The Geographic Electromagnetic Radiation Domain Control System (GERDCS™)

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Abstract

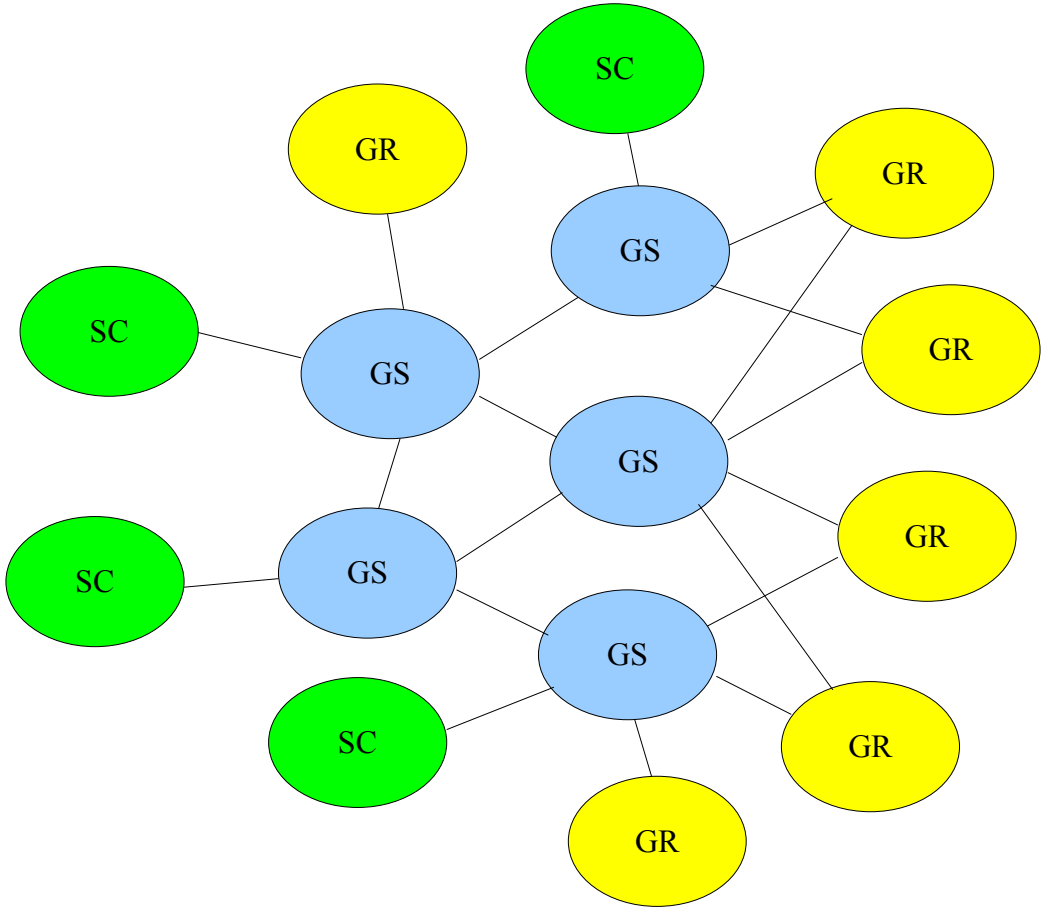
The Geographic Electromagnetic Radiation Domain Control System (GERDCS™)

This system was seeded from the need to promote frequency reuse, plan for coexistence between licensed and license-exempt spectrum users, determine spectrum availability and efficiently convey needed information in a timely manner. It consists of a web of client, server and resolver computers

GERDCS Defined

- **Is a web framework of on-line networked computers**
- **It consist of**
  - Spectral Clients (SC)
  - Geographic Servers (GS)
  - Geographic Resolvers (GR)
- **Is similar in nature to**
  - The Internet Domain Name System (DNS)
  - That resolves names (URLs) to IP addresses
- **Intends to comply with the needs expressed in**
  - 22-06-0242-09-0002-draft-recommended-practice.doc
  - With alterations avoiding what WISPs perceive as unacceptable pitfalls
  - US FCC Report and order on TV whitespace

GERDCS Defined



GERDCS Audience

- **Regulators**
- **Transmitter operators**
  - Licensed incumbents
  - License-exempt
- **Network planners**
- **Emergency response personnel**

Goals

- **Help in resolving coexistence issues**
  - Help to protect licensed operators
  - Inform license-exempt operators
- **Provide an efficient communication system**
- **Proactive and effective**
- **At quickly disseminating notifications**
- **Propagating data in a scalable fashion**
- **With multiple interfaces**
  - machine to machine
  - human-machine

Scope

- **GERDCS is not**
  - A coexistence assurance system
  - A dispute resolution system
- **GERDCS allows uniform communication**
  - Enhancing operator awareness
  - Enhancing disparate system coexistence

- **Provide privacy protection**
  - Comply to privacy laws
  - Protect sensitive information from unauthorized use
- **Provide scalable information**
  - Flow, management and communication

Security

- **GERDCS devices communicate**
  - Over secured links (SSH or HTTPS)
  - Between registered devices/operators
  - Authenticate all users
  - Log and provide extensive audit trails
  - Allow authorized parties
    - Controlled visibility on information sources
    - Change tracking

Awareness

- **Helps to avoid and resolve coexistence issues**
  - Between license-exempt operators
  - Agnostic to transmission system characteristics
- **Help to protect licensed operators**
  - From license-exempt operators

Regulatory Compliance Assurance

- **Operation in compliance to**
  - Regulator requirements
  - GERDCS requirements
- **GERDCS avoids responsibility discharge**
  - It provides information to enable decision taking
  - It provides policies to assist with decision logic
  - Final decision is made by the transmitter operator equipment
- **Is, always has been and remains**
  - The sole legal responsibility of transmitter operators

Function

- **GERDCS receives, validates, conveys and disseminates**
  - data pertaining to the maximum radiation levels
  - a license-exempt transmitter or
  - an array of Same Frequency Network transmitters
  - should be allowed to emanate
  - at a given time, location or region
  - before such radiation exceeds
  - levels that could violate
  - legal protection allocated
  - by regulatory protected contours

GERDCS

- **Is designed from the ground up to**
  - Allow for enhanced coexistence
  - Subjugate license-exempt services to
    - Regulatory requirements
    - Incumbent license priorities
  - Provide for coordination
    - Between transmitter operators
  - Protect information confidentiality
  - Provide usage logs and audit trails
  - Provide information source identity

GERDCS Concern for Privacy

- **Authorized clients may request information**
  - For whatever reason over entire geographical areas
  - Irrespective of whether they actually have
    - Transmitters or receivers in that area
  - Without divulging
    - How many they may have or where they are
- **As a request covers a geographical area**
  - It does not divulge
    - Quantities or location of transmitters and receivers
    - Circumventing WISP operator objections
      - Of divulging their network topology and BS locations
      - To un-authorized third parties
  - Sensitive queries are sent to the operator's repository
    - Allowing the operator final control on information release

Geographic Resolver

- **An instantiation of a GERDCS client device**
- **It runs under the supervision of an operator**
  - Of a transmitter
  - Of a network of transmitters
- **May be audited**
  - By authorized parties such as the regulator
- **May be used by a network designer**
  - Seeking for optimum future transmitter locations
  - In the potential evaluation of available sites

Geographic Resolver

- **Requests**
  - Secure GERDCS client-server connections
  - Queries GERDCS database servers
  - Receives responses and notifications
  - Receives policies and procedures
- **Transmitter operators**
  - who want to operate and coexist
  - use a resolver to assess
  - if a channel is cleared for use and available
  - How it can be used
    - Bandwidth, Power level, Orientation, Beamwidth, etc...

Geographic Resolver

- **One of its tasks and responsibilities is**
  - To receive and analyze
  - Specific bandwidth allocation requests
  - Made by the transmitter operator
- **It analyzes and resolves**
  - local transmitter geographic electromagnetic radiation coexistence issues
  - in a given geographic reception area
  - based on
    - available data
    - established rules and agreements

Geographic Resolver

- **The result of this analysis is**
  - A matrix of maximum allowable field strength vectors
- **This time-bound matrix covers the entire geographic area the transmitted field may reach**
  - Including direct paths, reflection, etc...
- **This multi-dimensional matrix has indexes of**
  - Time
  - Position
  - Polarization
  - Incident arrival angle

Antennas

- Transmitter and receiver antennas
- Have complex multi-dimensional free-space radiation patterns

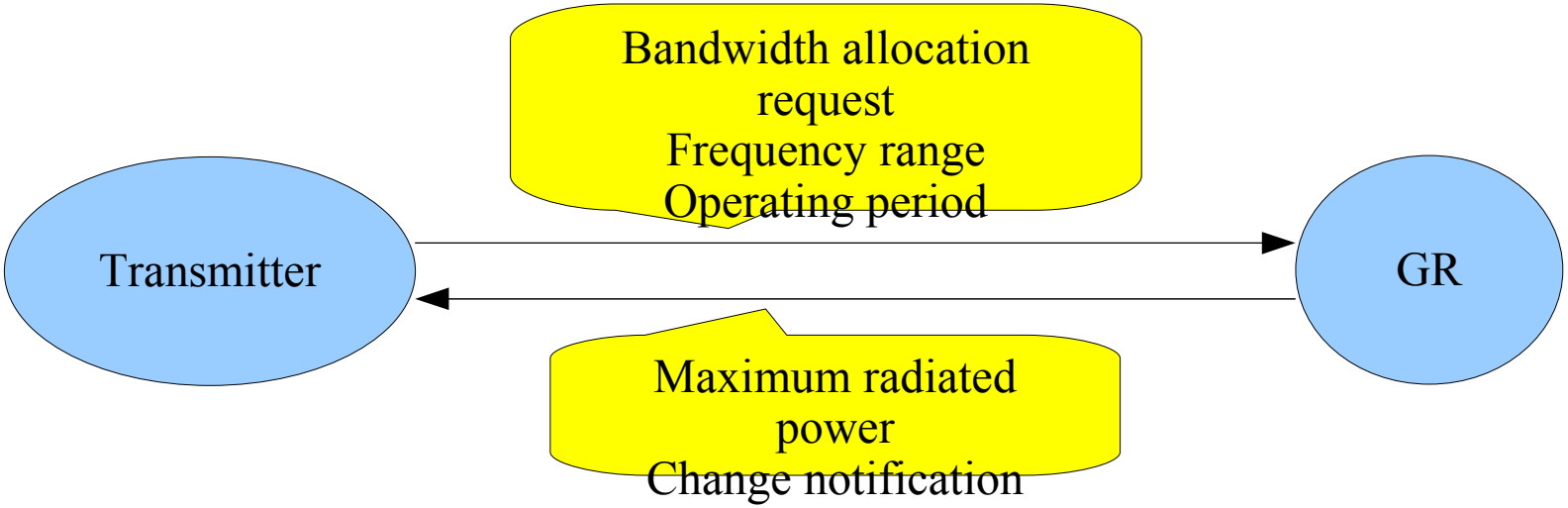
Geographic Resolver

- **The resolver as a cognitive system device**
- **Knows a-priori about**
  - The transmitter's antenna properties
  - Surrounding terrain propagation characteristics
- **It considers all these factors and determines the maximum allowable EIRP and field strengths emanating from the transmitting antenna in the determination of the maximum allowable radiated power a given transmitter may emit**

Geographic Resolver

- The output of the resolver is the maximum allowable output power in dBm over a requested frequency range and operating period
- The resolver, requesting and maintaining active connections also receives and reacts to pro-active GERDCS environmental change notifications

Transmitter – Resolver relationship



Geographic Database Server

- **The Geographic Database Server (GS)**
  - Receives secure connection requests
  - From registered GERDCS clients
- **Grants secure client-server**
  - connection sessions
- **Stores and forwards**
  - Information
  - Notifications

Geographic Database Server

- **Receives and responds to client queries**
- **Issues update notifications**
- **Validates requests for given**
  - Geographical areas
  - Regulatory domains
- **Acts as**
  - Authoritative information cache
  - Network information forwarder
- **Answers**
  - About a given domain
  - Or how to get “closer” to another GS
    - With authoritative information about the domain

Spectral Client

- **Is also a GERDCS client**
- **It runs under the exclusive supervision and control of**
- **The operator of**
  - A transmitter or
  - A network of transmitters
- **Or under the control of a regulator**

Spectral Client

- It requests secure client-server connections
- Feeds and queries servers
- Issues notifications
- Receives responses

Spectral Client

- **Is used by transmitter operators**
- **Who want to**
  - Announce their license-protected domains and claims or
  - Signal their license-exempt domains
    - To improve controlled sharing
    - To help avoid coexistence issues
- **The Spectral Client is used to**
  - Create, edit, delete and register domains
  - Make claims about these domains

Domain Definition

- **A GERDCS Domain is**
  - A collection of bubbles where each bubble has
    - A Name with a root GS URL
    - An Author
    - A Time to Live

- **A domain may for example represent a broadcaster's designated market area**
- **It may also represent a protection area around an event covered by a group of microphones**
- **A temporary area to be protected for emergency services**

Domain Attributes

- **The Domain name is a metaphor used to**
  - Identify the domain
  - Provide a root GS URL and regulator
    - Example: MyDomain.AuthoritativeServer.vt.GERDCS.us
- **The Author is the name of the domain claimant**
  - Used to allow others to contact to the claimant
  - Allow traceability toward domain claims
- **Claims describe the authority over the domain**
  - Possible values at this time are
    - license # ...
    - license-exempt

Domain Attributes

- **Time To Live (TTL)**
  - Is a domain data validation specification used to force periodic updates
  - Allows a resolver to select and favor the most recent data available amongst multiple sources
  - Allows for domain cancellation

Domain Attributes

- **Number Of Bubbles**
  - The Number Of Bubbles (NOB) attribute
  - enumerates the quantity of bubbles
  - forming the domain that intersect a specified area

Bubble Definition

- **A GERDCS bubble is a 7 dimension construct describing the particulars of the domain claim**
- **The bubble dimensions are**
  - Three dimension geographic space bound by
    - Altitude, Latitude and Longitude ranges
  - Direction of arrivals bound by
    - Azimuth and Elevation ranges, polarization
  - A spectral space bound by
    - Frequency range
- **Bubbles can be understood as**
  - elements of 22-06-0242-09-0002-draft-recommended-practice.doc 2.1.1.3.1.2 polygons
  - AGES shapefiles
- Bubbles allow for the creation of "swiss cheese" contours.

Bubble Definition (cont.)

- Bubbles allow for broad spectral coverage, such as
  - Sideband protection
  - Swiss cheese coverage
  - Receiver weaknesses
    - Taboo channels
- Protection of transmitter arrays
  - Multiple microphones on multiple frequencies
- Protection of designated market areas
  - Protected area shape is arbitrary
- Protection exceptions
  - Licensed point-to-point and point-to-multipoint links
- Squelched transmitters
  - Need protection but may go off-air while idle

Bubble Data

- **The Spectral Limit Record (SLR)**
  - Contain all the data describing a specific bubble
  - With a signal amplitude level (microvolts/meter)
  - That can not be exceeded without causing
  - Significant harm to the domain author's service

SLR Resolution

- SLR Latitude, Longitude and Altitude attributes
- Have a resolution of .00001 degrees
- Equivalent to worst case of ~1 meter

GC Protocol Elements

- **Registration Request**
  - Sent by GR to GS
  - Used to establish or maintain
  - A virtual client-server connection
  - Is periodically issued to signal continued presence
  - Indicates continued interest in notifications

GERDCS GC Protocol Elements

- **Spectral Limit Queries (SLQ)**
  - Issued by GR or GS
  - Received by GS
  - Specifies an interest in
    - A domain or class of domains
    - A geographical area
    - A spectrum range

GERDCS GC Protocol Elements

- **When a GS receives an SLQ**
  - It may respond with
    - An array of SLRs
    - An alternate GS (to allow scaling and load management)
    - One or more URLs closer to the most authoritative GS
- **When the GS responds with a URL, the GR**
  - Abandons the query with this GS
  - Makes the same SLQ to the indicated GS

SC Protocol Elements

- **SC protocol elements are used to**
  - Request additions, deletions and edits to SLRs
- **The GS returns**
  - an ACK if it abides by the request
  - A NAK if it refuses the request
    - NAK is followed by textual description of refusal cause
    - Example: NAK:outside regulatory bounds
- **GS internal validation policies**
  - are beyond the scope of this presentation

GERDCS

- **Using domain name definitions**
- **Along with multiple SLRs**
- **The SC can define irregularly shaped**
  - Coverage areas or Designated Market Areas
- **Allow for sideband protection claims such as**
  - Adjacent channels
  - Taboo channels
- **Preempt for the possible use of fail-over channels**

USE

- **A transmitter or transmitter network operator**
  - Typically queries a resolver for a set of receivers
  - With a time range (date & time)
  - With a spacial target (long, lat,alt range)
  - With a expected angle of arrival range and polarization
- **The resolver, consults it's cache and known GS**
- **Responds in correspondence with**
  - the maximum allowable received radiation level

USE (cont.)

- **Many such request will be made**
- **The transmitter should cap its output power**
- **To comply with**
  - All the returned requirements
  - Taking into account its antenna pattern
  - Terrain topography & propagation models
- **And dynamically react to notifications**

GERDCS

- GERDCS is like a dynamic road sign
- In itself, it does not enforce or ensure rule enforcement
- It provides a common framework
- It disseminates information
- Allowing law-abiding citizens to make informed decisions to comply with complex requirements
- The audit trail negates ignorance as a plea or excuse for non-compliance
- Its an evolutionary system which evolves with time

GERDCS

- **Transmitter operators are responsible**
  - To limit claims sensibly to and only to their legal rights
    - With traceability and recorded audit trails
  - To be courteous bandwidth sharers
  - To comply to regulatory requirements

Cost Reductions

- **If a MAC enforces GERDCS compliance**
  - Products may operate with far less hardware and complexity
  - There is no need to embed the resolver in the product hardware
  - Resolver functionality may reside in a host driver (PC or other)
  - Greater control and centralized upgrades are possible
    - Without user knowledge, intervention and hassles
  - Products may be simplified as a large portion of
    - cognitive functions may be offloaded to network-based resolver support
  - The system may be more amenable to local regulator requirements
    - because standard CPE and BS do not need to be modified
    - to adopt behaviors in compliance to local regulator requirements
    - or to modify the behavior as regulators modify policy from time to time

Cost Reductions (cont.)

- **If a MAC enforces GERDCS compliance**
  - Sensors, which can only react to and cannot preempt situations
    - May no longer be required
  - The MAC no longer needs to know about and understand
    - Complex cognitive policies
    - Policies which may be implemented by the Geographic Resolver
      - Examples: Taboo channels, sideband protection, location vs incumbent protected contour or designated market areas, etc...
  - Products therefore are
    - simpler, easier to implement, faster to market and costing less
    - more appealing to the general public, incumbents and regulators
    - under better control
  - GERDCS would in essence be a dynamic on-line lite-licensing system.

Regulatory Compliance Insurance

- **If a regulator also enforces GERDCS compliance**
  - GERDCS can be extended to enforce compliance via
    - Live, on-line communication
      - Regulators may be given additional tools to query resolvers to obtain
        - "Unlicensed" (illegal) GERDCS connected transmitter location
        - Owner and contact information
        - GR-GS registration information from authoritative GS
        - Order on-line shutdown or apply restrictions to offending devices

  - GERDCS can become a electromagnetic environment code
    - Similar to road traffic codes that regulate road vehicles
  - Coexistence can be enhanced as the GERDCS provides a uniform out of band means to coordinate various devices that may not be able to communicate over the air.