

- ATC: N12U traffic at 3oclock 10 miles, B767heavy.

- P: N12U, roger, traffic in sight and will track visually.

- P: Flight Following, N12U. Whats the current weather in ABQ?

- ATC: N12U, ABQ reports overcast at 17Kft, winds 180 at 20, visibility 10 miles, haze. Altimeter 29.90.

- P: N12U, thank you sir.

- P: Flight Following, N12U has ABQ in sight will contact terminal approach and land. G'day.

- ATC: N12U, Flight Following terminated.

- CS: Net12, info service granted, 40 miles east of ABQ on chan 17.

- U: Net12 ACK.

- CS: Net12, known user located 10 miles north of your position.

- U: Net12 ACK. Have sensed interference in that quadrant.

- U: Coex Server, Net12. Any emissions detected in ABQ area?

- CS: Net12, ABQ currently detects 2% duty cycle emitter, -85dBm, unknown location.

- U: NET12 ACK

- U: Coex Server, Net12 channel utilization nearly idle, Net12 powering down for night.

- CS: Coex Server ACK. Service terminated.

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What you see is what you get...
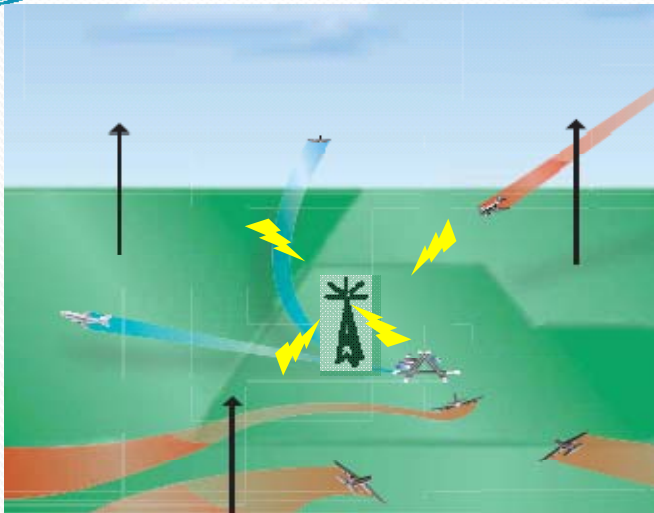
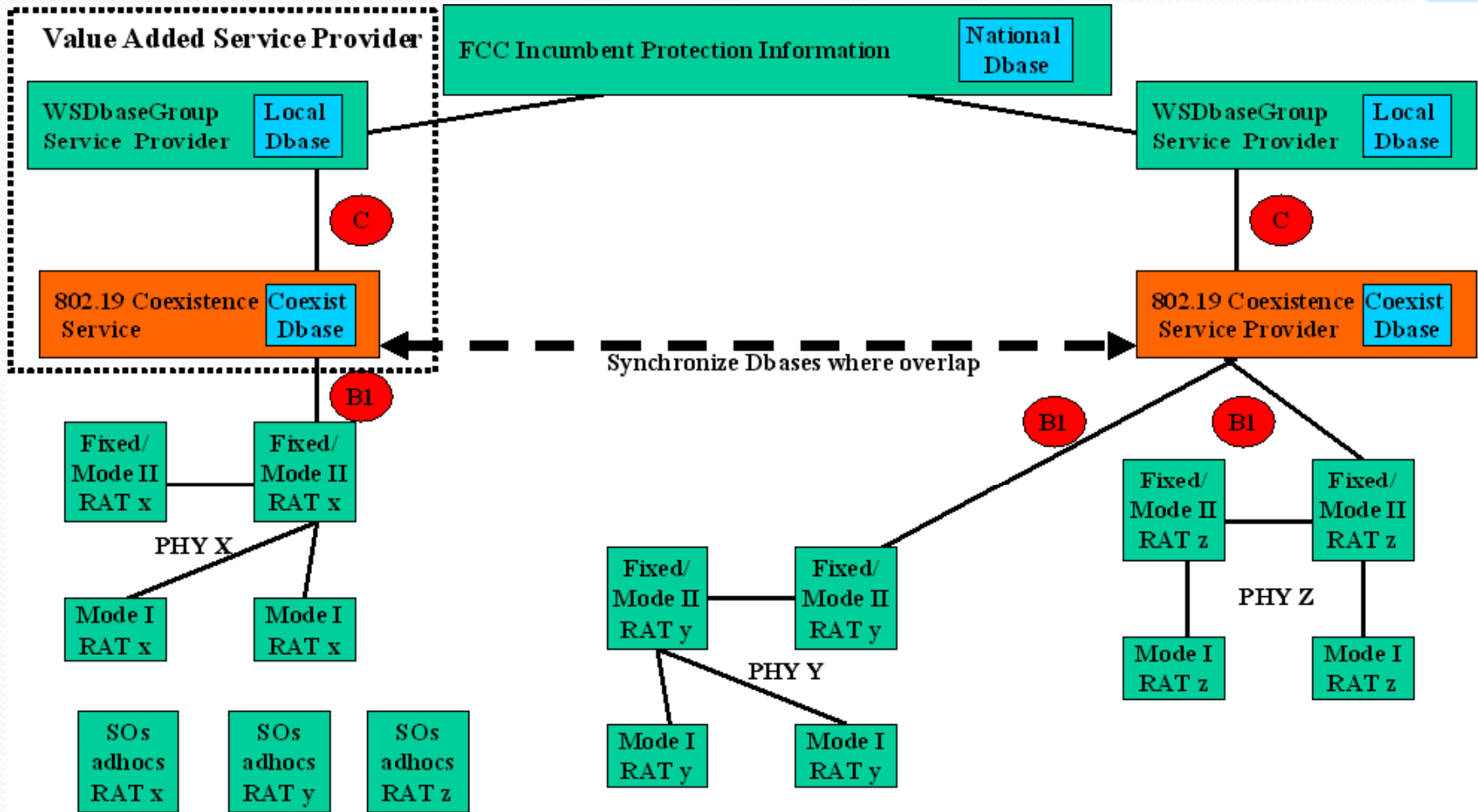ATC advice is only as good as the radar info the controller sees.
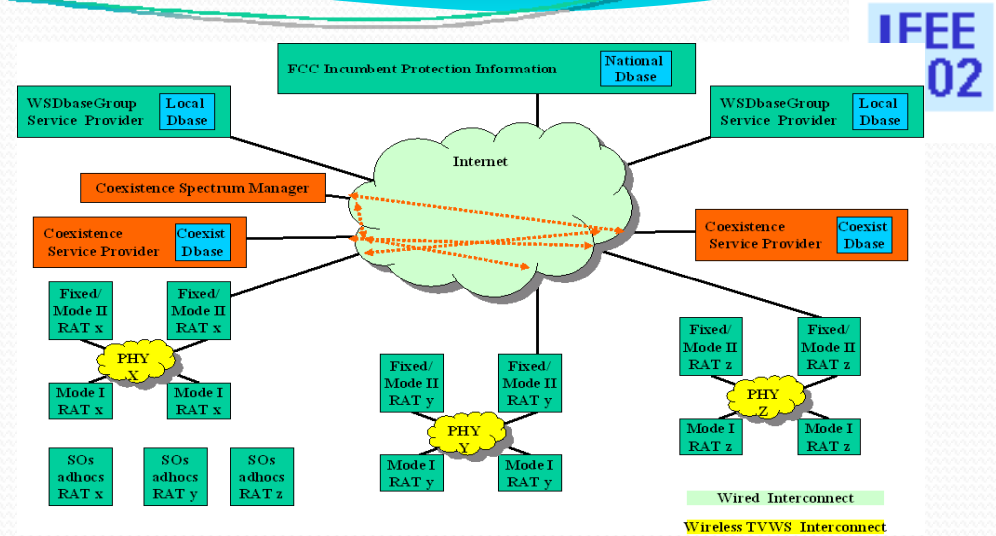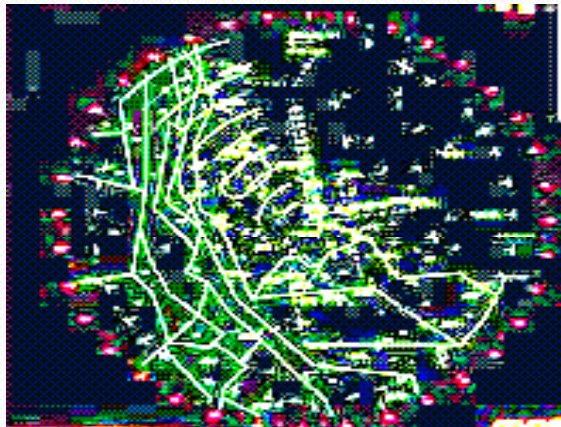
Coex Server advice is only as good as the user data it has in its coexistence database.

So how do we get all the coexistence data?

…As Regulatory Gateway for all TVWS Access

FCC TVWS Database Manager as Coexistence Service Provider

- Already serving all TVWS users for FCC channel availability
- Has centralized server and internet infrastructure
- Has required Geo-Topo database information & tools
- Has means for user authentication, billing and collection
- Can collocate additional value added services for TVWS to attract more TVWS users
- NEEDS spectrum management and propagation tools
- NEEDS standardized Coexistence Service Specification
  - To enable coordination with peer Coex Service Providers
  - To provide algorithm details for coexistence decisions

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Business Models for Coexistence Services

- The FCC TVWS Database Manager is in a privileged position to offer coexistence services for all active TVBDs.
- Other options exist:
  - Coexistence Services added to other large internet servers:
    - DNS server + Coexistence Service
    - AAA servers + Coexistence Service
    - Google Search Engine server + Coexistence Service
  - Standalone Coexistence Service provider
  - Coexistence Servers integrated into private networks
  - Coexistence Servers integrated into BSs, APs, and RNCs.
- Revenues fall with decreasing subscriptions, size matters.

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Can TVWS Users Operate w/o Coexistence Services ?

- Yes, if network is isolated.—No need for ATC if you are the only plane in the sky.

- In other cases, it depends on "cognitive" ability of network to assess its environment.

- Sensing alone will not provide adequate information.
    - Cannot sense receivers.
    - Sensing cannot *locate* neighboring transmitters
    - Sensing cannot provide neighbor Rx sensitivity (RF susceptibility)

- Network with neighboring TVWS users will benefit from coexistence services.

- In urban areas, networks without Coexistence Services will likely suffer spectrum collisions and decreased QOS.

--DON'T FLY BLIND--

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Conclusions

- TVWS spectrum congestion is likely to be widespread, except in rural areas.

- FCC relying on shared database for incumbent protection.

- Shared database approach also shown to have value for Coexistence Services

- FCC TVWS Dbase Managers are in ideal position to collect and share data for Coexistence Services.

- Other business model options for Coexistence Services exist.

Questions….

Thank you!