Distributed Utility-based Rate Adaptation Protocols For Prioritized, Quasi-elastic Flows

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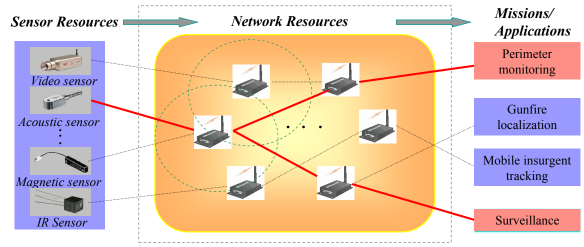
"How must sensor-enabled applications (missions) share the wireless bandwidth to maximize the effectiveness of all missions and satisfy the demands of missions?"

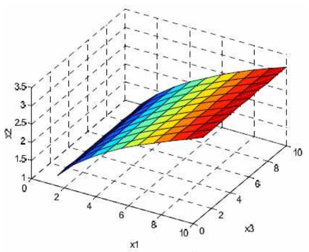
- Missions have minimum-acceptable utility
- Missions have priorities, not necessarily unique
- Need to satisfy demands in order of priority
- Not all demands may be feasible
- Utility needs to be maximized

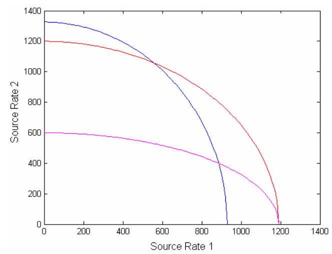


Basic Utility-Maximization Model

$$\frac{d}{dt}x_s(t) = \kappa\left(\sum_{m \in Miss(s)} w_{ms}(t) - x_s(t) \sum_{\forall q \in flow(s)} \frac{\mu_q(t)}{\sum_{\forall (k,s) \in l} c_{k,s}} + x_s(t) \sum_{\forall demand, i} \left(\eta_{is}\frac{\partial f_i(X)}{\partial x_s}\right) \right)$$

$$\eta_{is} = \begin{cases} [1 - f_i(X(t))/D_i]^+ / \varepsilon^p & if\ f_i(X) < D_i \\ 0 & otherwise \end{cases}$$



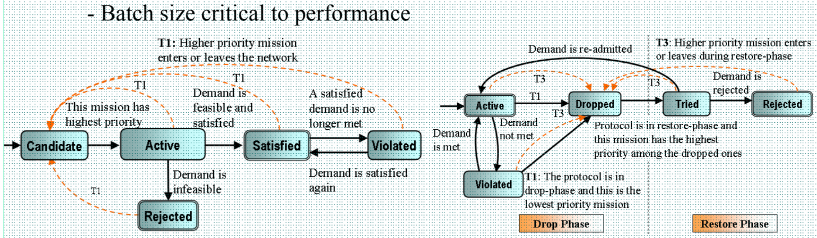


- **η_{is} is the per-bit cost of not adhering to the demand**
- η_{is} acts as congestion reduction factor when rate is lower than demand
- Willingness to pay increases proportional to:
  - Incremental gain in utility
  - Distance from satisfying the demand * rate at which a change in x helps it move towards this goal (partial derivative)
- **This model is sufficient when all demands are collectively feasible.**
- If demands are collectively infeasible, an optimal subset of feasible demands must be selected satisfying:
  - *Utility property:* utility is maximized
  - *Priority property:* a lower priority demand does not preclude a higher priority demand from being satisfied

Infeasible Demands

UNIQUE (STRICT) PRIORITIES FOR MISSIONS

- **Incremental protocol**
  - Demands are included sequentially, in decreasing order of priority.
- **Batch Protocol**
  - *Drop Phase:* Demands are dropped sequentially, from lowest priority
  - *Restore Phase:* Dropped demands are retried, from highest priority
- **Hybrid protocol**
  - Demands are grouped into batches, in order of priority
  - Each batch runs Batch protocol
  - Batches are tried sequentially, starting from highest priority
  - Batch size critical to performance

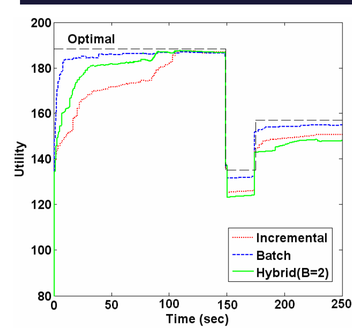


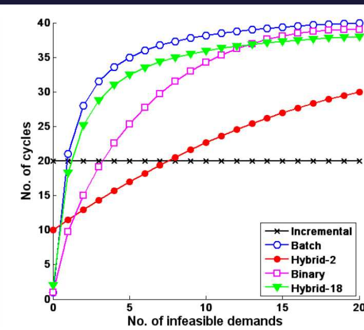
NON-UNIQUE PRIORITIES FOR MISSIONS

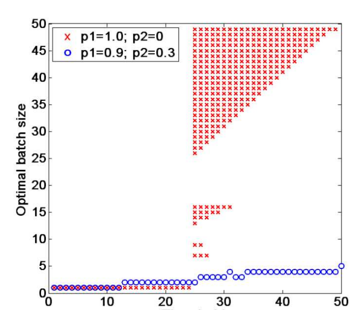
- Different metrics can be used to decide the "best" set of demands:
  - Total utility
  - Total utility of satisfied missions
  - Total number of satisfied missions
  - Weighted utility of satisfied missions

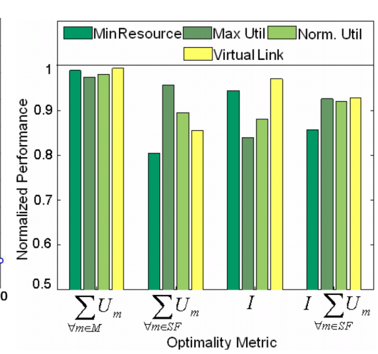
  } ***NP-hard*** (last three)
- Heuristics for selecting "optimal" subset of demands:
  - Minimum resource: order by bandwidth requirement
  - Maximum utility: order by utility requirement
  - Maximum normalized utility: order by per-bit utility requirement
  - Virtual link: order by dependence on virtual links

Simulation Results









Publications and Future Work

Future work includes:

- Studying performance of heuristics.
- Analyzing batch size for different probability distribution function.
- Analyze feasibility probability from empirical data.

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