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Mobility Models and Routing Protocols in Opportunistic Networks: A Survey

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Abstract: Opportunistic networks (OppNets) are a form of MANETs, where node gets connected to each other opportunistically, when they are in range. The two key parameters to obtain an optimized route are Mobility Models and Routing Protocols. Mobility models are those which should depict mobile nature of nodes exactly. Routing protocols help nodes to transmit message between nodes i.e. source and destination. In this paper we survey and examine different Mobility Model and Routing Protocols used in Opportunistic network to optimize its route in an easy way with its taxonomy. A comparison table is given for better understanding. Hence, we provide an overview of Mobility Models and Routing Protocols to the current research and propose Fuzzy-PRoPHET for 100 percent data transmission from source to destination.

Key words: Opportunistic Networks, Mobility Models, Routing Protocols, PRoPHET, Fuzzy-PRoPHET

1.0 INTRODUCTION

OppNets are one of the most significant evolutions in MANETs. Even in the absence of route, MNs are enabled to communicate. Furthermore, nodes are not supposed to have complete knowledge about the network, which is essential in traditional MANET routing protocols. When the nodes enter the communication range of each other, then the link is established and the communication occurs [1]. When leaving the range, the nodes get disrupted and wait for some other node in that range. Source to destination cannot be just one hop. OppNets are multi hop, transmitting node is source and the final receiving node is destination and remaining in between are intermediate nodes. In OppNets, connections are opportunistic not deterministic.

In many cases the node movement is reflection of users, so the routes can be predicted in those cases. The places where a user mostly stays, for ex: office and home etc; are stored and can be connected easily. By this features of OppNets, it overcomes the issue of dynamic nature network. An important component of a simulator is a mobility model which should ideally represent the movement of MNs. We don't want MNs to travel in a straight line, because real MNs will not always travel in straight line. This movement forms a topological evolution in MNs therefore these are essential for any simulation for mobile wireless networks. Mobility Models dictates the way nodes moving during simulation. Mobility plays a crucial role, as it permits to bridge disconnected clouds and enable end-to-end communication, despite of network breakage.

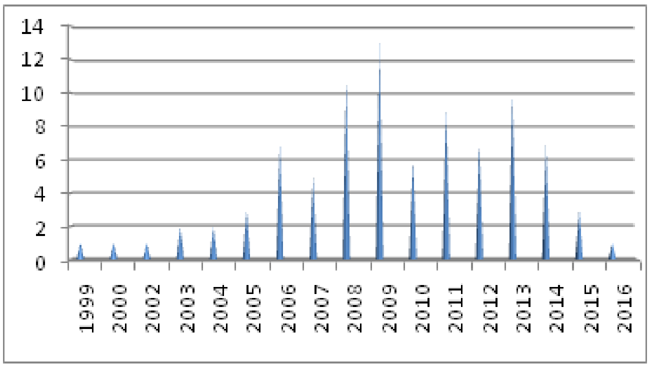
Due to absence of infrastructure, the MNs do not have any information to forward the message. From many nodes, few nodes are selected as the Best Candidate if they are moving towards destination. This Best Candidates then carry the message. Here comes the key issue in OppNets i.e. design of efficient routing protocol. Routing in an OppNet exploits the node mobility and consists of solving the following problems: at any given time, each node should find when and where to forward the data stored in its buffer so that it reaches the destination in a timely manner [2]. Mobility models and routing protocols are considered as two key parameters; by changing them an optimal route is designed.

2.0 SELECTION CRITERIA

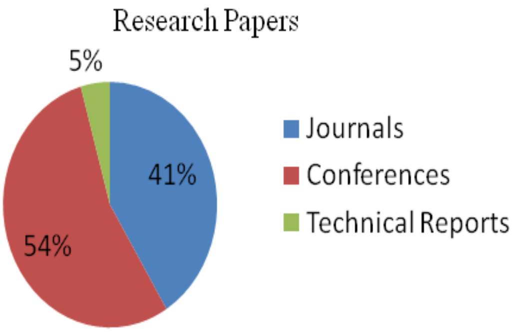
This section discuss about the selection of research papers, to attain high search rate a huge research was carried on and many relevant journals, conferences, technical reports and online materials were studied. Collections are done from various scholar materials of IEEE explore, Springer, Research Gate, ACM, Science Direct etc. We have shown year wise distribution of research papers in graph 1 and shown percentage of individual research papers studied i.e. Journals, Conference and Technical Report in graph 2.

List of research paper selected for reviewing

Selected Research Journals	No. of papers
Journals	35
Conferences	49
Technical Reports	4
Total	89



Graph 1: Year Wise Distribution of Reviewed Research Papers



Graph 2: Percentage Wise Research Paper

3.0 MOBILITY MODELS

In performance evaluations, the protocol should be tested under realistic conditions, but not only limited to a sensible transmission in range, storage of messages, buffer space, representative data traffic models and realistic movements of the mobile users i.e. Mobility Models [3]. Mobility Models defines the algorithm and rules that generate node movement paths [4]. Recent studies have showed that Mobility Models of OppNets are very different from traditional models. Mobility Models are broadly classified into, Trace and Synthetic models. Traces are those Mobility Models, which works on real data for fixed infrastructure. Synthetic, determines its path synthetically i.e. no traces are used. Synthetic Mobility Models are basically divided into two categories based on node movement.

Entity Mobility Models: In this each node is independent from other i.e. the movement of one MN, does not affect the other.

Group Mobility Models: In this, few nodes are formed into groups and are dependent to that node, which are in group. This group Mobility Models works all together to complete the task.

3.1 RANDOM BASED MODELS

In random based Mobility Models, the mobile nodes move randomly and freely without restrictions. To be more specific, the destination, speed and direction are all chosen randomly and independently of other nodes [5].

3.1.1Random Walk (Brownian Model): Random Walk is the simplest and is also called as Brownian motion. In this MNs move randomly choosing speed and direction. The new speed and direction are both chosen from pre defined ranges [min-speed, max-speed] and [0, 2*pi] respectively [6]. Random Walk model is memoryless, because they cannot keep records of previous patterns. It has advantage that that they do not need memory space.

3.1.2 Random Waypoint: Random Waypoint includes a random pause time after reaching destination. As the simulation starts, each MN randomly selects one location in the simulation field as the destination [7]. It then travels towards this destination with constant velocity chosen uniformly and randomly [0, V_{max}], V_{max} is the maximum allowable velocity. A MN stays in one location for certain time i.e. Pause time T_{pause}. Upon reaching the destination, the node stops depending on its T_{pause}. If T_{pause} =0, it is continuous mobility or it is similar to Random Walk.

3.1.3 Random Direction: Random Direction overcomes the problem of non-uniform distribution found in Random Waypoint [8]. Instead of selecting a random direction, in Random Direction Model the node randomly and uniformly chooses a direction by which it moves along until it reaches the boundary. As it reaches the boundary of simulation, it stops for sometime i.e. pause time T_{pause} and again elects direction and moves randomly. It chooses a new direction by applying angle between 0 and 2Π. In Random Direction Model a user chooses a direction to travel in a speed at which to travel, and time duration for this travel [9].

3.1.4 Levy Walk: This model is very similar to Random Walk, except that the movement lengths and pause time are taken from a power law distribution [8][10]. It is capable to produce almost similar inter-contact time distribution as many real world traces. Another important characteristic of Levy Walk is its high diffusivity [8]. It means that variance of displacement between current position at time t and the previous at time to be very high.

3.2 MODELS WITH TEMPORAL DEPENDENCE:

The nodes are influenced by their past movement. Mobility of a node may be constrained and limited by the physical laws of acceleration, velocity and rate of change of direction [7]. Hence, the current velocity depends on the previous ones. We call this as 'temporal dependencies of velocities'.

3.2.1 Gauss-Markov: The name itself says that it is based on Gaussian model and hence can provide smoothness to the simulation. It depends on previous velocities and directions to select a node in future. At each node the next hop is chosen based on previous knowledge of the node.

3.2.2 Smooth Random: In real life, MNs tend to move in certain velocities [V1, V2, Vn] rather than the speeds uniformly distributed in range [0,V_{max}]. In Smooth Random, probability distribution node is given as: if it is in range, then its probability is high V(t) and the uniform distribution is assumed to be in range [0, V_{max}]. In Smooth Random, the frequency of speed change is assumed to be a Poisson process [5]. In an event of speed change, a new target U(t) is selected according to its probability and then speed of MNs is changed depending on acceleration or deceleration a(t).

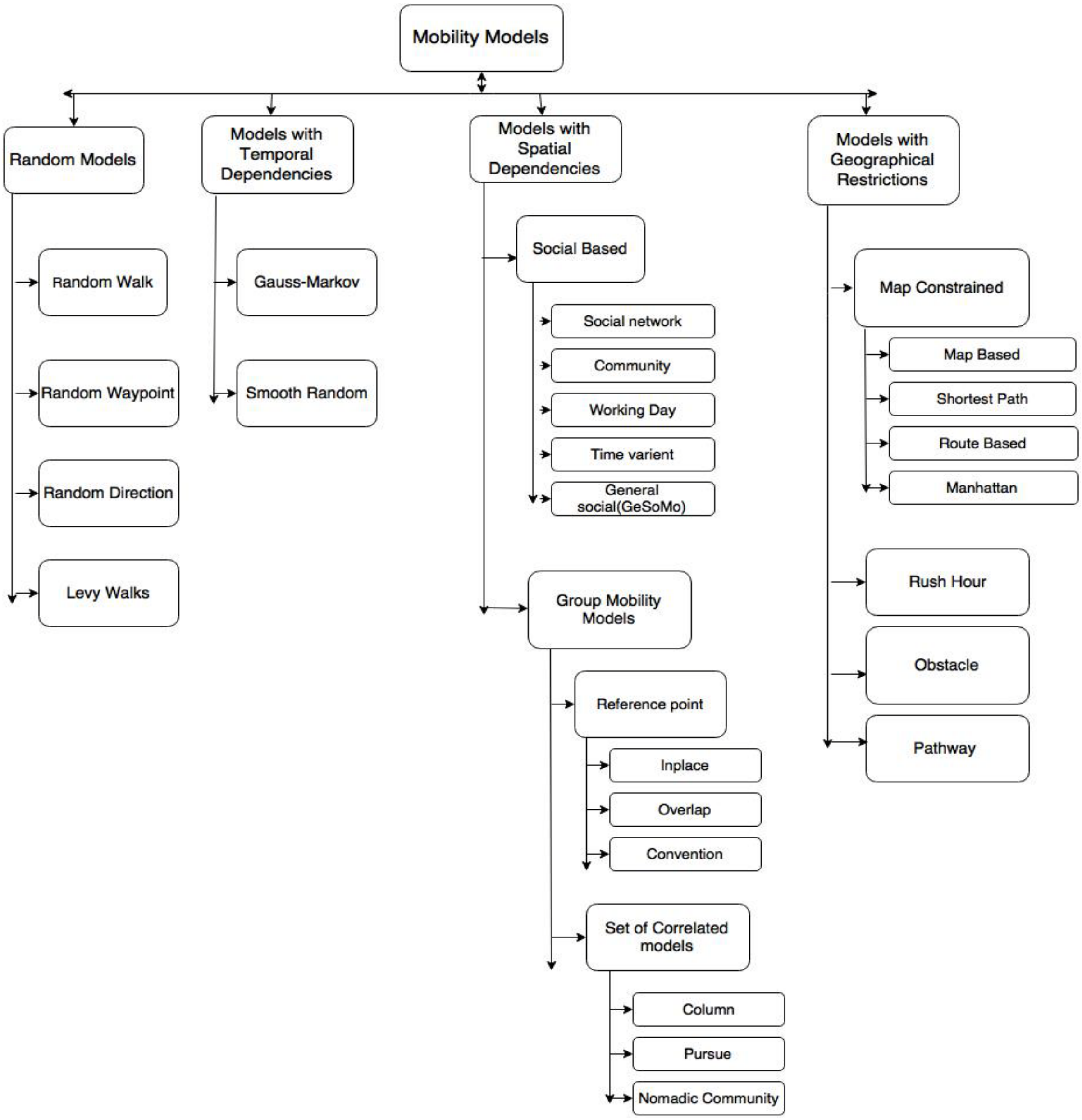


Fig. 1 Taxonomy of Mobility Models

3.3 MODELS WITH SPATIAL DEPENCENCE:

In Random models, a node moves independently of other nodes. Therefore the location, speed and direction of MNs are not affected by other nodes. Therefore the mobility of nodes could be influenced by neighboring nodes. Since the velocities of different nodes are 'correlated' in space, thus we call 'spatial dependencies in velocity'.

3.3.1 Social Based

They predict the social activities of a user and keeps a record for further use. The place once visited has a every chance to visit again. Aim of establishment of social relationships among individuals to define groups of hosts that move together in the simulated scenarios [11].

3.3.1.1 Social Network Model: In recent years, social networks have been much investigated and are used in sociology, Mathematics, Physics etc; Theoretical models have been developed to reproduce the properties of these networks such as scale free models or small world models. Social Networks shows greater level of Clustering. This is strictly related to humans since they usually organize themselves in communication.

3.3.1.2 Community Based: Community Mobility Model is the first and flexible model of Social Network. In y8Community, nodes are grouped as friends who belong to same community and non-friends which are from different community. Initially, the simulation area is divided into grids and each community is given a grid. A link is established between friends and non-friends community to derive node mobility. Community MM has a disadvantage that if one node wants to leave community, all the nodes follow the same called gregarious behavior of nodes. To avoid this, Home Cell Community MM (HCMM) was introduced. The Probability of moving a node from its home community towards a given community is proportional to the number of this with nodes the destination community [12].

3.3.1.3 Time Variant: The whole simulation area (terrain) is divided into sub terrains and is designated as communities. All nodes belong to any one of the community. Nodes are assigned a fixed global velocity, so that they can travel from one community to other. The arrangement of communities and there transition probabilities are constant for some time period.

3.3.1.4 Working Day Mobility Model: M. Shahzamal et al [8] explain that real mobility patterns can be achieved by modeling human performances i. at home ii. Office iii. To any outing with friends. These activities are the most common and capture most of a working day for the majority of people [13]. Communities and social relationship are formed when a set of nodes are doing the same activity in the same location [14]. Working Day Model provides inter-contact time and contact time distribution which follow closely to the real world measurements.

3.3.1.5 General Social Model (GeSoMo): M. Shahzamal et al [8] it's a social network model. It accepts social network as input and creates traces which becomes schedules for node movement. It creates traces of meetings between nodes to depict social relations. It describes real world human social mobility model.

3.3.2 Group Mobility Models

In above section we have seen individual Mobility Models, whose actions are completely independent of each other. In an adhoc network however, there are many situations in which it is necessary to model the behavior of mobile nodes (MNs) as they move together. In order to model such situations, a group Mobility Model is needed [3].

3.3.2.1 Reference Point Group Mobility Mode: In each group, a center is present which is either a logical center or group leader. Thus, every group has one leader and few members. The mobility of the group is determined by the group leader's movement. The movement of group member is dependent on leader. For each node, mobility is assigned with reference point that follows the group movement [15].

3.3.2.1.1 In Place: In this the entire field is divided into many regions. Each region is exclusively occupied by a single group [7]. Best example for this is battle field communication.

3.3.2.1.2 Overlap: In this model, different groups with different tasks travel in the same field, due to which they overlap each other. Best example for this is disaster relief

3.3.2.1.3 Convention: The entire field is divided into several regions and few groups are allowed to travel in between regions. This scenario is used to study mobility behavior in conference.

3.3.2.2 Set of Correlated Models

M. Sanchez and P. Manzoni [16] proposed a set of mobility model which include Column Mobility Model, Pursue Mobility Model and Nomadic Community Model. These Mobility Models are expected to have high spatial dependency on their neighboring nodes.

3.3.2.2.1 Column Mobility Model: This mobility model represents a set of MNs travelling in fixed direction, mostly in forward direction. In this each MN, has a single Reference Point, which moves around its reference point. When the MN is about to travel beyond the boundary of simulation field, the movement direction is then flipped 180 degree [7].

3.3.2.2.2 Pursue Mobility Model: In Pursue Mobility Model, a Reference Point (RP) is pursued by all MN in that group. The direction, speed, and other parameters are dependent on the movement of RP. These are mostly used in target tracking and law enforcement. When the RP changes, all the MNs travel to the new area defined by the RP. The RP move freely, according to Random Waypoint. An application for this is a tourist guide.

3.3.2.2.3 Nomadic Community: The Nomadic Community Mobility Model is to represent the way in which group of nodes move together. In Column Mobility Model, which also works on reference grids is bit different, since in Column Mobility Model each group has a different Reference grids. Unlike, in Nomadic same Reference grids are used for all groups. The Reference Points (RP) are determined based on the movement of MNs. These are best applied in military applications.

3.4 MODELS WITH GEOGRAPHIC RESTRICTIONS:
In real life applications, we observe that nodes are affected by environmental conditions. Vehicles and pedestrians may be blocked by buildings and other obstacles. So, it is same for nodes. When they hit any obstacle, they divert or they may drop. These are called as Geographical Restrictions.

3.4.1.1 Map Based: It is the derivative of Random Walk. In this model, MNs move randomly based on maps following the roads. The area is divided in horizontal and vertical streets. It has options to select only these nodes which use only certain part of the map. These nodes move until the end of the road, and then they turn back or end up in an intersection.

3.4.1.2 Shortest Path: This is the improved of Map Based Model. Initially, nodes are placed randomly in map, after all nodes travel to some extent, Dijikstra's shortest path algorithm is then applied to discover shortest path to destination. After reaching destination, they wait for some time and then randomly select another destination.

3.4.1.3 Route Based: In this model, few nodes are chosen and they are fed with routes that they need to travel. In this model, a route contains many points, these points are called stops. At each stop, node waits for sometime before travelling to the next stop. Nodes follow the shortest path approach to reach the destination [17].

3.4.1.4 Manhattan Mobility Model (MMM): Manhattan Mobility Model is another Map Constrained Mobility Model that is widely used. This model is applied to imitate, movement in urban areas where mobile devices are supported by computing services. The map of MMM is formed on horizontal and vertical grids. These have probabilities in the map area, to select next destination. The probability for same street is 0.5, left turn 0.25 and right turn 0.25.

3.4.2 Rush hour: W.K.G Seah et al [18] Rush hour mobility model, it observes the increasing rise in the node traffic at rush hour. It identifies from where the traffic is originated and where it is sinking. It represents conditions before and after rise in the node traffic. Each location is identified by its geographic location, origination of node, node interval, minimum and maximum location ranges. It gives a quiet closer representation of real world traffic nodes.

3.4.3 Obstacle Mobility Model: Amit Jardosh et al [19] nodes move randomly bouncing at buildings, electric poles and other structures, here we study obstacle based mobility models. Its key features are i. to give object spaces and sizes ii. to give routed map i.e. to show where objects are placed so that the nodes may change its directions when required. Object locations and connecting routes are computed at the beginning of simulation and is maintained the same till end.

3.4.4 Pathway Mobility Model: The vertices of graphs are drawn on the simulation field, which represents buildings, edges of streets etc; to help nodes to find freeways between them. Initially nodes are placed randomly and they are allowed to pick random destination. The nodes move based on the given map.

Table 1: Comparison of Mobility Models

Mobility model	Description	Temporal Dependency	Spatial Dependency	Geographical Restrictions	Entity/Group
Random Based	Nodes move randomly without restrictions	No	No	No	Entity
Temporal dependent models	Nodes are influenced by their past temporally	Yes	No	No	Entity
Spatial Dependent models	Nodes of various velocities are spatially co related	No	Yes	No	Entity
Group Mobility model	A group of nodes complete a single task	No	Yes	No	Group
Geographically restricted models	Nodes are geographically distracted by some obstacles	No	No	Yes	Entity

4.0 ROUTING PROTOCOLS

Opportunistic networks (OppNets) are highly dynamic in nature, due to absence of knowledge about other nodes in the network. In such cases, routing becomes a challenge. So, routing protocols play a key role in the performance of wireless models. Depending on several scenarios many routing protocol have been designed. Till day no one has become a standard one. As in OppNets contacts are the only way for messages to progress towards the destination, the distribution of inter-contact time plays a key role in determining the performance of forwarding protocols [20].

Find opportunity: A node has to find its neighbouring nodes in its area so as to start communication. The nodes act spontaneously when they come close to each other. The links among the nodes are temporary.

Message Exchange: The communication starts as soon as the nodes identify each other. Within a direct range the nodes can communicate with their neighboring nodes.

Information Sprinkler: An information sprinkler can be defined as a fixed node with in a particular location in an opportunistic network. It operates similar to the other nodes which use a data sharing protocol which collects the information from other opportunistic nodes within its area and forwards the data to the other information sprinklers. The information sprinklers are connected to each other through wired of wireless networks.

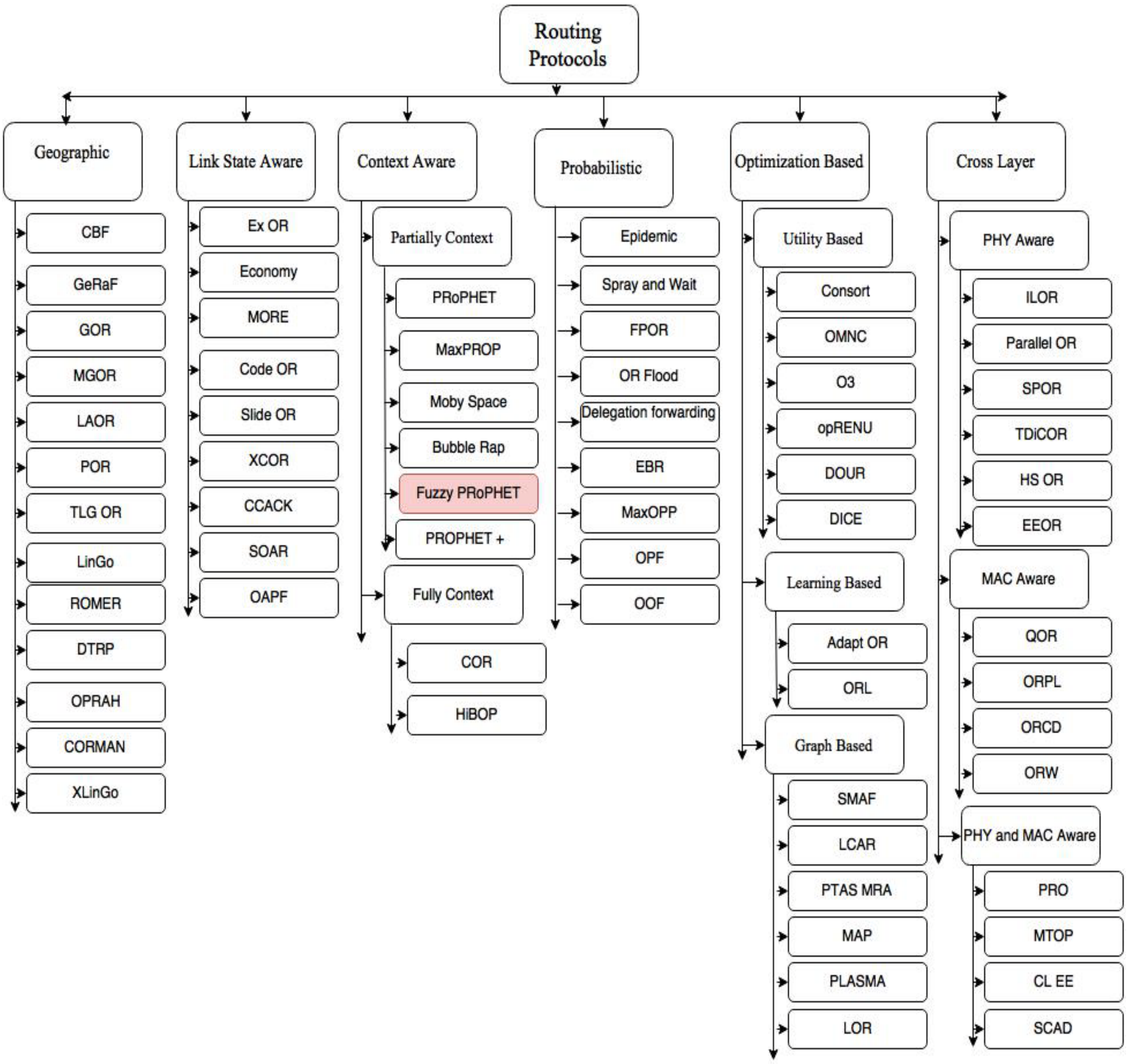


Fig 2: Taxonomy of Routing Protocols

4.1 GEOGRAPHIC

In early days opportunistic routing protocols were proposed to provide a location aware routing ad hoc networks. Geographical routing, is done based on the locations i.e. geography. The nodes within geographical area form a network and exchange messages. Due to the topology independent property and dynamic operation, geographical opportunistic routing helps to overcome lack of infrastructure.

4.1.1 Contention Based forwarding (CBF): Holger Fubler et al [21], CBF is a greedy position based forwarding algorithm, it does not require any proactive transmission i.e. beacon messages [22]. Instead, data packets are forwarded to their direct neighbors and the neighbor itself can decide whether to forward it to the other node or no. The actual forwarder is selected by a time based contention process and it suppresses other useless forwarders, while forwarding the best. A distributed location service by geocast [23] is applied to get the geographical position of nodes.

4.1.2 Geographic Random Forwarding (GeRaF): B. Sundar Raj et al [24], proposed GeRaF for Adhoc. It is completely a unique routing technique, it is geographic based and receiver nodes are selected randomly. Any sensible theme is set, which selects the destination and its performance is near to the best case.

4.1.3 Geographic Opportunistic Routing (GOR): Kai Zeng et al [25] in GOR, packet advancement, reliability and MAC coordination time are analyzed. A new local parameter Expected One Hop Throughput (EOT) is used to balance all these factors. Upper bound of EOT is analyzed; it indicates as the reliability increases, the packet advancement to destination is early. Maximum EOT can be achieved by selecting relaying nodes which are closer to destination.

4.1.4 Multi-rate Geographic Opportunistic Routing (MGOR): Kai Zeng et al [26], two multi-rate parameters are proposed i. expected medium time (EMT) and ii. Expected advancement rate (EAR) and their corresponding candidate selection schemes such as least medium time opportunistic routing (LMTOR) and Multi-rate GOR. In MGOR, multi rate, interference, candidate selections were extensively studied. Multi-rate GOR outperforms single-rate GOR.

4.1.5 Location Aided Opportunistic Routing (LAOR): K. Zeng et al [27] for multi rate transmissions we have introduced a local parameter opportunistic effective one hop throughput (OEOT), to explain the composition/ratio between one hop packet advancement and packet forwarding time.

4.1.6 Position Based Opportunistic Routing (POR): S. Yang et al [28] POR takes advantage of wireless channel and opportunistic forwarding. It keeps a forwarder list based on the previous hops. The packets are forwarded in a multi-cast nature with multiple forwarders. The packets are loaded with previous hop's IP address and are then forwarded.

4.1.7 Topology and Link Quality Aware Geographical Opportunistic Routing (TLG OR): Z. Zhao et al [29], uses multiple metrics like network topology, link quality and geographic location to study coordination mechanism in network.

4.1.8 Link Quality and Geographical Aware Opportunistic Routing (LinGo): D. Rosario et al [30] LinGo is a protocol designed to enable video dissemination with QoE support. LinGo enables finding optimized routes to transmit multimedia as per user's choice. Multiple metrics are considered such as link quality progress and remaining energy.

4.1.9 Resilient Opportunistic Mesh routing (ROMER): Y. Yuan et al [31] ROMER, a resilient and opportunistic routing solution for mesh network balances long term routes stability and short term opportunistic performance. ROMER constructs a run time forwarding mesh on basis of per packet forwarding. Mesh is formed while nodes are in the way to destination.

4.1.10 Directed Transmission Routing Protocol (DTRP): Mathew S Nassr et al [32] the protocol DTRP relies on the beacon messages which are originated from sink node and are flooded in the network by sensor node. Unlike distance vector protocols, DTRP uses beacon messages to know hop distance between sink and sensor nodes.

4.1.11 Opportunistic Routing in Dynamic Ad hoc Networks (OPRAH): C. Westphal et al [33] we may always be interested in finding a best path for the whole life, making paths helps in high availability. OPRAH is a protocol, even in the presence of interference it helps in finding an optimal route for a pair of nodes.

4.1.12 Cooperative Opportunistic Routing in Mobile Ad hoc Networks (CORMAN): Z. Wang et al [34] when a node sends data packet through upstream and is received by downstream along the route, it most probably reaches destination as early as possible. This has been achieved due to cooperation. It is an extension to Ex OR.

4.1.13 Cross-layer Link Quality and Geographical Aware Beaconless Opportunistic Routing (XLinGo): D. Rosario et al [35] Flying Ad hoc networks FANETs must be ready to adapt any topological changes. XLinGo enhances transmission of multiple videos over FANETs by maintaining reliable persistent multi hop routes. XLinGo uses a set of cross layer and human related information to improve QoE.

4.2 LINK STATE AWARE

It mainly considers network reliability issues by using delivery probabilities. Reliability of packet delivery in a network is to be improved to benefit broad cast nature of wireless networks. In OppNets, at each hop data is analyzed and transmission failures are limited. So, that packet progress towards destination guarantees.

4.2.1 Opportunistic Multi hop Routing for Wireless Networks (ExOR): S. Biswas and R. Morris [36] Ex OR is an integrated routing and MAC protocol for multi hop networks. When data packets are disseminated in the network, all neighbor nodes can hear them. In Ex OR, it selects 'best' from multiple receivers and only that can forward the data packet, Selection of 'best' is prioritized.

4.2.2 Economy: A Duplicate Free Opportunistic Routing: Che-Jung Hsu et al [37] economy, in which each packet is given a token and when the token arrives, the nodes checks if it already had that token, then it discards else it accepts it. Thus it avoids duplication. In Economy, message duplication is less and keeps all OR benefits.

4.2.3 MAC independent Opportunistic Routing (MORE): S. Chachulski et al [38] MORE mix packets randomly and forward it. It ensures that the node which heard the packet once will not hear it again.

4.2.4 Code OR: Opportunistic Routing in Wireless Mesh Networks with Segmented Network Coding: Y. Lin et al [39], Code OR out performs than remaining forwarding protocols by transmission of multiple segments to completely utilize network resources. It performs better in moderate to small size data packets; further much small packet size decreases the decoding delay which is much helpful in real time applications.

4.2.5 Slide OR: Online Opportunistic Network Coding in Wireless Mesh Networks: Y. Lin et al [40] Slide OR, it encodes packets in overlapping sliding windows such that coded packets from one window can be useful to decode packets at the other window. It outperforms the available protocols with multiple segmented complicated schedules.

4.2.6 XCOR: Synergistic Interflow Network Coding and Opportunistic Routing: D. Koutsonikolas et al [41] in XCOR sources compute eventually and update their header at each possible hop towards destination. Similar to OR, XCOR packets broadcast at each hop. The node nearest to ETX after every transmission forwards the packet to other nodes, till then remaining nodes try to maintain timers. If any node over heard it, then they cancel its timer. The node with higher priority than the previous one only will forward packets.

4.2.7 Cumulative Coded Acknowledgment (CCACK): D. Koutsonikolas et al [42] CCAK is used to acknowledge coded traffic in upstream nodes in a simple and efficient way, unconscious about loss rates and with least overhead. CCACK enables an efficient credit based, rate control algorithm [42].

4.2.8 O3: Optimized Overlay-based Opportunistic Routing: M. Kyung et al [43] O3, which uses overlay network that performs overlay routing and inter flow coding without any loss of packets. In this we parallel optimize opportunistic route, inter flow, intra flow coding and rate limits.

4.2.9 SOAR: Simple Opportunistic Adaptive Routing Protocol for Wireless Mesh Networks: E. Rozner et al [44] SOAR has the following four conditions to achieve high throughput and fairness i. adaptive forwarding path is selected to reduce duplication ii. Nodes are forwarded based on time based priority so that the best node forwards the packet iii. Local loss recovery should be efficiently done to retransmit lost packets iv. Adaptive rate control should be maintained to set the sending rate of any node.

4.2.10 Opportunistic Any Path Forwarding (OAPF): Z. Zhong et al [45] in OAPF few 'best' nodes are selected, which reduces number of transmission, which in turn minimizes interference. A local parameter expected any path transmissions (EAX) is introduced which captures the expected number of hop to destination. EAX then selects few best candidates and prioritize them.

4.3 CONTEXT AWARE:

Routing in OppNets is a challenge due to absence of complete knowledge of nodes in the network. In some cases a piece of information is available to a node which helps it choose correct destination quickly, this is called context information.
It is i. partially context aware ii. Fully context aware

4.3.1 Partially Context Aware
It exploits some piece of information to optimize forwarding task

4.3.1.1 Probabilistic Routing Protocol using History of Encounters and Transitivity (PRoPHET): A. Lindgren et al [46] a metric called 'delivery probability' plays a vital role in selecting the next forwarder. The node exchanges information to other node, only if its delivery probability is high. As the node keeps on forwarding they keep updating their probabilities.

4.3.1.2 MaxProp: J. Burgess et al [47] MaxProp, it prioritizes both forwarding packets as well as dropped packets. Prioritization are done based on likelihood to forward, depending on previous history of nodes or any other mechanism like acknowledgment, lists of intermediate nodes etc;

4.3.1.3 MobySpace Routing: J. Leguay et al [48] here we address a generic algorithm based on Euclidean distance, we call it as MobySpace. It is evaluated based on how frequently a node visits for each possible location. MobySpace outperforms when compared with other algorithms especially when routing of nodes have high connection time.

4.3.1.4 Bubble Rap: P. Hui et al [49] Bubble is designed to efficiently improve forwarding efficiency by Divide and Conquer method which is applied to separately show feasibility of decentralized and centralized inherent predictability. In Bubble, due to limited packet size instead of hierarchical community structure flat community can be seen.

4.3.1.5 PRoPHET+: An Adaptive PRoPHET-Based Routing: T. K. Huang et al [50] extension of PROPHET is introduced i.e. PROPHET +, to reduce packet delivery delay which deliberately increases probability of successful deliveries between source to destination. To increase delivery rate, each node I added by an weight. On proper selection of logical weights, PROPHET+ outperforms PROPHET.

4.3.2 Fully Context Aware

Fully context aware helps not only to exploit information, but they also help in using context information.
4.3.2.1 Context Aware Routing (COR): Z. Zhao et al [51], COR, has a threefold process. Firstly, it uses context aware metrics like link quality, geographic progress and remaining energy of nodes. Secondly, it allows every node to participate in packet forwarding. Finally, it exploits relative mobility of nodes to improve its performance

4.3.2.2 History Based Opportunistic Routing Protocol (HiBOp): C. Boldrni et al [52] HiBOp a context aware protocol which refers the frame work, learn and represent its context such as user behavior and their social relations to achieve a optimized path. On comparison of HiBOp with respect to other context aware routing it outperforms them.

4.4 PROBABILISTIC

The main step in opportunistic routing is how to choose the next node. In this nodes are chosen depending on their probabilities. The receiver node should have high probability than the sender node. Then only message can be forwarded.

4.4.1 Epidemic Routing: A. Vahadat and D. Becker [53] Epidemic routing protocol allows message delivery even if there do not exist any path between a pair of nodes. They can be used especially in disaster relief scenarios, the nodes are wide spread geographically, the random pair-wise exchange of messages ensures message delivery.

4.4.2 Spray and Wait: An Efficient Routing Scheme for Intermittently Connected Mobile Networks:
T. Spyropoulos et al [54] Spray and Wait, Spray: it sprays number of copies of data into the network and Wait: it waits till one o them reaches destination. Spray and Wait outperforms that all existing protocols with respect to average message delivery delay and number of

transmissions. Spray and Wait is nearly same as optimized protocols.

4.4.3 Fixed Point Opportunistic Routing (FPOR): V. Conan et al [55] FPOR a new protocol with single copy and multiple hop protocol is designed to improve routing performance and to minimize overhead. It is a fixed point recursive process; it provides minimum delivery time for independent exponential pair wise inter-contacts.

4.4.4 Opportunistic Flooding (OR flood): S. Cuo et al [56] in OR Flood early packets are sent via links outside the energy-optimal tree to minimize flooding delays and redundancy. A forwarder selection method is proposed to control the hidden terminal problem and link quality based back off to decide simultaneous transmissions.

4.4.5 Delegation Forwarding: V. Erramilli et al [57] Delegation forwarding is a algorithm whose objective is to reduce cost. In this, we analyze two variants of delegation forwarding considering that both are quality independent of underlying contact rate and quality identical to nodes contact rate. In both cases, delegation forwarding reduces cost from O (N) to O√N with high performance.

4.4.6 Encounter Based Routing (EBR): Samuel. C. Nelson et al [58] EBR is designed, which maximizes delivery ratio and minimizes overhead and delay. EBR can also protect itself from black hole DoS attacks.

4.4.7 MaxOPP: A Novel Opportunistic Routing for Wireless Mesh Networks: R. Bruno et al [59] MaxOPP is able to select the candidate forwarder at each hop or anywhere in run time. It enables selection of best candidates to forward data packets efficiently to maximize throughput.

4.4.8 Optimal Probabilistic Forwarding (OPF): M. Lu and J. Wu [60] OPF, a routing algebra to study compatibility of routing metrics and routing protocols. OR algebra based routing protocol is designed to identify essential metrics of OR in mathematical form so that they can be analyzed easily

4.4.9 Optimal Opportunistic Forwarding (OOF): C. Liu and J. Wu [61] Optimal Opportunistic Forwarding OOF and OOF- which increases delivery rate and reduces expected delay. In this nodes accept only a fixed number of copies within a given life span. As the life span of the copy ends, it is discarded.

4.5 OPTIMIZATION BASED

This mainly focuses on optimizing opportunistic routing protocols building blocks using optimization programming.

4.5.1 Utility Based: This works to improve utility of the network. It optimizes the network source utilization.

4.5.1.1 Consort: X. Fang et al [62], Consort allows each user and node to adjust its behavior individually. Consort when compared with MORE and Dice, it out performs both.

4.5.1.2 Optimized Multi Path Network Coding (OMNC): X. Zhang and B. Li et al [63] OMNC induces multiple paths to forward a data packet to its destination; it uses MAC to broadcast the data packets to destination. With the help of distributed algorithms encoding and broadcast rate are allocated to all transmitters.

4.5.1.3 Opportunistic Residual Expected Network Utilities (OpRENU): J. Wu et al [64] a utility based routing where successful delivery of data packets gives benefit. It helps in maximizing the utility of resources i.e. reduce cost of transmission and causes much benefit. Here Residual Expected Network Utilities (RENU) are combined with OppNets to form OpRENU, to maximally utilize network resources in OppNets.

4.5.1.4 Time Sensitive Utility Based Opportunistic Routing (TOUR): M. Xiao et al [65] TOUR is proposed, if the node reaches destination within the given deadline then it gets positive reward, if it cannot be reached then it gets zero reward. For every success or failed transmission, cost o transmission is deducted. Each node initially selects forwarding path made of series of forwarding opportunities in a distributed and greedy manner.

4.5.1.5 Dice: X. Zhang and B. Li [66] Dice is designed to resolve multiple competing flows in wireless multi path network coding. Dice, considers it as a network game, in which many players shares bandwidth resources through negotiation or competition. If players are willing to cooperate, a Nash bargaining solution is achieved through negotiation algorithm. If players are selfish, socially optimal equilibrium is achieved by enforcing pricing mechanism. In both cases, the player performs local optimization.

4.5.2 Learning Based: It works on learning of nodes. Context is known as a piece of information, which is always not present to a node. So, learning helps a node in choosing the next hop.

4.5.2.1 Adapt Opportunistic Routing: A.A. Bhorkar et al [67], Adapt OR has low complexity, less overhead and distributed asynchronous implementation. Therefore the main aspect of this protocol is to assume that it has zero knowledge, secondly it applies reinforcement learning and finally it optimally selects the receiver nodes. The design of routing protocols requires a consideration of congestion control along with the throughput performance [68].

4.5.2.2 Opportunistic Routing with learning algorithm (ORL): P. Tehrani et al [69] the main objective of this is to design are a online learning algorithm. Both centralized and distributed online learning algorithms are designed for unknown wireless models. It locally ranks the nodes within the network to allow better regret scaling. This algorithm achieves optimal logarithmic regret order with respect to time.

4.5.3 Graph Based: They use Graph-Theoretic tools to optimize network

4.5.3.1 Shortest multi rate any path first (SMAF): R. Laufer and L. Heinrock [70] for a given network topology and destination, we want to find forwarding distance as well as transmission rate of any node, so that the distance to destination is reduced. We introduced SMAF; it has the same complexity as Dijikstra's so it can be embedded in link state routing protocols.

4.5.3.2 Least Cost Any Path Routing (LCAR): H. Dubois – Ferriere et al [71] LCAR has the main concept to minimize cost of forwarding a packet. Basically LCAR considers how to place nodes in the network so that the expected cost of forwarding is minimized. We apply LCAR to low power; low rate wireless communication networks.

4.5.3.3 Polynomial Time Algorithm for Multi rate any path Routing (PTAS MRA): R. Laufer et al [72] polynomial time routing algorithm use both set of next hop and a selected transmission rate. But both the sets are never jointly optimized. The protocol proposed here has same running time as when compared to shortest path routing protocols. So they can be embedded in any routing protocol.

4.5.3.4 Multi Constrained Any Path Routing (MAP): Xi Fang et al [73] MAP has considered any path routing with K constraints and a simple polynomial time algorithm for K is designed to compute K-approximation. If K Value is 1 i.e. K=1, then it is optimal polynomial time algorithm. If $K \geq 2$ then, it's in the first order of NP hard problem.

4.5.3.5 PLASMA: A New Routing Paradigm for Wireless Multi hop Networks: R. Laufer et al [74] in PLASMA, each packet is delivered over the best path available in that network. The best path and gate ways are not selected by the source; they are being selected while the data is flowing.

4.5.3.6 Localized Opportunistic Routing (LOR): Y. Li et al [75] a distributed minimum transmission selection (MTS-B) algorithm is used which produces forwarder list to any given source to destination in a distributed manner. Then with the utilization of OR, we establish close-node-set (CNS) that separate wireless topologies into several nested nodes with local knowledge. All these are been designed in LOR. These are extensively used for large scale wireless networks.

4.6 CROSS LAYER

Recent studies proposed that interaction between network layer and underlying layer are used to design more efficient and protocol opportunistic routing protocol.

4.6.1 PHY Aware: We try to improve the network throughput by considering channel state information dynamics.

4.6.1.1 Interference Limited Opportunistic Relaying (ILOR): A. Blestas et al [76] ILOR, which can relay even in delay using cooperative communication and even in the presence of interference. The thing is that source to destination paths must be strong. In this no inter relay communication, no network coding is needed.

4.6.1.2 Parallel Opportunistic Routing (Parallel OR): W.Y. Shin et al [77] Parallel OR is designed in which many nodes perform parallely to maximize the opportunistic gain while controlling inter user interface.

4.6.1.3 Simple and Practical Opportunistic Routing (SPOR): G. Y. Lee and Z. J. Haas [78] SPOR is applied for short haul paths since in long haul paths is only marginal increase in throughput and complexity increases. So, SPOR is suggested for short haul paths. These can be easily embedded into existing routing protocol only by just minor changes.

4.6.1.4 High Speed Opportunistic Routing (HS OR): W. Hu et al [79], Practical Opportunistic Routing (POR), the key functions of POR are high packet forwarding based on feedback given by per packet, adaptation which selects a good path and a novel cost estimation which selects a good path sets data rates a per the required conditions.

4.6.1.5 Energy Efficient Opportunistic Routing (EEOR): X. Mao et al [80] in EEOR the basic idea is to improve throughput. The core idea applied here is to use forwarder list, and only those can participate in packet forwarding which are in forwarders list. The low priority packet discards high priority packet. The main issue comes here is how to select forwarder nodes and prioritize them. In this we considered two situations fixed and changeable. Optimum algorithms are designed to select and prioritize forwarder list.

4.6.2 MAC Aware:

These are proposed for WSNs, since the performance and life time of nodes are dependent on MAC

4.6.2.1 QoS Oriented Opportunistic Routing (QOR): Q. Lampin et al [81] QOR, its key features are to increase link quality and provide good quality of service. QOR is a threefold process i. a joint routing structure and addressing scheme that allows us to identify and select best relays that can relay between a pair of nodes ii. Acknowledgements are used to avoid replication iii. QOR effectively uses opportunistic links for reliable and replication free data packet transmission.

4.6.2.2 Opportunistic Routing for Low Power and Lossy Networks (ORPL): B. Pavkovic et al [82] ORPL is an extension of RPL and opportunistic routing is applied to ORPL. Unlike RPL, ORPL selects different parents every time to forward a packet to optimize route. ORPL outperforms RPL in packet delivery ratio, incurred delay and overhead.

4.6.2.3 Opportunistic Routing with Congestion Diversity (ORCD): M. Naghshvar and T. Javidi [83] with combination of both shortest path and backpressure routing, ORCD is designed. It routes nodes according to their ranks based on congestion cost.

4.6.2.4 Opportunistic Routing for Wireless Sensor Networks (ORW): E. Ghadimi et al [84] ORW depicts the number of duty cycled wake ups needed to deliver a packet between a pair of nodes. It reduces both radio-on time and end to end packet delay

4.6.3 PHY and MAC Aware

These are quiet interesting but are not much investigated. It provides practical and efficient opportunistic routing protocols

4.6.3.1 Protocol for Retransmitting Opportunistically (PRO): M. H. Lu et al [85] PRO is a link layer protocol which allow overhearing packets to retransmit the data packets instead of source, if it has learned about failed transmissions. Due to which utilization of resources become high. Relays with good connectivity have a chance to retransmit nodes successfully.

4.6.3.2 Maximizing Transmission Opportunities in Wireless Multi hop Network (MTOP): J. Y. Lee et al [86] MTOP allows frame of packets to be forwarded in multi hop consecutively to reduce MAC layer overhead, high throughput and low latency. It has been proven that collision prone nonstop forwarding is better in USRP/GNU radio based experiment.

4.6.3.3 Cross Layer Aided Energy Efficient Opportunistic Routing (CL EE): J. Zuo et al [87], CL EE mainly concentrates on cross layer to exchange information such as frame error rate, to increase number of retransmissions in MAC etc.

4.6.3.4 Sensor Context Aware Adaptive Duty Cycled beaconless Opportunistic Routing (SCAD): Z. Zhao and T. Braun [88] SCAD, a cross layer routing protocol which selects packets based on multiple types of network contents. It implements duty cycle of sensors which are based on real time traffic load to balance performance and energy efficiency.

Table 2: Comparison of Routing Protocols

Protocol	Author	Year	Contribution	Packet Delivery Rate	Hopping	Scalability	Reliability
CBF [21]	Hogler et al	2003	Used in VANETs	High	Multi hop	High	High
GeRaF [24]	B. Sundar Raj et al	2015	Algorithm is designed to estimate hop count	High	Multi hop	High	High
GOR [25]	Kai Zeng et al	2007	Geo Routing in single channel	High	Multi hop	High	Low
MGOR [26]	Kai Zeng et al	2008	Comparison of MGOR and GOR	Better than any single rate OR	Multi hop	High	High
LAOR [27]	Kai Zeng et al	2009	Geo Routing in multi channel	Better than GOR	Multi hop	Better than GOR	High
POR [28]	Shengbo Yang et al	2009	Routing based on position of nodes	Upto 90%	Multi hop	High	High
TLG OR [29]	Zhao et al	2013	Uses network topology and link quality for better QoS and QoE	Low , since if destination is not found they are dropped	Multi hop	High	High
LinGo [30]	Denis Rosario et al	2013	Cross layer link quality and geo OR for better videos. Outperforms about 30%	High, due to cross link layers	Multi hop	High	High
ROMER [31]	Yuan Yuan et al	2005	Resilience against lossy links and permanent channel outages, outperforms 40% in data packet rate	High , about 195% than single path	Multi hop	High	High
DTRP [32]	Matthew S. Nassr et al	2007	To improve Scalability and Reliability	Upto 93%	Multi hop	High	High
OPRAH [33]	Cedric Westphal	2006	Nodes are discovered through backward learning, optimizes path by 77%	High	One hop	High	High
CORMAN [34]	Zehua Wang et al	2011	It is extension of Ex OR	High	Multi hop	High	High
XLinGo [35]	Denis Rosario et al	2014	A cross layer link quality and	Low since packet loss is high	Multi hop	High	Low

			geographical aware beaconless opportunistic routing protocol				
ExOR [36]	S. Biswas and R. Morris	2005	A protocol is designed Ex OR, is integrated routing and MAC protocol	High , improves by factor of 2 to 4	Multi hop	High	Low
Economy [37]	Che Jung Hsu et al	2009	A protocol that is free from duplicate transmission	Almost 100%	Multi hop	High	High
MORE [38]	Szymon Chachulski et al	2007	A MAC independent protocol	High , improvement by 22% than Ex OR	Multi hop	High	High
Code OR [39]	Yunfeng Lin et al	2008	Use of intra session network coding to increase throughput	High	Multi hop	High	High
Slide OR [40]	Yunfeng Lin et al	2010	To combine online network coding with TCP Vegas with recording in intermediate nodes	High	Multi hop	High	High
XCOR [41]	D. Koutsonikolas et al	2006	Integrates interflow NC with OR	High ,since it already keeps the information of other node	Multi hop	High	High
CCACK [42]	D. Koutsonikolas et al	2011	A novel protocol to acknowledge network coded traffic	High , better than MORE	Multi hop	High	High
O3 [43]	M. K. Han et al	2011	A novel overlay frame work to decouple OR and interflow NC	High , since it optimizes end to end performance	Multi hop	High	High
SOAR [44]	E. Rozner et al	2009	A novel protocol which selects forwarding nodes judicially with priority based timers	High	Multi hop	High	High
OAPF [45]	Z. Zhong et al	2006	A novel protocol which reduces the number of transmissions to destination	High	Multi hop	Low	High, since few better nodes were preferred
PROPHET [46]	A. Lindgren et al	2003	A novel protocol, delivers based on highest probability	High , since it delivers based on probability	Multi hop	High	High
MaxProp [47]	J. Burgess et al	2006	Prioritization of packets is done for both transmitting and dropped	High	Multi hop	High	High
MobySpace[48]	J. Leguay et al	2006	Based on frequent visits to a node, Euclidean distance is considered	High	Multi hop	High	High
Bubble Rap [49]	P. Hui et al	2008	Places which are mostly visited by people in public or group[are	High	Multi hop	High	High

			different and are considered as BUBBLE				
PROPHET+ [50]	T.K. Huang et al	2010	Nodes are logical weighted based on probabilities to improve throughput	High	Multi hop	High	High
COR [51]	Zhongliang Zhao et al	2014	A protocol COR is introduced which improves OR features , outperforms about 20-40%	High , due to awareness of geographical position of nodes	Multi hop	High	High
HiBOp [52]	C. Boldrini et al	2008	A history based algorithm learns from past transmissions	High	Multi hop	High	High
Epidemic [53]	A. Vahadat and D. Becker	2000	A novel protocol were random pair wise exchange of messages can be done to improve delivery rate	Upto 100% in some scenarios	Multi hop	High	High
Spray and Wait [54]	T. Spyropoulos et al	2005	Effective routing in intermittently connected networks	High	Multi hop	High	High
FPOR [55]	V. Conan et al	2008	Single copy and multi hop strategy helps in minimum delay and high delivery ratio.	High	Multi hop	High	High
OR Flood [56]	S. Guo et al	2009	A delay driven flooding method particularly designed for low duty cycle WSNs	High	Multi hop	High	High
Delegation Fwd [57]	V. Erramilli et al	2008	A new forwarding strategy to reduce cost and increase quality	High , since it prefers high quality nodes	Multi hop	High	High
EBR [58]	S. C. Nelson et al	2009	Encounter based transmission is done to increase delivery rate by 40%	High , improvement of 145% when compared	Multi hop	High	High
MaxOPP [59]	R. Bruno et al	2010	A novel protocol which ensures efficient tradeoff between reliability and opportunistic benefits	High	Multi hop	High	High
OPF [60]	M. Lu and J. Wu	2009	A protocol which is designed using routing algebra	High	Multi hop	High	High
OOF [61]	C. Liu and J. Wu	2012	Several forwarding protocol are considered and it outperforms by 30%	High , in higher mobility regularities	Multi hop	High	High
Consort [62]	X. Fang et al	2011	Slowly dynamic	High	Multi hop	High	High

			changing networks are considered and there utility is improved				
OMNC[63]	X. Zhang and B. Li	2009	Rate control protocol is used to improve throughput	High , twice of Ex OR	Multi hop	High	High
OpRENU [64]	J. Wu et al	2008	Retransmissions are done to properly utilize resources and improve throughput	High, since retransmissions are done	Multi hop	High	High
TOUR [65]	M. Xiao et al	2013	Nodes are made time sensitive to reduce duplication of messages	High. Since duplication is reduced	Multi hop	High	High
DICE [66]	X. Zhang and B. Li	2008	A game theory is applied to improve participation of nodes	High , since are much active due to competition	Multi hop	High	High
Adapt OR [67]	A.A. Bhorkar et al	2010	Selection of nodes are done based on ranks to improve throughput	High	Multi hop	High	High
ORL [69]	P. Tehrani et al	2013	A online learning algorithm is designed	High	Multi hop	High	High
SMAF [70]	R. Laufer and L. kleinrock	2008	Polynomial time algorithm is introduced to optimize network	High	Multi hop	High	High
LCAR [71]	H. D. Ferriere	2011	Least cost algorithm is introduced to reduce cost	High	Multi hop	High	High
PTAS MRA [72]	R. Laufer	2011	Polynomial time algorithm is described for an optimal path	High	Multi hop	High	High
MAP [73]	X. Fang et al	2010	K constraints are considered, optimality depends on K value	High	Multi hop	High	High
PLASMA [74]	R. Laufer et al	2012	Distribution algorithm is designed to optimize transmission rate as well as gateways of node	High	Multi hop	High	High
LOR [75]	Y. Li	2012	Large network topologies are partitioned in small nested networks to reduce cost overhead	High	Multi hop	High	High
ILOR [76]	Aggelos Blestas et al	2009	It exploits slow fading networks to access the destination	High, even in interferences	Multi hop	High	High

Parallel OR [77]	W. Y. Shin	2011	Parallel evaluation of metrics is done for net improvement	High	Multi hop	High	High
SPOR [78]	G.Y. Lee and Z.J. Haas	2011	Simple and practical algorithm is designed for improvement of throughput	High	Multi hop	High	High
HS OR [79]	W. Hu et al	2013	Packet forwarding is done based on per packet feedback to improve throughput	High	Multi hop	High	High
EEOR [80]	X. Mao et al	2011	Energy efficient algorithm is designed to optimize energy	High	Multi hop	High	High
QOR [81]	Q. Lampin et al	2012	QoS based data collection is done in WSNs	High, since QoS is high	Multi hop	High	High
ORPL [82]	B. Pavkovic et al	2011	Forwarding parents are for every forwarding to improve throughput	High	Multi hop	High	High
ORCD [83]	M. Naghshvar and T. Javidi	2010	Nodes are selected based on less congestion	High	Multi hop	High	High
ORW [84]	E. Ghadimi et al	2014	EDC a algorithm is used to predict the sleep and wake up of nodes in WSNs	High	Multi hop	High	High
PRO [85]	M. H. Lu et al	2009	On overhearing any node can retransmit if any transmission is failed	High, since packet drop is reduced	Multi hop	High	High
MTOP [86]	J. Y. Lee et al	2013	It allows a frame of packets to consecutively transmit over a multi hop network	High	Multi hop	High	High
CL EE [87]	J. Zuo et al	2013	By applying cross layer energy efficiency is done in both opportunistic routing and traditional routing	High	Multi hop	High	High
SCAD [88]	Z. Zhao and T. Braun	2014	Based on many forwarders best is chosen for improving throughput	High	Multi hop	High	High

5.0 PROPOSED FUZZY-PRoPHET ROUTING PROTOCOL

Zadeh [89]”fuzzy logic is a precise conceptual system of reasoning, deduction and computation in which the objects of discourse and analysis are, or are allowed to be, associated with imperfect information. Imperfect information is information which in one or more respects is imprecise, uncertain, incomplete, unreliable, vague or partially true". PRoPHET is a probabilistic based approach and can be fastest when in range. Fuzzy logic is applied to PRoPHET; instead of crisp sets fuzzy sets are applied. Fuzzy sets are functions which can map any value between 0 and 1. We proposed fuzzy PRoPHET, for accurate results of both probability and fuzzy.

6.0 CONCLUSION AND FUTURE WORK

In this paper we have studied various mobility models and routing protocols, which help us in future to further carry out research in a competitive way. Using various mobility models and routing protocols we can design quiet new models for further research. In further papers we will try to simulate various routing protocols and compare them mathematically.

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