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AN EFFECTIVE OPPORTUNISTIC NETWORKING ROUTING PROTOCOL FOR THE WESTERN HIMALAYAS

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Abstract

In the field of computer networking, the different computing devices exchange data with each other using connections between nodes, which are devices that originate, route and terminate data. The data links between nodes are established over cable media or wireless media. Opportunistic Networking (OppNet) is one of the most interesting evolutions of MANETs, where mobile nodes are enabled to communicate with each other even if a route connecting them never exists. Typically, the Western Himalayan region has communication challenged remote areas. One of the main challenges in emergency scenarios is the interruption of information flow in the light of either absence or damage to the existing communication infrastructure, to optimise the response and decision making of the concerned authorities. There may be extensive delays or regular disruptions in the connection between network devices. OppNet can be deployed in such situations using mobile devices carried by members of the rescue team and installed sensor devices which form the intermittently connected network which uses opportunistic contacts among nodes to allow bundles of data to jump node-to-node from source towards the destination. A novel energy-aware routing protocol mechanism is hereby proposed with the background of the MaxProp protocol in the field of OppNet, where messages are forwarded based on the node's remaining battery, delivery predictability and the kind of nodes. The logic is then applied through simulation work over the specific remote geographic area under study - taking example of the Kinnaur region in the Western Himalayas, analysed and compared the performance through results achieved in terms of delivery probability,

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overhead ratio and average latency among other parameters.

Keywords: *OppNet, Networking, DTN, ONE, Himalayas*

1. Introduction

A mobile or wireless ad hoc network (MANET) is a continuously self configuring, infrastructure-less network of mobile devices connected wirelessly [1]. Each device in a MANET (Fig 1) is free to move independently in any direction and thus changes links with other devices frequently. As each such device forwards traffic unrelated to its own use, it needs to be a router, which is a main challenge in building a MANET, that is, equipping each device to continuously maintain the required information to route the traffic properly.

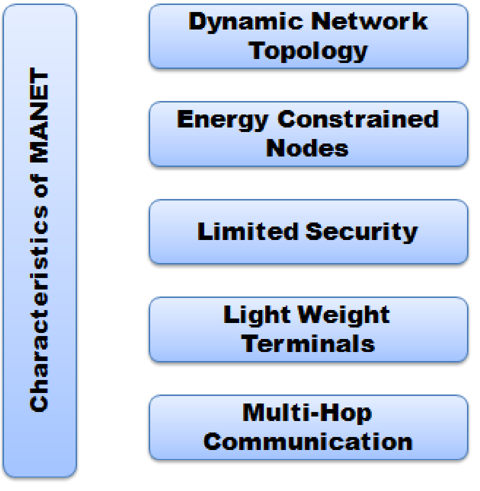

Fig 1 MANET Characteristics

The routes are built dynamically while the messages are en-route between the sender and the destination and any possible node can opportunistically be used as a next hop, provided that it is likely to bring the message nearer to the final destination. Such requirement makes it an interesting and highly challenging research field to enable communication between source and destination without the support of a fixed network infrastructure as in Fig 2 and Fig 3

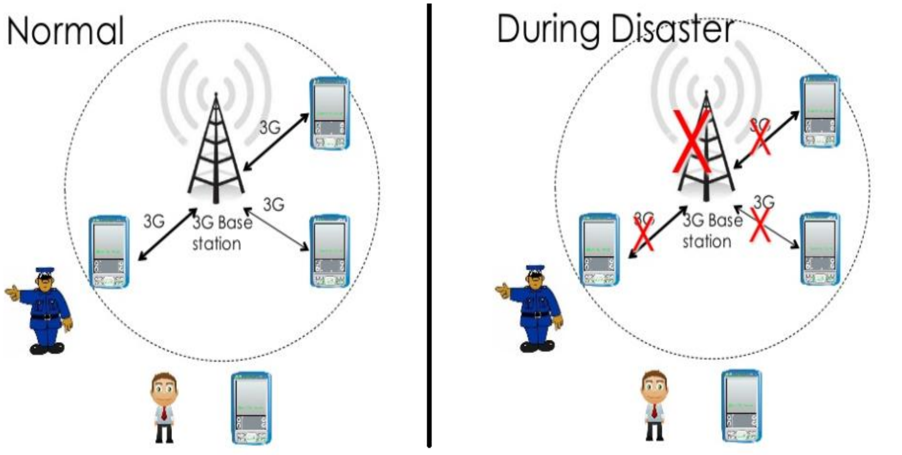

Fig 2 Need for OppNet

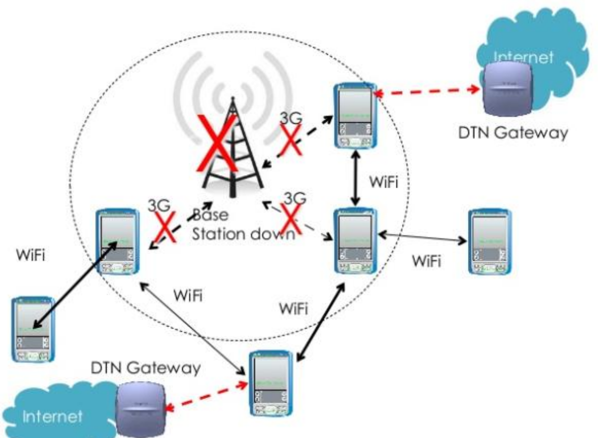

Fig 3 OppNet in Emergency Response Scenario

In real mobile ad hoc networks, the connectivity is such that an end-to-end path between message source and destination might never exist. OppNets turn this obstacle, that is, mobility, into an opportunity by allowing nodes to carry the messages with them while they move, until a next hop is encountered. Mota et al [6] surveyed the evolution of OppNet research. Mumeed et al [8] consider human aspects of trust, privacy and security on the performance of the OppNet. Described by Yodmani et al (2001) [9] is the emerging role of communication technologies in mitigation, preparedness, response and recovery phases of disaster management and highlight the emerging challenges in making the application of these technologies effective. Authors in [10] presented a paradigm of OppNets in the context of emergency preparedness and response (EPR).

In 2002, Kevin Fall [2] firstly used the name delay-tolerant networking (DTN) for the terrestrial networking using inter-planetary network similar architectures. Bundle based architecture [7] is at the heart of DTN. DTNs are participatory networks made up of battery-constrained devices that adopt store-and-forward mechanism to cope with the problem of intermittent path as shown in Fig 4. It is a challenge for scheduling nodes transmission avoiding frequent overflow of nodes buffers due to the limited storage of each node. In order to achieve efficient utilization of the available network resources, it is highly important to come up with an effective message scheduling strategy to determine which messages should be forwarded and which should be dropped in case the buffer is full.

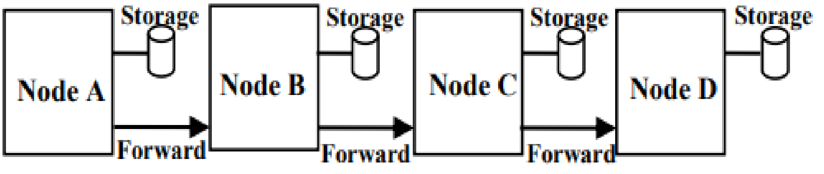

Fig 4 Store & Forward Mechanism

Going through the studies, it can be pointed that a typical opportunistic network is loosely connected, links between the nodes are often disrupted and the network topology is subject to constant changes which makes it unfit to predict which single routing strategy is full proof in any given situation. Research on routing is still in its infancy.

II Simulation

Simulation plays an important role in analyzing the behaviour of OppNet routing and application protocols. The simulation environment (Fig 5) used in this work is based upon ONE, a powerful simulator used to implement realistic scenarios [3]. ONE is written in Java and follows a strict objectoriented approach with focus on easy extensibility to allow for development of new protocols or mobility models. A set of well known protocols and mobility models are shipped along with the ONE. We used it to extensively evaluate the different performance dynamics of the various routing strategies. It offers a broad set of protocol simulation capabilities in a single framework.

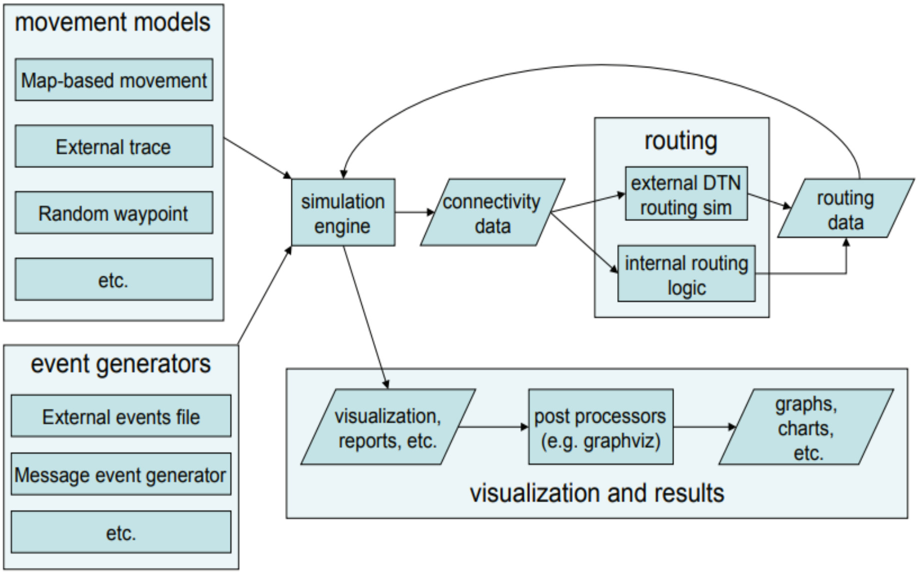

Fig 5 ONE Simulation Environment

In order to evaluate the performance of various OppNet routing protocols in the challenging and remote areas from the communication point of view, area of the Kinnaur region from the state of Himachal Pradesh in India, representing a part of the Western Himalayas has been studied in this work. While people are making optimum use of communication technology, the inhabitants of remote valleys in tribal belt of Kinnaur district are struggling hard to stay connected with the rest of the world [4].

Kinnaur is one of the most remote and high altitude districts of India (Fig 6). It has rugged mountainous terrain with altitude ranging from 1300m to 6000m above mean sea level. It consists of high mountains, deep valleys, gorges, glaciers and rivers.

Fig 6 Map of the Kinnaur District, Himachal Pradesh, India

For the simulation scenarios and comparison of the results obtained, another map-based model of a part (Fig 7) of the well-developed and well-connected city of Helsinki, the capital of Finland is also used. Helsinki has one of the highest urban standards of living in the world. In 2011, the British magazine ‘Monocle’ ranked Helsinki the world's most liveable city in its liveable cities index [5].

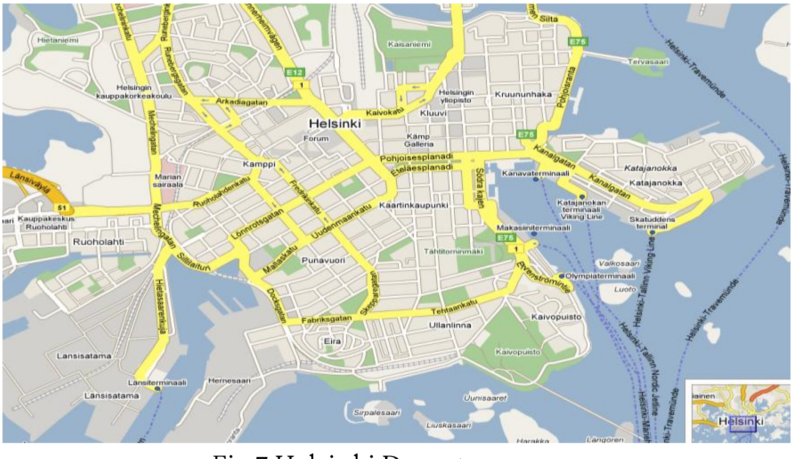

Fig 7 Helsinki Downtown area

III Proposed Network Environment

The message routing and node mobility have a determinant impact upon the overall energy consumption in the network. Furthermore, at OppNet typical environments the access to an external power supply is very limited. Therefore, in the design of OppNet routing algorithms energy consumption must be carefully considered as an important evaluation measure. In order to analyze the impact of energy upon the performance of different routing protocols, an energy module is introduced (Fig 8) that receives as parameters the amount of energy expend in search for other nodes, transmission and reception of messages, typically in units per second. Moreover, a node may recharge its battery.

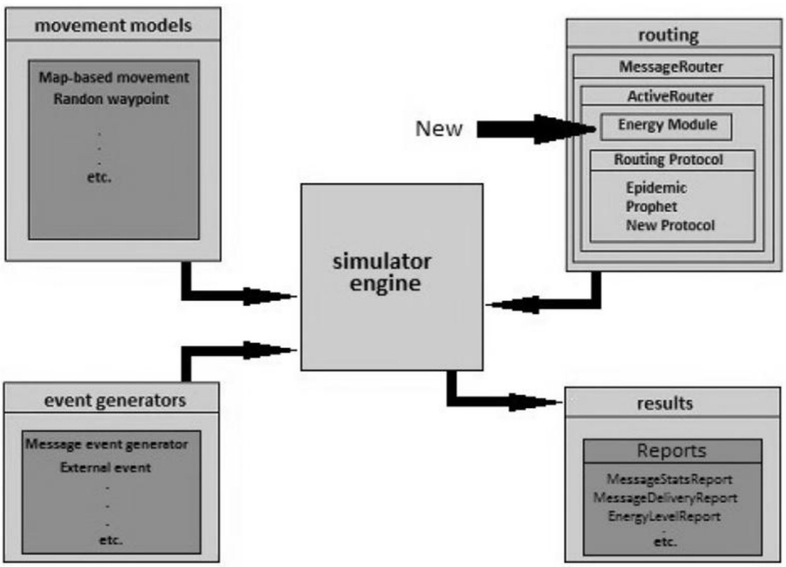

Fig 8 Interaction of the modules

Delivery Probability is the ratio of the number of delivered messages to the total number of messages created by the source node. High delivery probability means that more messages are delivered to the destination. Overhead Ratio is the ratio of difference between the total number of relayed messages and the total number of delivered messages to the total number of delivered messages, it shows how efficient a protocol is in terms of correct relay decisions. Latency is the time elapsed between the creation of a message and its final delivery at the destination. Buffer Time average is the average time that messages are stored in the node buffers.

A number of experiments are performed over the ONE simulator with different settings and with diverse routing protocols in order to strengthen our study to increase the overall lifetime of the network in challenging environment.

IV Experiments & Results

Exp 1: To study the impact of varying the number of nodes or nodal density on the performance evaluation metrics for the unlike protocols.

Simulation and delivery-based performance evaluation of six routing protocols of OppNets namely First Contact, Direct Delivery, Epidemic, Spray & Wait, PRoPHET and MaxProp was performed and the summary data of simulation runs stored in the form of reports. Each simulation was run for 43200 seconds.

All nodes except one are assumed to be mobile in nature. The nodes communicate with each other using Bluetooth at 2Mbit/sec data rate with 10m of radio range and generate one new message on average after every 25-35 seconds with message size varying between 500KB-1MB and the message lifetime of 300 minutes. The buffer size for each node is 20MB. All nodes present in the simulation area are divided into six different groups:

Group 1 nodes are normal pedestrians which move at speeds of 0.5-1.5 m/s.

Group 2 nodes are quick reaction trained personnel which move at the speeds of 0.75-2.0 m/s.

Group 3 nodes are normal vehicles which move at a speed of 2.5-15 m/s.

Group 4 nodes are quick reaction support vehicles which move at the speeds of 5-25 m/s with both Bluetooth and high speed interface with speeds of 250kbps, 10Mbps and transmission ranges of 10m, 1000m respectively.

Group 5 nodes are public transport buses which move at the speeds of 2-25 m/s.

Group 6 has a fixed base-station stationary node at a central strategic location.

The nodal density was varied among different groups between 17-121 as per Table 1 to obtain readings for the different evaluation metrics.

Table 1 : Distribution of Nodes among different Groups

Nodes	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
17	5	3	4	3	1	1
31	10	5	8	5	2	1
61	20	10	16	10	4	1
91	30	15	24	15	6	1
121	40	20	32	20	8	1

Analysing the results obtained, it is observed as in the Fig 9 that the value for delivery probability continuously increases till the node density is 61 in a well connected environment. Thereafter, it keeps increasing with the node density for the Spray & Wait, Prophet and Epidemic routing protocols, whereas it decreases for the MaxProp, First Contact and Direct Delivery protocols upto node density 91 after which the MaxProp protocol shows a steep jump while the other two do not vary much in terms of delivery probability. On the contrary, in a challenging network environment, there is a continuous increase in delivery probability with the number of nodes in the Prophet, MaxProp, Spray & Wait, First Contact and Epidemic protocols. The Direct Delivery routing protocol does not show a very consistent pattern.

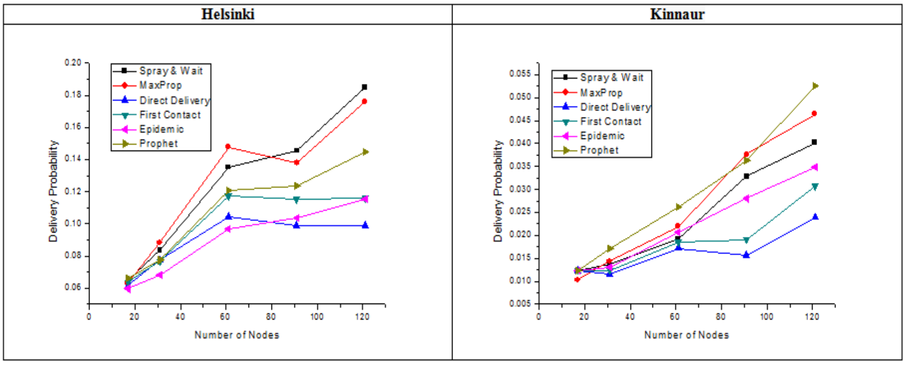

Fig 9 Comparative Analysis - Number of Nodes versus Delivery Probability

Fig 10 shows that the value for overhead ratio goes on increasing with the number of nodes for the Epidemic, Prophet, MaxProp and First Contact routing protocols in both environments. The Spray & Wait protocol shows the same increase upto the node density 61 for challenging environment.

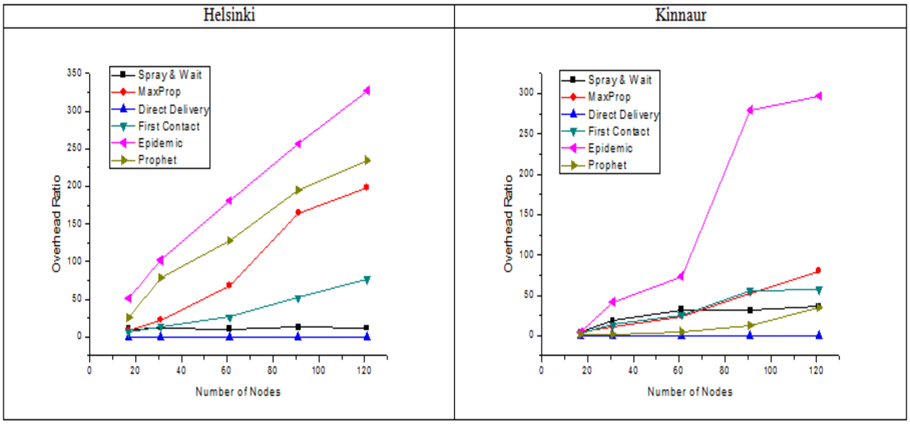

Fig 10 Comparative Analysis – Number of Nodes versus Overhead Ratio

Through Fig 11 it is observed that in a well connected scenario, the Prophet routing protocol shows a continuous increase with the number of nodes in terms of latency average while the Spray & Wait, Epidemic and Direct Delivery protocols show a similar increase beyond the nodal density of 61. The maximum latency average noted in all the routing protocols except the Spray & Wait in the challenging environment is observed on nodal density 61.

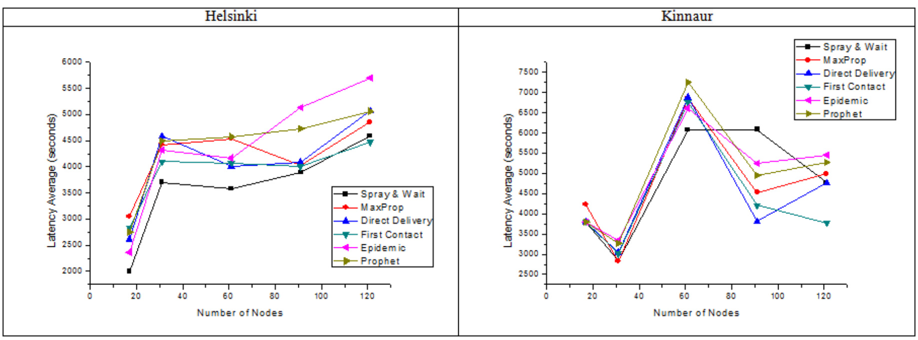

Fig 11 Comparative Analysis – Number of Nodes versus Latency Average

Exp 2: To study the impact of varying buffer size of the nodes on the performance evaluation metrics for the different protocols.

Simulation and delivery-based performance evaluation of six routing protocols of OppNets namely First Contact, Direct Delivery, Epidemic, Spray & Wait, PRoPHET and MaxProp was performed. The summary data of simulation runs is stored in the form of reports. Each simulation was run for 43200 seconds.

All nodes except one are assumed to be mobile in nature. The nodes communicate with each other using Bluetooth at 2Mbit/sec data rate with 10m of radio range and generate one new message on average after every 25-35 seconds with message size varying between 500Kb-1MB and the message lifetime of 300 minutes. All nodes present in the simulation area are divided into six different groups:

Group 1 - 20 normal pedestrians which move at speeds of 0.5-1.5 m/s.

Group 2 - 10 quick reaction trained personnel which move at the speeds of 0.75-2.0 m/s.

Group 3 - 10 normal vehicles which move at a speed of 2.5-15 m/s.

Group 4 - 16 quick reaction support vehicles which move at the speeds of 5-25 m/s with both Bluetooth and high speed interface with speeds of 250kbps, 10Mbps and transmission ranges of 10m, 1000m respectively.

Group 5 - 4 public transport buses which move at the speeds of 2-25 m/s.

Group 6 - a fixed base-station stationary node at a central strategic location.

The buffer sizes for the nodes were varied between 1Mb-30Mb to obtain readings for the different evaluation metrics.

Analysing the results obtained, it is observed as in the Fig 12 that the value for delivery probability continuously increases upto the buffer size of 15MB in a well connected environment for the Epidemic, Direct Delivery, First Contact, Spray & Wait and MaxProp routing protocols, whereas it increases upto 10MB in communication challenged scenario for the Direct Delivery, First Contact, Spray & Wait, MaxProp and PRoPHET protocols. The value is seen to either reduce or remain constant thereafter.

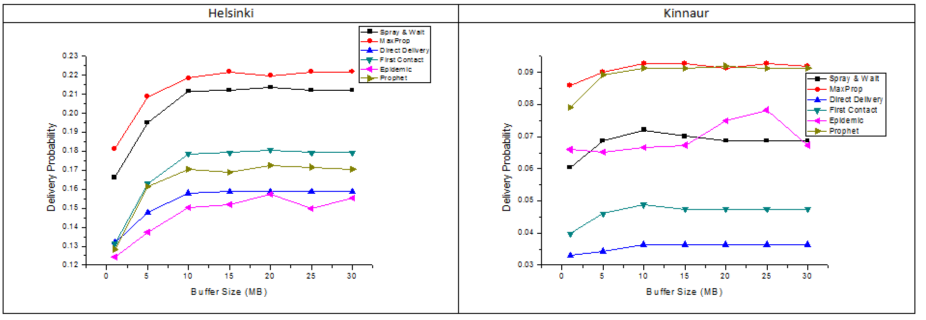

Fig 12 Comparative Analysis - Buffer Size versus Delivery Probability

Fig 13 shows that the value for overhead ratio is noted to be the highest for buffer size 1-5MB in all the scenarios

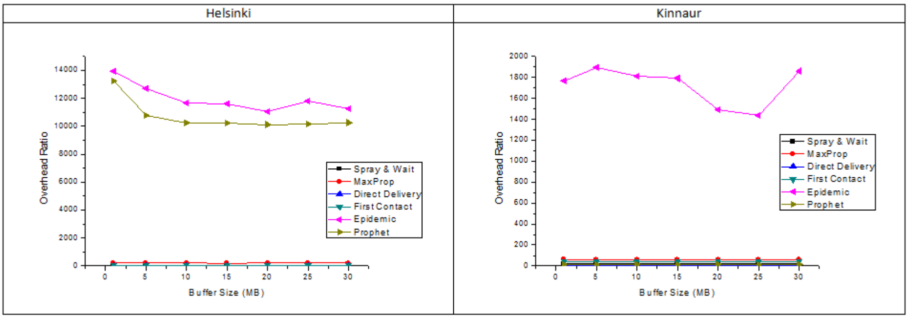

Fig 13 Comparative Analysis – Buffer Size versus Overhead Ratio

Through Fig 14 it is observed that the latency average is found to be the maximum at buffer size 15MB for the routing protocols Direct Delivery, First Contact, Spray & Wait and MaxProp in challenged network environment and minimum for 1MB buffer size for all protocols except Epidemic. In well connected environment, the latency average is minimum for all six protocols for 1MB buffer size.

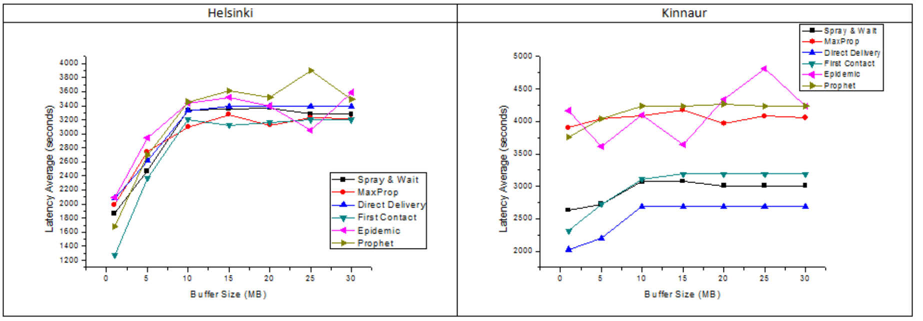

Fig 14 Comparative Analysis – Buffer Size versus Latency Average

Exp 3: To study behaviour of the energy-aware MaxProp OppNet routing protocol over a network environment as proposed for a communication challenged geographical region, taking Kinnaur in the Western Himalayas as an illustration.

All nodes present in the simulation area (50 km x 30 km) have a buffer size of 15MB and are divided into six different groups:

Group 1 - 20 normal pedestrian nodes with a recharge interval of 21600 seconds, moving at speeds of 0.5-1.5 m/s in a Random Walk movement model.

Group 2 - 10 quick reaction trained personnel nodes with recharge interval of 36000 seconds and which move at the speeds of 0.75-2.0 m/s in a Random Walk movement model.

Group 3 - 10 normal vehicle nodes with a recharge interval of 43200 seconds moving at a speed of 2.5-15 m/s in a Map Based Movement model.

Group 4 - 16 quick reaction support vehicles with a recharge interval of 72000 seconds and which move at the speeds of 5-25 m/s with both Bluetooth and high speed interface with speeds of 250kbps, 10Mbps and transmission ranges of 10m, 1000m respectively. The nodes move in a Map Route Movement model.

Group 5 - 4 public transport buses with a recharge interval of 28800 seconds and which move at the speeds of 2-25 m/s in a Map Route Movement model.

Group 6 - a base-station stationary node at a central strategic location with recharge interval of 432000 seconds. The node remains fixed in a Stationary Movement model.

The different groups have an initial energy according to the Table 2.

Table: 2 Initial Energy scenarios for different node groups

Initial Energy (in units)	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Case 0	No Energy Concept					
Case 1	600	800	700	900	500	1000
Case 2	6000	8000	10000	18000	12000	48000
Case 3	12000	16000	20000	36000	24000	192000
Case 4	24000	32000	40000	72000	48000	384000

The nodes communicate with each other using Bluetooth at 2Mbit/sec data rate with 10m of radio range and the message lifetime of 3000 minutes (or 50 hours) with the message creation interval rate between 0-10 seconds and each message size between 0 KB-1 MB.

The simulation is run for 430000 seconds (or 5 days) and the readings recorded for the varied cases.

The Fig 15 and Fig 16 display the trend in the number of messages delivered, relayed and dropped during the different energy settings in the network environment. The Case 0 relates with the ideal scenario where there is no reference of the energy concept at all and hence it shows the highest number of delivered messages. The other four cases show a rising tendency in terms of the messages delivered, relayed and dropped relatable with the rising energy levels as clearly indicated in the Fig 17 where the pointer is delivery probability on one axis. The overhead ratio too displays a similar trend in the Fig 18 being the lowest in Case 0 as expected.

The latency average is recorded to be maximum for Case 2 as in the Fig 19. Thereafter, it shows a declining pattern with the increasing energy levels, whereas it is the lowest in the ideal state environment of Case 0. The buffer time average too marks a decreasing trend with the rising energy levels as seen in the Fig 20.

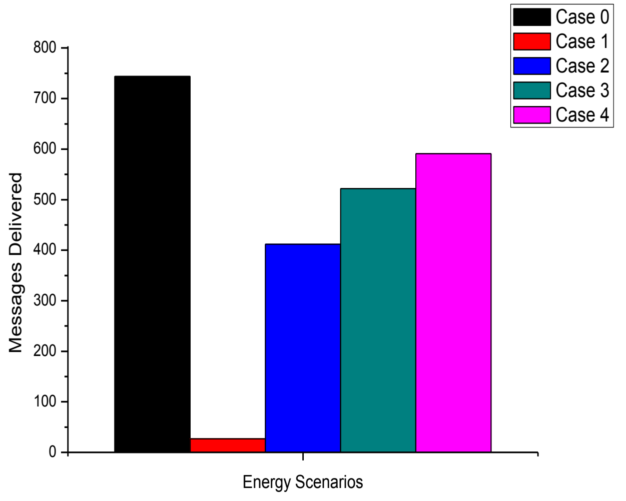

Fig 15 Comparative Analysis – Messages Delivered in different Energy Scenarios

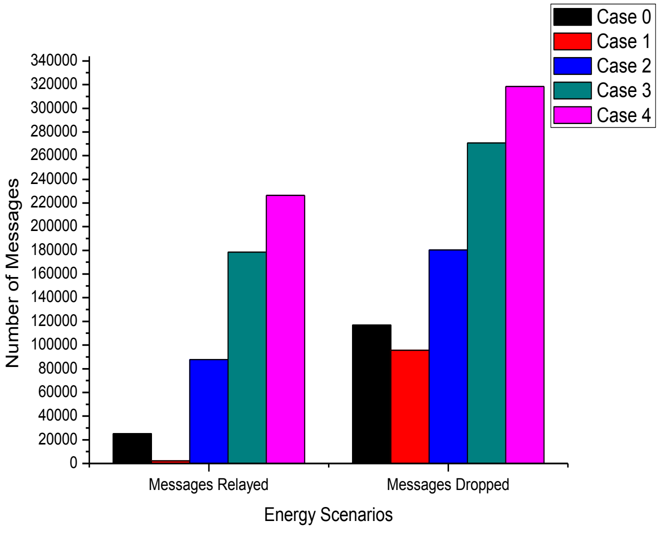

Fig 16 Comparative Analysis – Messages Relayed & Messages Dropped in different Energy Scenarios

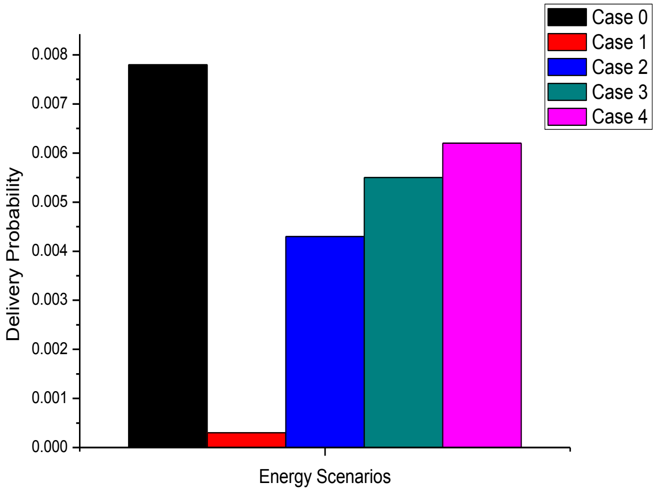

Fig 17 Comparative Analysis – Delivery Probability in different Energy Scenarios

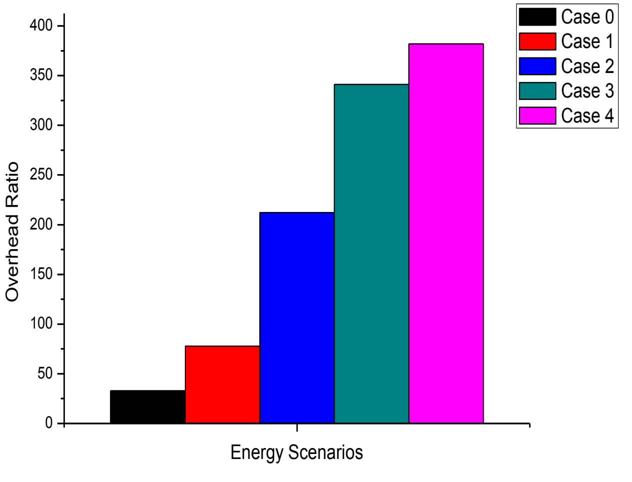

Fig 18 Comparative Analysis – Overhead Ratio in different Energy Scenarios

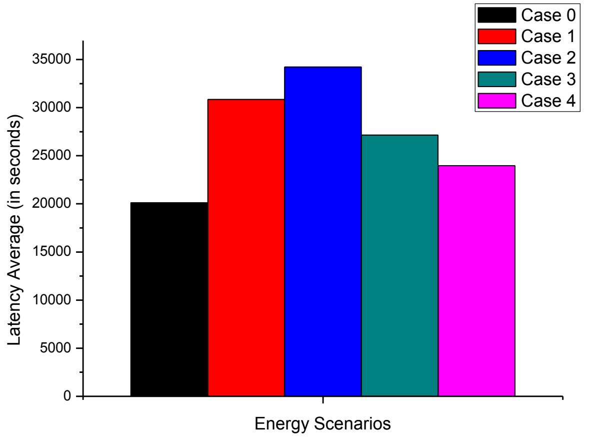

Fig 19 Comparative Analysis – Latency Average in different Energy Scenarios

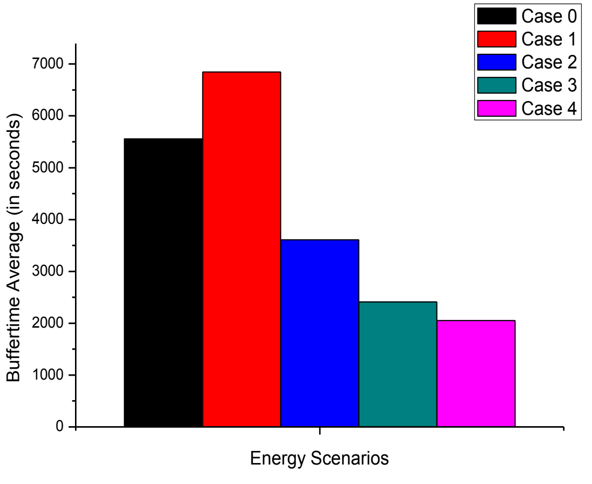

Fig 20 Comparative Analysis – Buffer time Average in different Energy Scenarios

V Conclusion

A number of simulation experiments were conducted to obtain the performance evaluation metric readings for the different OppNet protocols in terms of the nodal density, buffer size for the nodes, the message creation interval rates and the best message size to be transmitted over the selected mapped geographical areas – one being very remote and the other being very well connected for an even handed result contrast.

A novel energy-aware routing protocol mechanism is then proposed with the background of the MaxProp protocol in the field of OppNet, where messages are forwarded based on the node's remaining battery, delivery predictability and the kind of nodes. The proposed logic is then applied through simulation work over the specific remote geographic area under study, analysed and compared the performance through results achieved in terms of delivery probability, overhead ratio and average latency among other parameters.

Through the results obtained, it could be well established that the protocol proposed for the communication challenged network environment can be used in such hard difficult geographical areas all over the globe to improve the overall network connectivity in the regions implicated. With an enhancement in the initial energy of the nodes involved, the overall network lifetime is improvable based upon the available resources.

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