Mobility Prediction Based Relay Deployment Strategies for Conserving Power in MANETs*

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Mobility-Aided Networks

- Traditionally, the mobility of nodes in a mobile ad hoc network (MANET) is presumed to be beyond the control of any network protocol
- Mobility-aided network utilize the presence of special relay nodes with controllable mobility to improve the performance of the MANETs
- We consider a heterogeneous network consisting of
  - ***Traditional MANET nodes*** – Energy Constrained
  - ***Relay nodes with controllable mobility*** – Energy rich
- The goal of our research is to position and move such relay nodes in order to improve the energy efficiency across the traditional nodes

Energy Consumption in MANETs

$\mathbf{f_i}$: A flow in the network between nodes (s_i, d_i) with a data rate λ_i

$\mathbf{f_i} = (s_i, d_i, \lambda_i)$

$\delta_{s_i d_i}$: The distance between the nodes (s_i, d_i)

$P_T(\delta_{s_i d_i})$: The power consumed by the f_i to transmit one unit of data

$P_T(\delta_{s_i d_i}) = a + b\delta^{\alpha}_{s_i d_i}$

$\alpha \geq 2, a, b$: Constants defining the communication channel

The energy consumed by the flow $\mathbf{f_i}$ over a time duration τ is then given by

$$E_i = P_T(\delta_{s_i d_i}) \cdot \lambda_i \cdot \tau$$

Relay Node Deployment Strategies

Relay Node Dynamics

(1) Service Set Computation

- Identify the subset of nodes to service for the duration of an epoch
- Every relay node computes its service set in a distributed fashion

(2) Relay Node Positioning

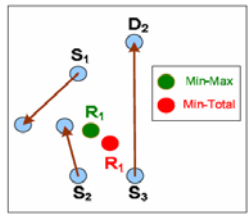
- Compute the optimal position of the relay node based on the service set
- Move the relay node based on the predicted positions of the nodes in its service set

Mobility Epochs

- The operation of the relay node is modeled using mobility epochs
- Epochs are of a fixed time duration
- The set of flows in the network does not change during the course of an epoch
- The mobility of the nodes is *predictable* during the course of an epoch. Nodes are NOT assumed to be static during an epoch

Illustrative Example

	x	y	$\delta_{s_i d_i}$	λ	P_T
S_1	30	262	18.1041	2	655.5169
S_2	30	236	13.0282	1.5	254.601
S_3	43	236	34.0006	1	1156.041
				Total Power	2066.159



Min-Total Solution

	x	y	$\delta_{s_i d_i}$	λ	P_T
S_1	30	262	14.7305	2	433.9753
S_2	30	236	11.9112	1.5	212.815
S_3	43	236	15.3574	1	235.8497
				Total Power	882.64

Min-Max Solution

	x	y	$\delta_{s_i d_i}$	λ	P_T
S_1	30	262	14.594	2	425.9697
S_2	30	236	13.2759	1.5	264.3743
S_3	43	236	15.4417	1	238.4461
				Total Power	928.7901

Notations

- Let the service set be

$$S_j : \{P_i = (x_i, y_i, \lambda_i) \mid i = 1, \ldots, K_j\}$$

where

- (x_i, y_i) : represents the position coordinates of the source node corresponding to a flow $\mathbf{f_i}$
- λ_i : represents the corresponding flow rate

Strategy1: Minimize Total Energy Consumed

Position the relay node so as to minimize the total energy consumed across all the nodes in its service.

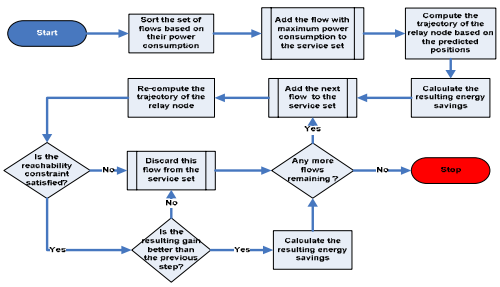
- The optimal position of the relay node is the weighted Euclidean center of the points $\mathbf{P_i}$

Strategy2: Minimize the Maximum Energy Consumed

Position the relay node so as to minimize the maximum energy consumed across all the nodes in its service set

- The optimal position of the relay node is the solution to the weighted 1-Euclidean center problem with $\boldsymbol{S_i}$ as the input set

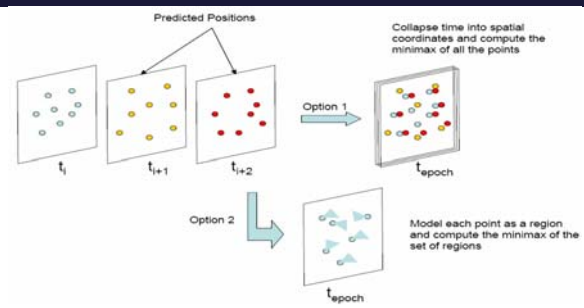
Algorithm for Min-Total Positioning



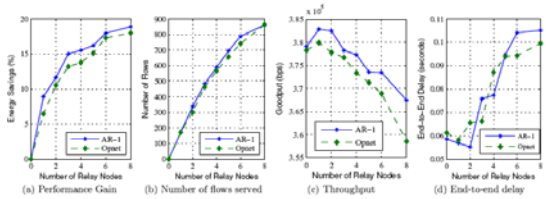
Mobility Prediction

- The relay node computes its optimal position at different time instants during the course of an epoch based on the predicted locations of the source nodes
- The framework currently utilizes two mobility prediction schemes
  - Linear Prediction Model
  - First Order Autoregressive Model

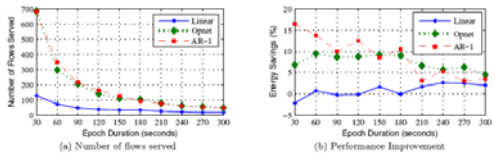
Algorithm for Min-Max Positioning



Simulation Results



Results with varying number of relay nodes



Results with varying epoch duration

Ongoing Research

- Modify the objective function
  - Minimize Energy Consumption
  - Maximize Connectivity
- Incorporate contextual prioritization
  - Identify set of nodes which are critical to the underlying mission

* A Venkateswaran, V. Sarangan, T. F. La Porta and R. Acharya, **A Mobility Prediction Based Relay Deployment Framework for Conserving Power in MANETs,** to appear in ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM) 2007