CoRaL – Policy Language and Reasoning Techniques for Spectrum Policies

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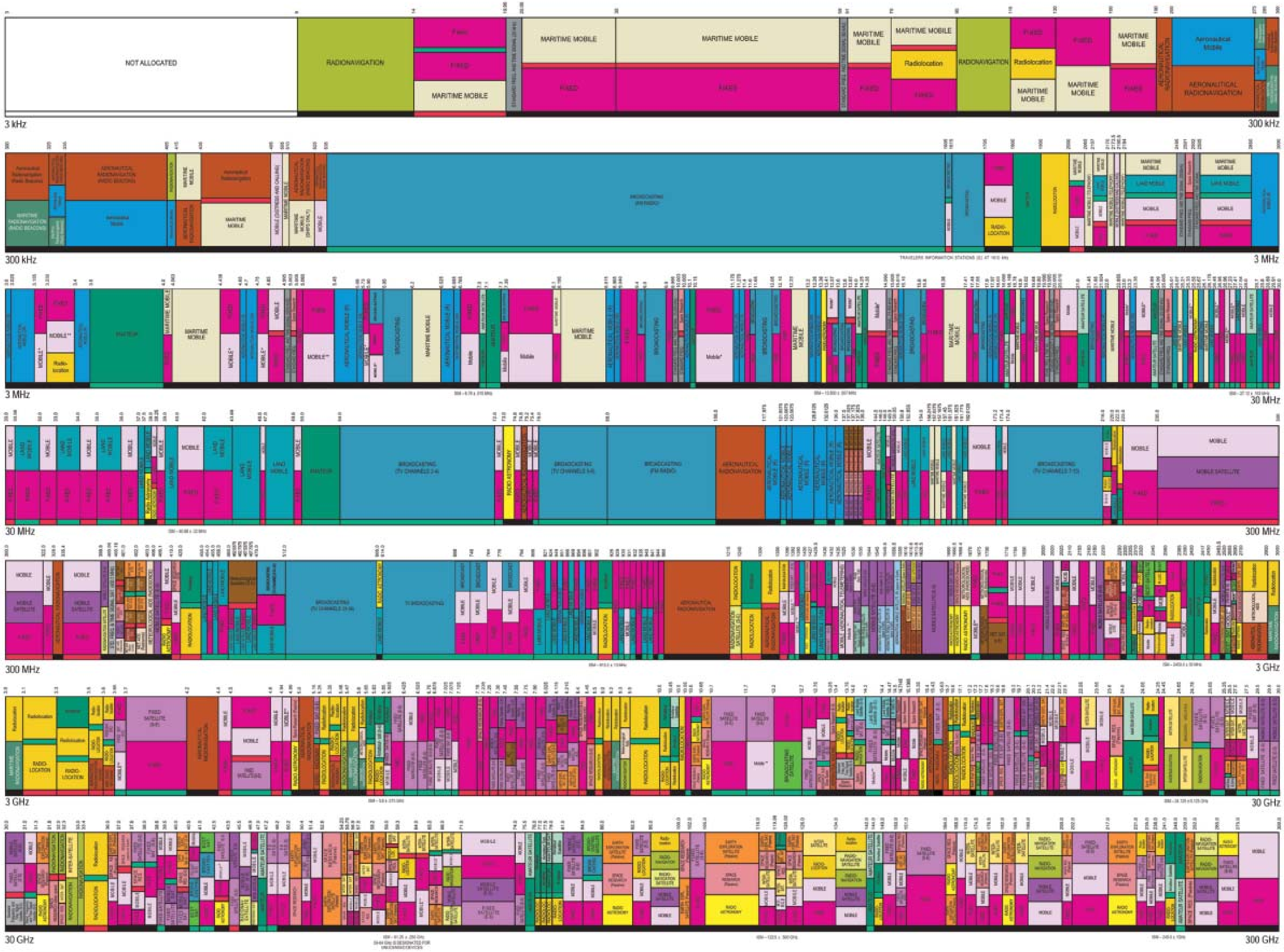

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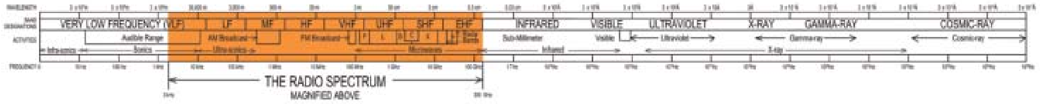


PLEASE NOTE: THE SPACING ALLOTTED THE SERVICES IN THE SPECTRUM SEGMENTS SHOWN IS NOT PROPORTIONAL TO THE ACTUAL AMOUNT OF SPECTRUM OCCUPIED.

Current Spectrum Policy Regime

- Policy = natural language document
- Policy enforcement – C code compiled into radio firmware
- Radio accreditation – Test radio with the compiled-in binary policies against some pre-defined test suite

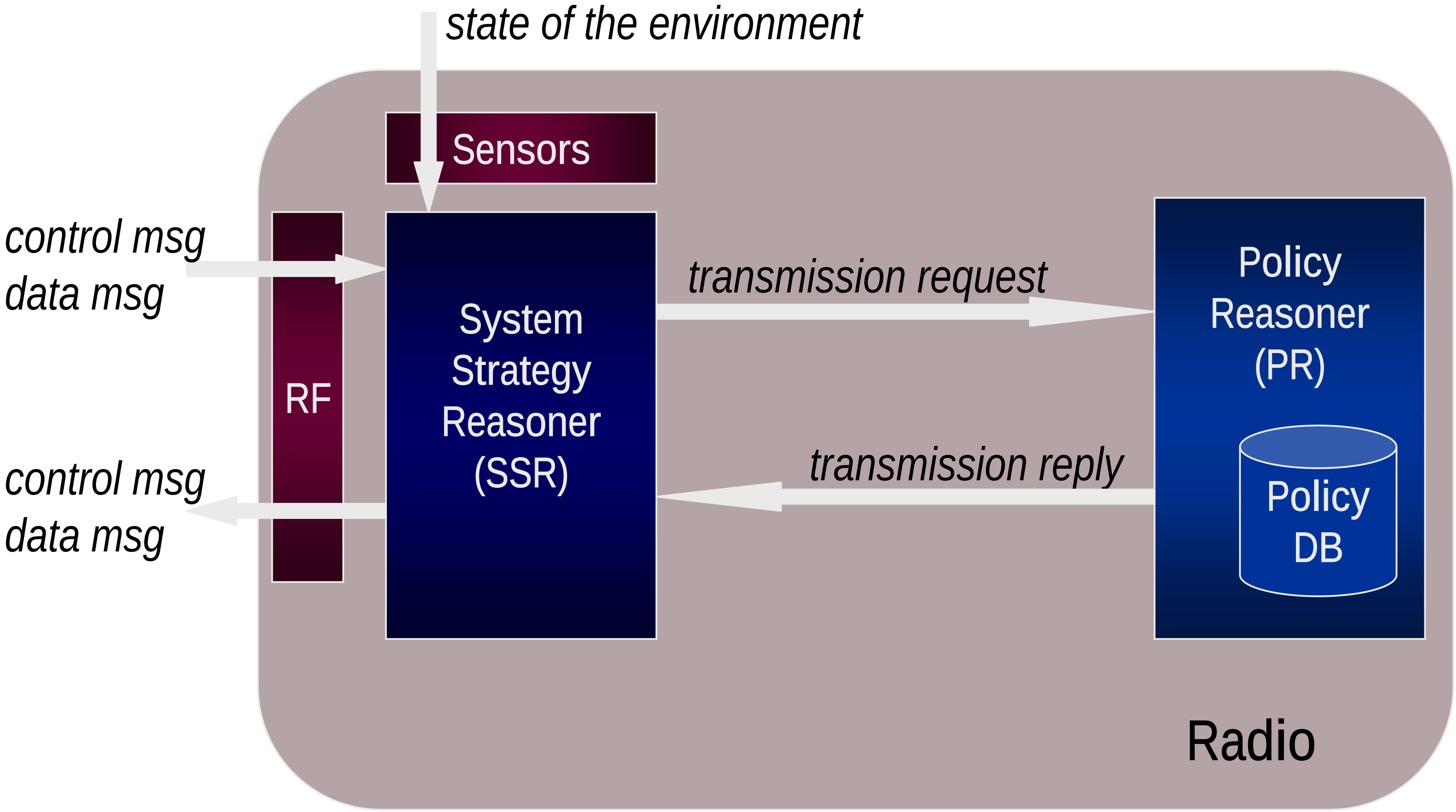
Problems

- Spectrum scarcity
- Deployment delays
  - Policy evolution
  - Different context – different policies

Solutions

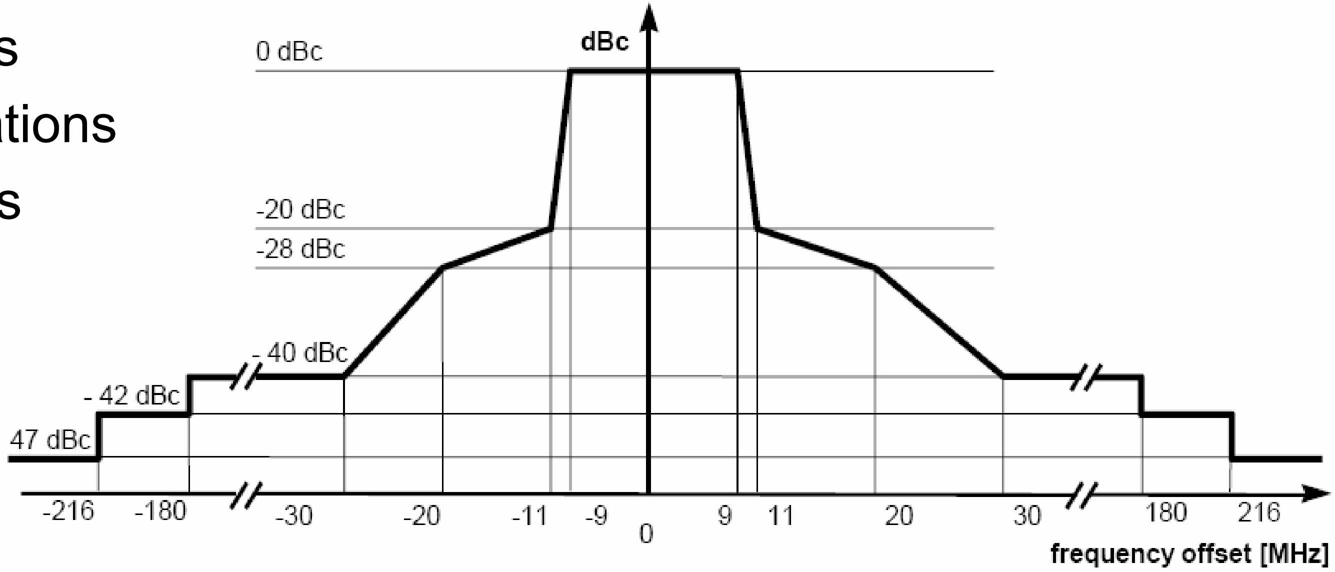
- Spectrum sharing
  - Most spectrum unused
  - Sensing to avoid interference
- Declarative policy language
  - Load new policies on the fly
- Separation of policy enforcement from other radio software
  - Accredit policy, policy reasoner, and radio software *separately*

The XG Architecture



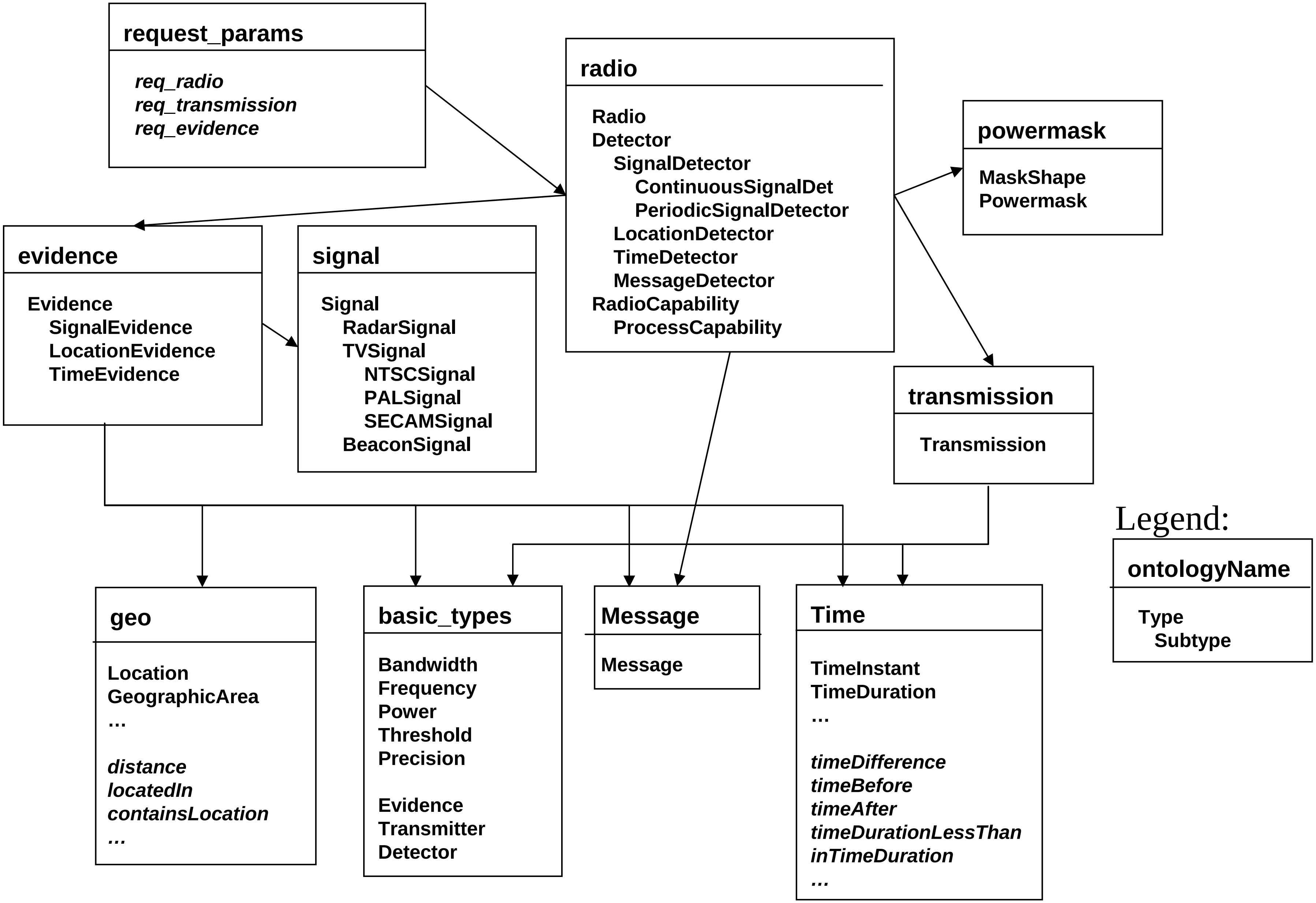
Policy Language Requirements

- Accreditability
- Extensibility
- Expressiveness
    - Functions
    - Computations
    - Orderings



CoRaL Language

- Typed first-order logic with equality
- Constraint Simplification
- Functional approach
  - To represent functions
  - Computations inside language
  - Term rewriting
- Ontologies
  - Algebraic Data Types
- Standard set theoretic semantics
- Operational semantics



request_params

req_radio
req_transmission
req_evidence

radio

Radio
Detector
  SignalDetector
    ContinuousSignalDet
    PeriodicSignalDetector
  LocationDetector
  TimeDetector
  MessageDetector
RadioCapability
  ProcessCapability

powermask

MaskShape
Powermask

evidence

Evidence
  SignalEvidence
  LocationEvidence
  TimeEvidence

signal

Signal
  RadarSignal
  TVSignal
    NTSCSignal
    PALSignal
    SECAMSignal
  BeaconSignal

transmission

Transmission

Legend:

ontologyName

Type
  Subtype

geo

Location
GeographicArea
…

distance
locatedIn
containsLocation
…

basic_types

Bandwidth
Frequency
Power
Threshold
Precision

Evidence
Transmitter
Detector

Message

Message

Time

TimeInstant
TimeDuration
…

timeDifference
timeBefore
timeAfter
timeDurationLessThan
inTimeDuration
…

Policy Examples 1/2

Allow to transmit in the band 5180 MHz to 5250 MHz, if the radio is at most 10 km away from the geographic coordinates 39 10’ 30” N, 75 01’ 42”, and only between 06:00 and 13:00 local time.

```
policy p1 is
   use request_params;

   allow if
        centerFrequency(req_transmission)in {5180.0 .. 5250.0} and
        (exists ?le:LocationEvidence)
                req_evidence(?le) and
                distance(location(?le),loc1) =< 10000 and
        (exists ?te:TimeEvidence)
                req_evidence(?te) and
                hour(timeStamp(?te)) in {6 .. 12};
end
```

Policy Examples 2/2

Prohibit transmission if peak sensed received power is more than -80 dBm:

```
policy p2 is
    use request_params;

    disallow if
        (exists ?se:SignalEvidence)
                req_evidence(?se) and
                peakRxPower(?se) > -80.0;
end
```

Logical Approach

If PR can prove

policies, facts from SSR $\vdash$ **`permit`**

Then transmission is allowed

Permissive and Restrictive Policies

- Policies contain axioms about **`allow`** and **`disallow`**
- A “meta-policy” relates **`permit`** to **`allow`** and **`disallow`**
- Typically,
  `permit iff allow and not disallow`
- i.e. restrictive takes precedence over permissive policies
- Other meta-rules can accommodate prioritized policies

Reasoning about Spectrum Policies

- Requirements on an ideal reasoner
  - Interactivity
  - Underspecified requests
- Prolog-based reasoner
  - Only yes/no answers, no constraints
  - clp/r
- Executable specification in Maude
- Current work – efficient implementation of part of CoRaL
  - Will be implemented on radio hardware

Conclusions

- Spectrum domain is highly amenable to a policy approach
- Special requirements on the policy language
- Special requirements on the reasoner