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QUALITY OF SERVICE RESOURCE MANAGEMENT FOR SEARCH STRATEGY DESIGN IN ELECTRONIC SUPPORT

INTRODUCTION

A core function of an electronic support receiver is the interception, detection and identification of radar emitters. A high probability of intercept P_I or identification P_{ID} is crucial, as well as a wide frequency coverage (e.g. 2-18 GHz). Possible approaches and their properties are:

Wide instantaneous bandwidth
- Good RF coverage & high P_I
- Reduced sensitivity

Several channels
- Good RF coverage & high P_I
- High costs, size & weight

Search strategy*: sequence of bands, dwell durations & execution times*
- Relatively narrowband receiver, but optimised search
- Increased P_I without disadvantages of wide bandwidth & several channels

We propose a method for designing optimised search strategies based on principles from quality of service (QoS) resource management. Given emitters with approximately known parameters, revisit and dwell times are chosen per frequency band. The goal is to maximise the utility achieved by the emitters' probability of identification under the constraint of limited receiver time.

SEARCH STRATEGY DESIGN

Per frequency band, revisit and dwell times are chosen by the search strategy optimisation procedure to maximise the overall utility achieved by a certain P_{ID} for a given emitter list.
The emitter list contains:
- Priority
- Beamwidth (min/max)
- Frequency (min/max)
- Scan rate (min/max)
- Maximum time for identification T_{ID}
- Desired P_{ID}, valid for T_{ID}
- Min. intercept duration needed for ID (depends on complexity of PRI modulation, for example)

Performance function
- Function to predict expected P_{ID} given a certain parameter selection
- Here: Window function based model by Kelly, Noone and Perkins

Utility function
- Defines the utility achieved by a certain probability of identification
- Examples:
  - Pid: Utility equals the P_{ID}
  - Step: 0 below values smaller desired P_{ID}, 1 above, "all or nothing"

Formally, the QoS resource management problem is defined as follows:

$$\max_{\Upsilon} \sum_{i=1}^{|B|} \sum_{j=1}^{|b_j|} \omega_{ij} \cdot \mathrm{u}(\mathrm{p}(v_i, e_{ij}))$$
$$\text{s.t.} \sum_{i=1}^{|B|} \frac{t_i}{T_i} \le r_l$$

$b_i \in B$: set of emitter parameters on the ith band from the set of all bands B
ω_{ij}: weight of emitter j on band i
u: utility function
p: peformance function
$v_i = \{T_i, t_i\}$: combination of revisit time T_i and dwell time t_i for band i
$e_{ij} \in b_i$: parameters of emitter j on band i
$\Upsilon = \{v_1, ..., v_{|B|}\}$: set of all selected receiver parameters
r_l: resource limit $r_l \in [0, 1]$

A solution to the optimisation problem is given by the **Q-RAM algorithm** (QoS-based Resource Allocation Model):

1. Start with zero utility and resources per band.
2. Evaluate resource and mean weighted utility values for every possible pair of revisit and dwell time on every band.
3. Extract the concave majorant in resource-utility space per band.
4. Allocate resources to the band with the highest increase in utility in relation to increase in resource for the next parameter combination on the concave majorant.
5. Repeat step 4 until no resources are left or utility can't be increased anymore.

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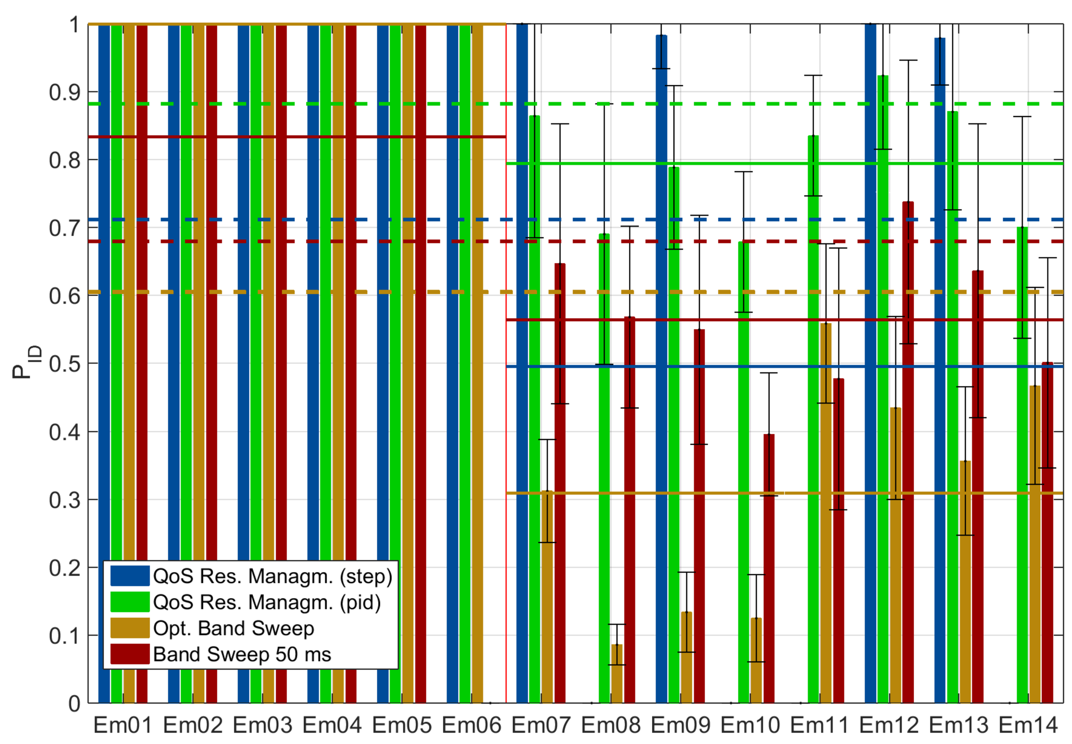
EXAMPLE

The presented example scenario contains 6 tracking and 8 scanning emitters. Tracking emitters have a higher priority and are always interceptable. For an expected P_{ID} of one for all emitters, about 159% of the resources would be needed. 1000 Monte Carlo runs were performed with 5 min simulated time per run. The following strategies were compared:
- QoS resource management with utility function "step" & "pid"
- Optimised band sweep: Periodic sweep through selected bands, dwell time is chosen as the maximum of the emitters' minimum required intercept duration for an identification
- Band sweep 50 ms: Periodic sweep through selected bands, constant dwell time of 50 ms

In the table below, dwell and revisit times as selected by the different approaches are given.

Band	2	4	6	8	11	15
QoS Res. Managm. (step)						
Dwell [ms]	–	304	7	135	4	–
Revisit [s]	–	0.701	0.976	0.976	0.976	–
QoS Res. Managm. (pid)						
Dwell [ms]	90	47	7	135	4	100
Revisit [s]	0.226	0.201	0.976	0.976	0.976	0.501
Opt. Band Sweep						
Dwell [ms]	21	5	7	135	4	2
Revisit [s]	0.1758	0.1758	0.1758	0.1758	0.1758	0.1758
Band Sweep 50 ms						
Dwell [ms]	50	50	50	50	50	50
Revisit [s]	0.3018	0.3018	0.3018	0.3018	0.3018	0.3018

Mean **probability of identification (P_{ID}) and standard deviation of the different approaches** for each emitter are given in the following figure. Dashed lines indicate mean over all emitters, whereas solid lines show the mean per priority class. The vertical red line is the boundary between priorities. Em01 to Em06 are high priority tracking emitters and Em07 to Em14 lower priority scanning emitters.



Band sweep 50 ms
- Can't identify Em06 (135 ms needed)

Optimised band sweep
- 135 ms dwell time for band 8 with Em06
- Identifies all high priority emitters with desired P_{ID}
- But: Reduced P_{ID} for others

QoS resource management
- Both variants also set dwell time for band 8 to 135 ms
- But: Much higher revisit time
- Spare resources can be used for scanning emitters
- Pid: Highest overall P_{ID}
- Step: 10 of 14 emitters reach the desired P_{ID} (pid: 7)

} **Utility function sets the focus**

CONCLUSION

- Method for designing **optimised search strategies** based on **quality of service** resource management principles
- Optimised dwell and revisit times are selected per frequency band
- Simulations show an **improved performance** over conventional band sweep strategies
- QoS resource management allows for a **flexible adjustment** of quality requirements, like **desired probability** in a given time
- Utility function can be used to specify the focus
- QoS resource management finds the **ideal compromise** between receiver time usage and achieved utility
- Improving the performance of a given receiver hardware