Spatial Correlation-based Link Quality Estimator and Its Applications in Location-Aware Wireless Sensor Networks

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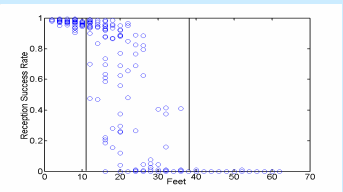
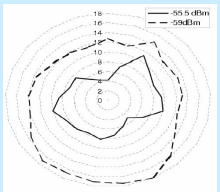
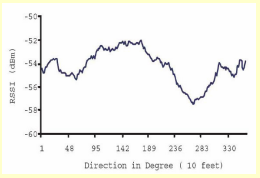
Problem and Motivation

Many higher-layer protocol designs are based on ***an ideal spherical*** communication pattern.





Need wireless link quality estimation and redesign of higher-layer protocols by taking into account link quality



Spatial Correlation ***in wireless communication link quality***

Leveraging spatial correlation in link quality estimation, such that communication between a pair of nodes can be used not only for the estimation between them, but also for nodes geographically close

Design of Spatial-based Link Quality Estimator

Using regression model to capture the spatial correlation and to estimate the link quality

How to model the spatial correlation ?

How the model adapt to link quality changes over time ?

How to ensure the model accuracy ?

Modeling the Spatial Correlation in Link Quality

- A source node collects
  - **s**: the location from a set of neighbor nodes
  - **p**: their link quality
- Correlation between **s** and **p** is modeled as

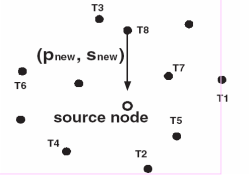
$$\hat{\mathbf{p}} = f(\mathbf{s}) = \beta_0\Phi_0(\mathbf{s}) + \beta_1\Phi_1(\mathbf{s}) + \ldots + \beta_k\Phi_k(\mathbf{s}).$$

- Regression coefficient are derived as

$$\beta = \left(\mathbf{\Phi}(\mathbf{s})^T\mathbf{\Phi}(\mathbf{s})\right)^{-1}\mathbf{\Phi}(\mathbf{s})^T\mathbf{p} = \left(\mathbf{\Phi}(\mathbf{x},\mathbf{y})^T\mathbf{\Phi}(\mathbf{x},\mathbf{y})\right)^{-1}\mathbf{\Phi}(\mathbf{x},\mathbf{y})^T\mathbf{p}$$

Sliding Window for Real-time Data Collection

- Regression model only considers the data falling into the sliding window
- Criteria for discarding data from the window
  - Temporal condition: oldest data is discarded (T_1)
  - Spatial Condition: the closest data within a threshold → (T_3)
- Regression Updates
  - Update $\mathbf{\Phi}(\mathbf{s})$ and $\mathbf{p}$ and re-compute regression coefficients
  - Or update regression functions based on a threshold hold for $(p_i - \hat{p}_i)^2$

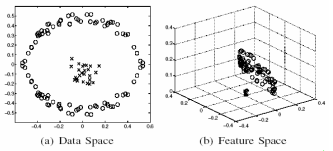


Weighted Regression Algorithm – capturing the irregularity in link quality

- **Weighted regression algorithm**:
  - classify collected **(p, s)** to **c** classes
  - derive a regression function for each class $f^{(i)}$
  - link quality at (x,y) is estimated as

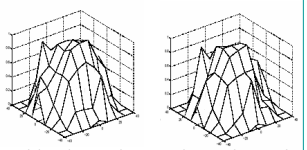
$$\hat{p} = w^{(1)}f^{(1)}(x,y) + w^{(2)}f^{(2)}(x,y) + \ldots + w^{(c)}f^{(c)}(x,y)$$

- The weight in the estimation
  - measuring the spatial closeness between the location point and each class
  - **space transformation tech:** weight is calculated by distance between the location point and the regression surface of a class in transformed space

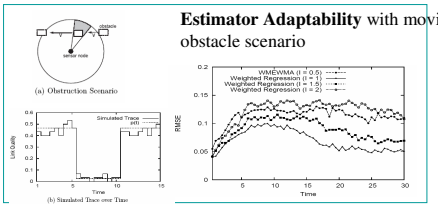


Performance Study

Link Quality Estimation

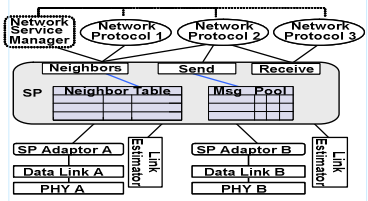


Estimator Adaptability with movin obstacle scenario

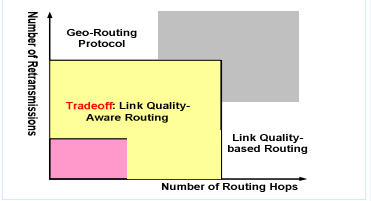


Link Quality-Aware Geo-Routing

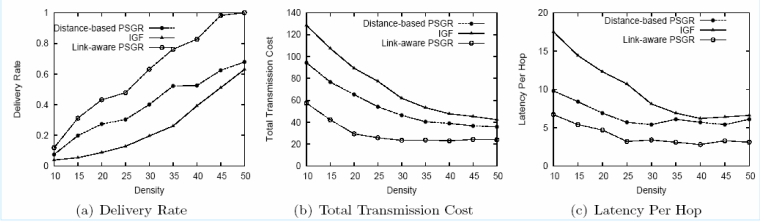
Link Quality Estimation Services



Link Quality-Aware Geo-Routing Design Space



Performance of Link Quality-Aware Geo-Routing



(a) Delivery Rate (b) Total Transmission Cost (c) Latency Per Hop