Opportunistic Data Forwarding:

Energy Efficient Routing for Delay Tolerant Wireless Sensor Networks

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Introduction

Opportunistic Connectivity protocol addresses the challenge of connectivity for isolated mobile nodes. This is through the process of discovery of regions with high node density. The concept involves four key components. These are adaptive sampling, coverage, handoff and directional communication.

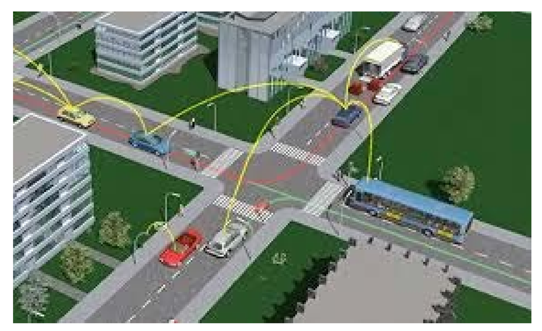
The protocols energy efficiency is achieved by minimisation of transmissions for node discovery and transmission power modulation for data collection through coverage, handoff and direction.

Node mobility causes change in the node encountering pattern that increases the exchange of overhead control signals. The exchange of these control signals is minimised by using Adaptive Resonance Theory 1 (ART1) neural network algorithm. Once a node encounters another node modulating the transmission power depending on the required range. These techniques together make the protocol energy efficient.

Applications

Wildlife Monitoring

Health Care



Vehicular Networks

Logistics Tracking

WSN Opportunistic data forwarding finds application in Wildlife monitoring [1,2], Health care sector, vehicular networks[3] and Logistic tracking. The protocol keeps collecting data and off-loads it whenever the isolated node (Patient, Animal etc being tracked) enter a region where multiple nodes are available.

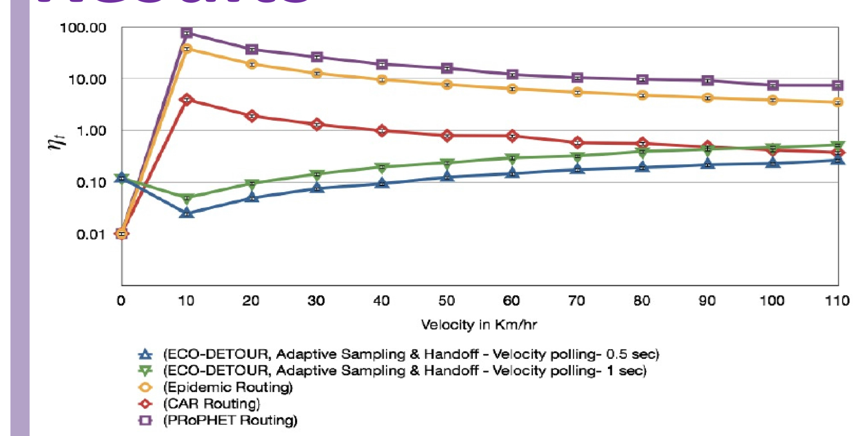
Research objectives

This research aims at extending the lifetime for isolated nodes in delay tolerant wireless sensor networks.

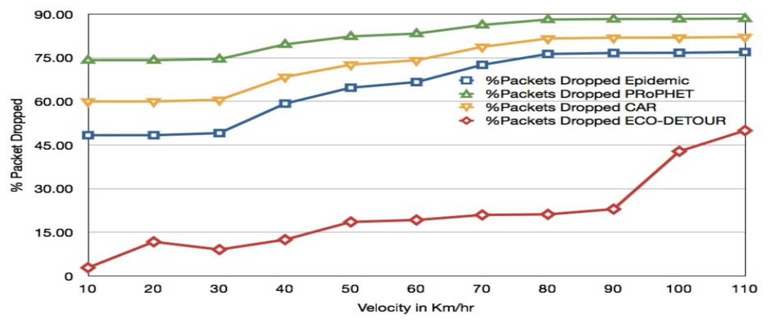
The research objective are:

- Minimisation of control signal exchange needed due to node mobility.
- Create node intelligence such that the node captures the spatio-temporal pattern of the trajectory and node encounters and use it to predict the next encounter
- Dynamic modulation of coverage range such that minimum power is used to maintain the range.
- For large data transfer Handoff is implemented to collect data over multiple nodes.
- Handoff is coupled with Direction dependent data transfer so static nodes in the trajectory of the mobile node are awake and ready.

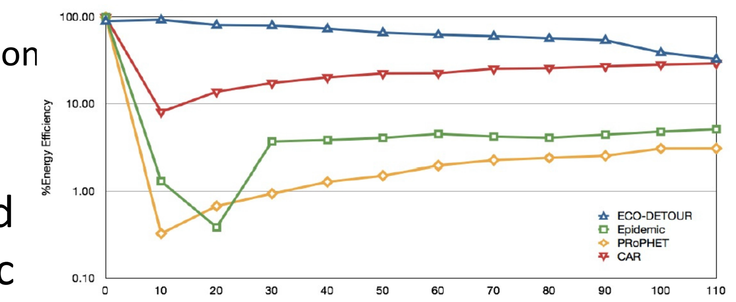
Results



3 (a) Variation in the Ratio of Overhead Transmission to Data Transmission with respect to velocity



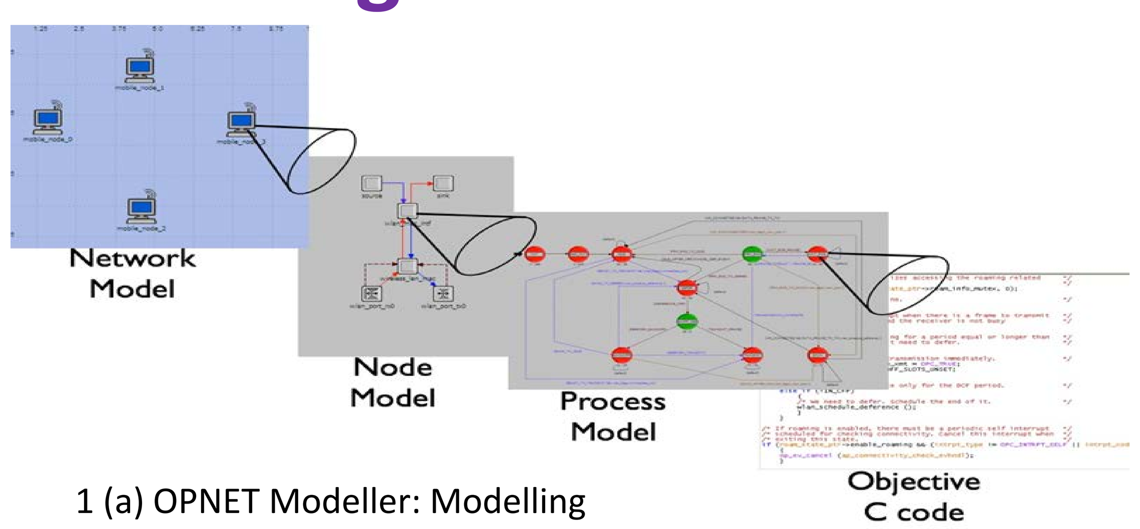
3 (b) % Packets Dropped with increasing velocity



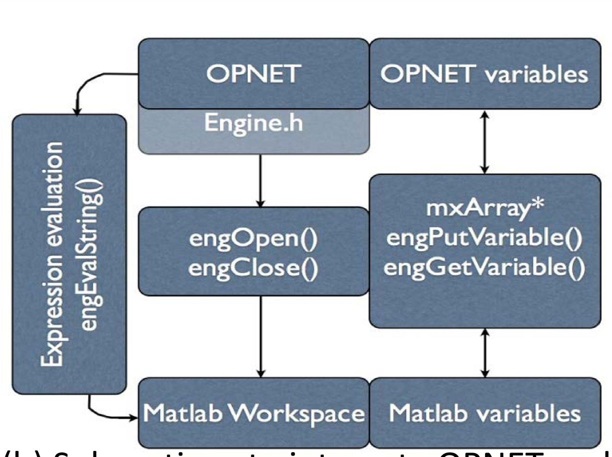
3 (c) % Energy efficiency with increasing velocity

The designed routing protocol termed ECO-DETOUR is compared with Epidemic Routing, CAR and PRoPHET for performance comparison. The performance metric considered are Transmission overheads, Packets Dropped and Energy efficiency, compared with respect to velocity. Fig. 3 (a) shows lower overhead transmission of ECO-DETOUR with respect to other protocols due to the far fewer samples it performs for node discovery. Fig. 3 (b) shows that overall packet drops for ECO-DETOUR even at high velocity is less than other protocols. ECO-DETOUR is 50% more energy efficient than other protocol fig. 3 (c).

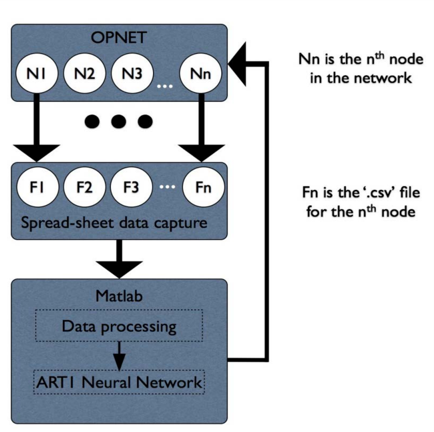
Modelling Tools



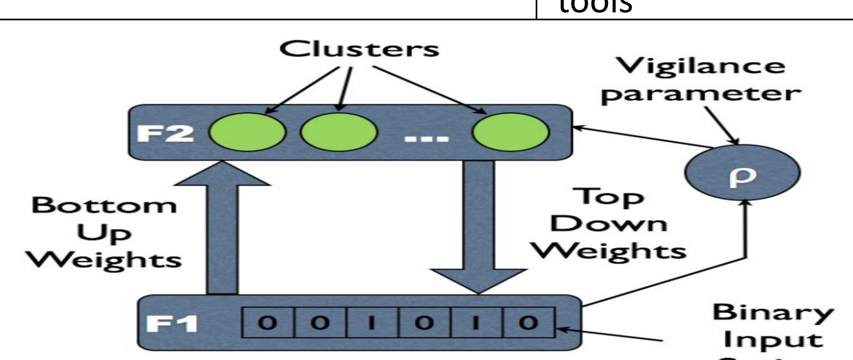
1 (a) OPNET Modeller: Modelling Hierarchy



1 (b) Subroutines to integrate OPNET and MATLAB



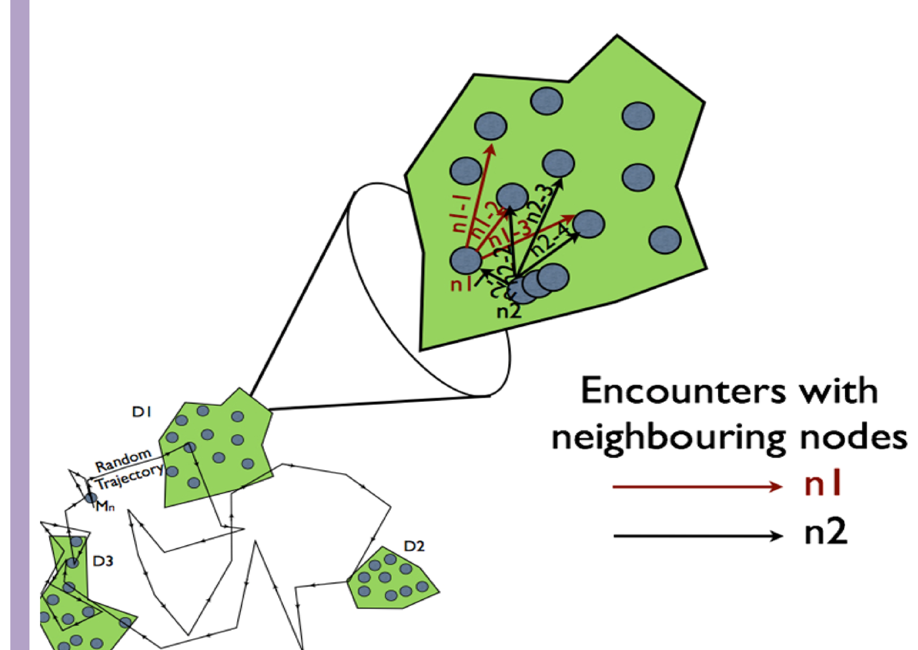
1 (c) Data flow between tools



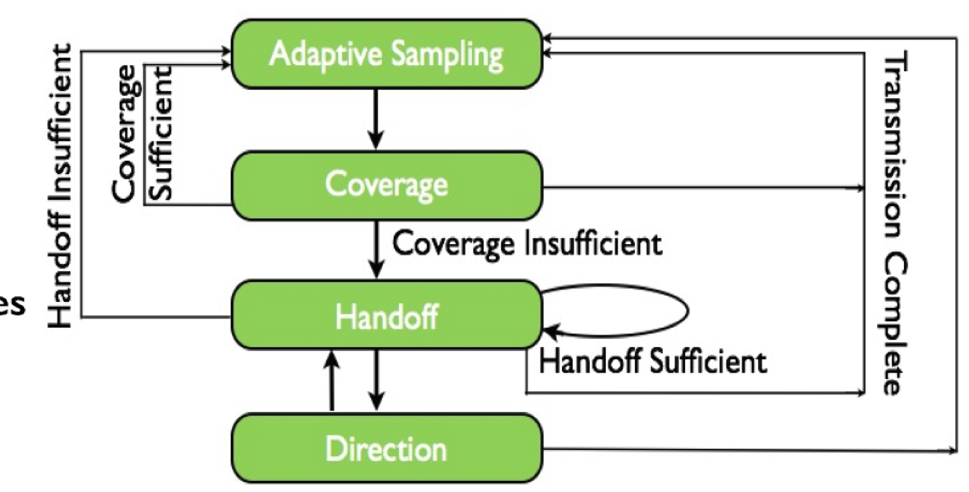
1 (d) ART 1 Neural Network Structure

The modelling of Opportunistic connectivity protocol requires simulation of mobility. OPNET allows creation of the trajectory on the GUI. To design learning capabilities ART1 NN has been used. Matlab is used to process mathematically complex functions.

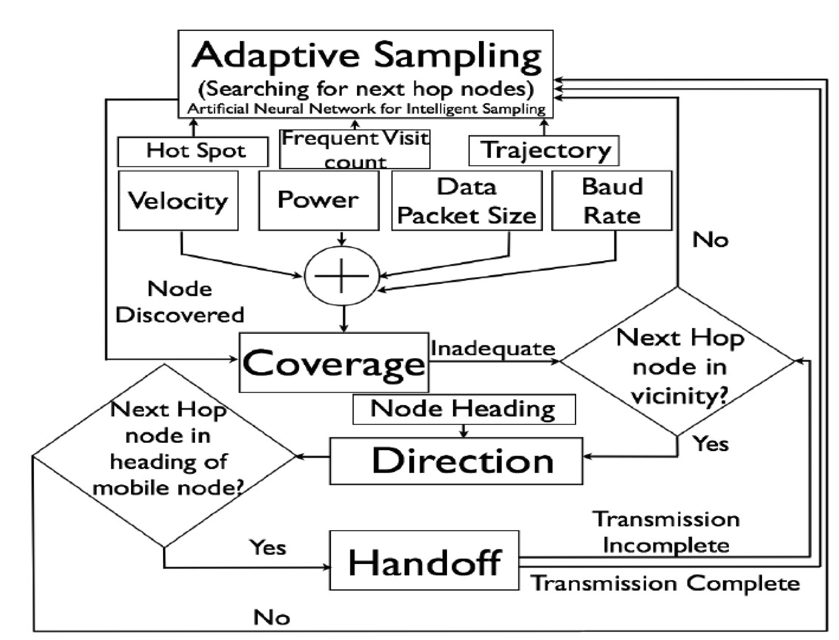
Protocol Concept and Design



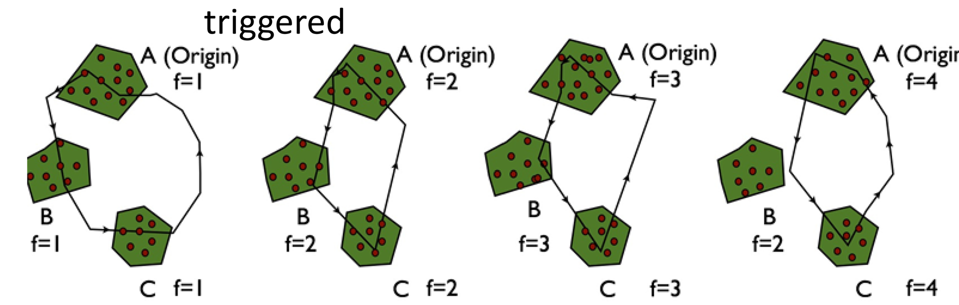
2 (a) Isolated Mobile Node Mn that Opportunistically Transmits Data in regions D1, D2 and D3



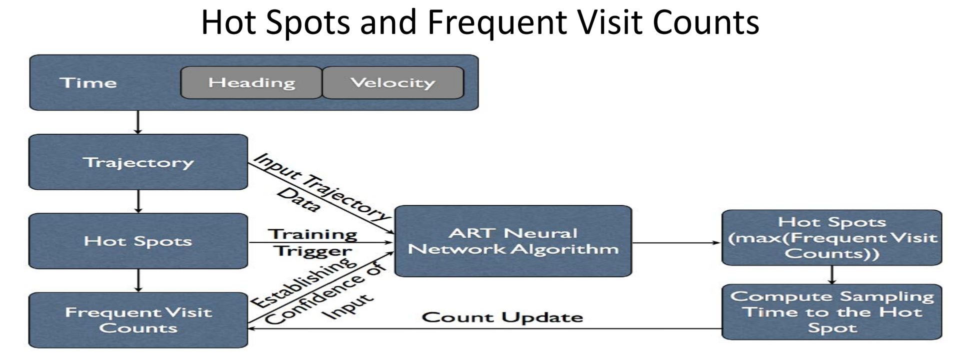
2 (b) High Level flow diagram depicting sequence in which the four components are triggered



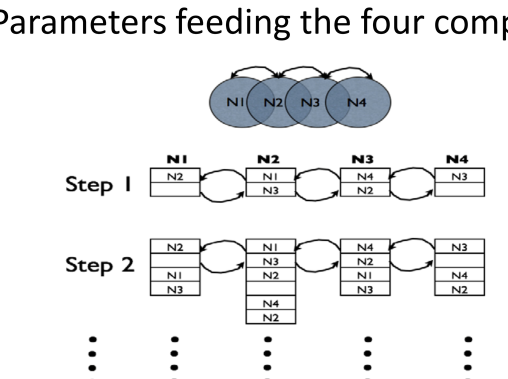
2 (c) Parameters feeding the four components



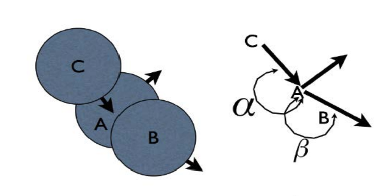
2 (d) Mobile Node trajectory with corresponding Hot Spots and Frequent Visit Counts



2 (e)Adaptive Sampling System Organisation



2 (f) Handoff Neighbour ID table creation



2 (g) Node Headings: (a) Nodes know their own heading (b) Bearing with respect to other nodes

The Opportunistic Connectivity protocol helps collect data from isolated mobile nodes as shown in fig 2(a). The nodes move between regions of high node density hot spot (A, B, C) fig 2 (d) where it encounters other nodes for data exchange. To search for these high node density regions the mobile node has to transmit beacons. Regular beacon transmission drains battery faster. The Adaptive Sampling component uses neural network to intelligently transmit beacons only when the node approaches the hot spot. This way the node does not transmit beacons until it reaches the destination. Once the node reaches the hot spot Coverage, Handoff and Direction fig 2 (b) and 2 (c) get triggered to maximise data collection . Fig 2 (e) shows the Input and output to the ART 1 neural network algorithm. The algorithm takes node trajectory and frequent visit count to the hot spot to predict the possible next hot spot. Fig 2 (f) shows the neighbourhood table created for handoff. It is used to forward data to next stationary node. The direction of a node is used to forward the handoff data to the next node.

Future work

Following are few area that need to be addressed.

For future work we will be looking at the following:

- Deviation from Origin: The trajectory mapping assumes that the node starts from and ends at the origin. Real life situation may have node starting and ending at different points in space.
- For node coverage the path loss is assumed to be free space. Other path loss models also need to be considered
- Handoff for multiple nodes: The current implementation of handoff only handles one mobile node at a time. As part of future work we intend to design a scheduling mechanism handle multiple mobile nodes.

References

[1] S.Sivakumar et al., “Adaptive sampling for node discovery: Wildlife monitoring & sensor network,” in 16th Asia-Pacific Conference on Communications (APCC), 2010, pp. 447-452, 31 Oct – 3 Nov 2010.

[2] S.Sivakumar and A. Al-Anbuky, “Analysis of network connectivity: Wildlife and Sensor Network,” in Australasian Telecommunication Networks and Applications Conference (ATNAC), 2009, pp. 1-6, 10-12 Nov 2009

[3] S.Sivakumar and A. Al-Anbuky, “Vehicular Networks Smart Connectivity,” in Eight International Conference on Wireless and Mobile Communication ICWMC, 2012, pp. 304-310, 24-29 June 2012