Bayesian Inference as a Problem Solving Tool in Proactive Routing Protocols

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***Abstract* – This paper rationalizes nine proactive protocols in terms of their efficiencies, inefficiencies and convergence properties. This is done in order to pinpoint challenges associated with these protocols, so that novel algorithms may be proposed for coping with the discovered issues. The methodology followed to put forward the said solutions is that of Bayesian inference. Bayesian inference is a statistical technique having wide applications in the decision theory. The paper highlights salient features of Bayesian inference and, in the meantime, scrutinizes its applicability as a problem solving mechanism in the decision making of proactive routing protocols.**

***Index Terms* – Bayesian inference, proactive routing protocol, features, directed acyclic graph**

I. INTRODUCTION

Routers use a routing protocol as a set of rules or a formula that governs the way they determine the appropriate path over which data is transmitted. In order to have low communication overhead in wireless networks, the routing protocol should lessen route setup and maintenance messages and should be able to converge instantly [1]. For this, different criteria are used in different protocols to select the best route according to the priorities of the network. Each routing protocol has its own plus points and drawbacks and network designers select from them as per their network requirements. Generally, the routing protocols are classified into proactive and reactive types.

The current study focuses on proactive protocols only and explores whether these protocols and Bayesian inference suit each other for reasons that are explained further in the paper. Each node in proactive routing protocols maintains routing tables, therefore, they are also called table-driven protocols. They are upgraded regularly (fresh lists) by periodically distributing routing tables throughout the network. If any topology change occurs in a network, a broad cast message is sent by the node to the entire network informing it about the change. Proactive protocols increase overhead as the network size increases. They are best suited with Bayesian inference as they provide the needed information as changes occur in the network and not on demand only, as done in the reactive protocols. Destination-Sequenced Distance-Vector Routing (DSDV), Babel, Optimized Link State Routing (OSLR) and Enhanced Interior Gateway Routing Protocol (EIGRP) are the examples of proactive protocols [2].

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"Bayesian Networks are directed acyclic graphs (DAGs) with an associated set of probability tables [3]." In these graphs, conditional independence relationships between different variables are encoded graphically. This way, they provide an adequate representation of the joint probability distribution over these variables. Figure 1 shows an example of such a DAG. These can be used as an aid in situations where the protocols in a network require decision making methodologies.

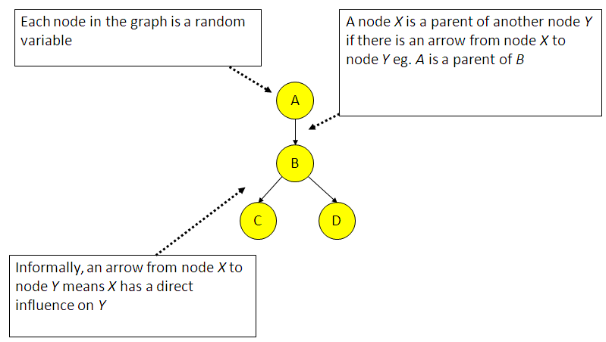

Fig 1. An example directed acyclic graph

II. REVIEW OF PROACTIVE ROUTING PROTOCOLS IN THE CONTEXT OF FINDING ROOM FOR BAYESIAN INFERENCE IMPLEMENTATION

Nine proactive protocols were reviewed in this study. Each one is discussed below. Furthermore, the selection metrics of each protocol have been given explicitly in Table 1 at the end of this section.

A. DSDV

DSDV has the following main features:

Performance: Regular updates are sent so heavy routing overhead is required. It decays the overall performance of the network.

Stability: DSDV is unstable whenever there come topology changes in the network; it remains so until the updates are propagated throughout the network and it successfully converges.

Scalability: According to simulation results in [4], DSDV performance decreases as number of nodes in the network increase and as mobility of the network increases.

QoS: DSDV provides more QoS enabled communication as compared to the Bellman Ford algorithm in terms of packet delay, dropped packets and loops.

Routing Tables: DSDV maintains two routing tables: one of them is meant for keeping a record of the addresses of all other nodes in the network. The other one has the timing

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information on the basis of which that node's update advertisements are scheduled.

Advancements in DSDV: Babel, AODV, Fisheye Routing (FER), Global State Routing (GSR) are all advanced versions of this protocol.

Problems of DSDV:

Looping problem: Loops are generated if information about a route is being updated among the nodes that no longer exist. Loops can be both shorter and longer in life and they need to be avoided because they waste resources and chances of loss of information increases with them. In order to overcome this, inter-nodal coordination method is introduced in [5] but this coordination becomes very difficult in scenarios like ad-hoc networks because the topology and environment change rapidly so management of information becomes difficult and DSDV lacks here. There is a need of some external helping tool in the protocol which can aid it to solve this issue.

Route Fluctuations: Since a DSDV node sends regular updates about the topology changes in the network, there can be more than one updates coming towards a node. In such a case, the node in result to responding to these updates will frequently change its route from one hop to other. This will result in route fluctuations. DSDV deals with it with the help of the 2 routing tables it keeps. When it gets many updates, it decides the route it has to take on the basis of the sequence number first and hop count on second priority. And then it doesn't broadcast the updates further unless it consults its second routing table (that keeps the update intervals and timings records) so this helps to avoid very frequent changes in a node's routes. This is called damping of fluctuations in DSDV terminology.

Unidirectional links: In wireless networks, unidirectional links do exist. But DSDV assumes that all links in a network are bidirectional. Since acknowledgments cannot be sent over the unidirectional links, this causes problems when the destination node generates an update; the nodes with a unidirectional link are not able to broadcast their source nodes about their existence. A proposed solution to this is that there should be enough communication within the network that each node is aware of the orientation of the links; in other words, DSDV should be able to differ between a bidirectional and a unidirectional link. In order to enhance the coordination among nodes, we propose the Bayesian solution which can help conveying the link orientation information as well in the routing tables.

USE OF BAYESIAN INFERENCE: We introduce the Bayesian Inference here to use the probabilities already provided by the DSDV routing protocol and then to decide about which node to coordinate with and which to not. Why Bayesian? In order to solve the stated problem, solutions such as triggered updates, split horizon, poison reverse and path hold-down mechanisms have been introduced which focus mainly on the convergence of protocol. However, solving this problem introduces other problems at times. We need an algorithm that makes DSDV smart enough to take correct decisions about coordinating with its neighbors and this would ultimately lead towards easier protocol convergence.

B. IARP

IARP (Intra Zone Routing Protocol) is a pro-active, table driven routing protocol which is also a sub-Protocol of Zone Routing Protocol (ZRP). ZRP is the one that maintains information about routes within the boundary of its own zone. The zone neighbors are restricted by the parameter known as Zone radius [6]. Main features of this proactive protocol include:

Routing Zone: Each IARP node S has a routing zone which is called its proactive zone as S collects the information about this zone in a proactive manner. Each node maintains a routing table for its routing zone, so that it can find a route to any node in the routing zone from this table. For S, if the radius of the routing zone is k, the zone includes all the nodes which are k-hops away. Figure. 2 shows an illustration of this mechanism.

Neighbor Discovery Mechanism: Each node transmits a hello message at regular intervals to all nodes within its transmission range. If a node P does not receive a hello message from a previously known neighbor Q, P removes Q from its list of neighbors.

Intrazone Routing: In intrazone routing, the packet is sent within the routing zone of the source node to reach the peripheral nodes.

Interzone Routing: In interzone routing, the packet is sent from the peripheral nodes towards the destination node. In IARP, Each node periodically broadcasts a message similar to a hello message kwon as a zone notification message. Just as a hello message dies after one hop, i.e., after reaching a node´s neighbors; a zone notification message dies after k hops. Each node receiving this message decreases the hop count of the message by 1 and forwards the message to its neighbors. The message is not forwarded any more when the hop count is 0.

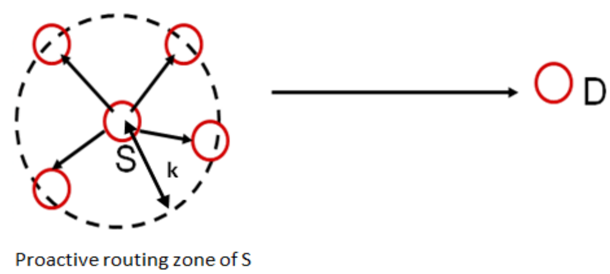

Fig 2. Proactive routing zone of a node in IARP route discovery mechanism

Selection Parameter: link state

Bandwidth Efficiency: In order not to waste the available bandwidth, the IARP boundaries are restricted with in a zone which is why it is known as 'Limited scope Proactive routing protocol'. This is because of the fact that changes in the neighborhood of a node have greater impact on the node than on the ones occurring in the far-end of the network [7].

Border casting: Out of the routing zone of S, routing in the inter-zone area is done reactively. This is why IARP is termed as a hybrid protocol. S sends a route request (RREQ) message to the peripheral nodes of its zone through broadcasting. First, P checks whether the destination D is

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within its routing zone and if so, sends the packet to D. Otherwise, P sends the packet to the peripheral nodes of its routing zone through broadcasting. If a node P finds that the destination D is within its routing zone, P can initiate a route reply to the RREQ sent by S.

Route Maintenance: When there is a broken link along an active path between S and D, a local path repair procedure is initiated. Repairing a broken link involves establishing a new path between two nodes within a routing zone.

Routing Zones overlapping and Flooding: Since each node has its own routing zone, the routing zones of neighboring nodes overlap heavily. Since each peripheral node of a zone forwards the RREQ message, the message can reach the same node multiple times without proper control. Each node may forward the same RREQ multiple times which will result in flooding of routing information.

Zone Radius Dependency: When the radius of the routing zone is 1, the behavior of IARP is like a pure reactive protocol, for example, like Dynamic Source Routing (DSR). When the radius of the routing zone is infinity (or the diameter of the network), ZRP behaves like a pure proactive protocol, for example, like DSDV. The optimal zone radius depends on node mobility and route query rates.

Control Traffic: Control traffic generated by a protocol is the number of overhead packets generated due to route discovery requests. In the intra-zone routing, each node needs to construct the broadcast tree for its zone. There is no intra-zone control traffic when radius k=1. The intra-zone control traffic grows fast in practice with increase in zone radius. So, it is important to keep the zone radius small. The control traffic can be reduced drastically with early query termination, when a RREQ message is prevented from going to the same region of the network multiple times. The amount of control traffic depends both on node mobility and query rate.

Performance: The performance of ZRP is measured by comparing control traffic with call-to-mobility ratio (CMR). The CMR is the ratio of route query rate to node speed. As CMR increases, the number of control messages is reduced by increasing the radius of the routing zone. This is because, it is easier to maintain larger routing zones if mobility is low. Hence, route discovery traffic also reduces. On the other hand, CMR is low if mobility is high. In such a case, the routing zone maintenance becomes costly and smaller routing zones are better for reducing control traffic.

USE OF BAYESIAN INFERENCE: IARP is basically dependent upon hop counts. Due to the limited number of hops in the zone, it considers time to live (TTL) in the Internet Protocol (IP) header and thus the Bayesian implementation over IARP is somehow inefficient to implement. Another reason for this is that it’s not a purely proactive protocol. Part of the network where this protocol works in a proactive manner is already well managed and issues are in the reactive part, where Bayesian inference is not suitable to be used. Apart from this, it has metric limitation as well and only on the basis of link state, we cannot plan to implement Bayesian inference in it.

C. *B.A.T.M.A.N*

B.A.T.M.A.N (Better Approach To Mobile Ad-hoc Networking) is a routing protocol for multi-hop ad-hoc mesh networks. It was basically developed to overcome the shortcomings of OLSR.

Meant for: Both wired and wireless networks.

Working/ features: It detects other BATMAN nodes by broadcasting originator messages (OGMs) and informing its neighboring nodes about its existence. OGMs contain originator address, sending node address and a unique sequence number. The receiving node then changes the sending address to its own address and rebroadcasts the OGM.

Information Maintenance: A batman node does not maintain all the information about the route, rather keeps the address of its immediate (next) node (that too of the best one).

Drawback of B.A.T.M.A.N: Quality of a link is never checked in this protocol. It just finds the existence of a link. Links are later compared with each other on the basis of the number of OGMs received during a specific sliding window.

Selection Parameters: Hop count

USE OF BAYESIAN INFERENCE: Bayesian inference can be implemented into B.A.T.M.A.N’s algorithm. We have two parameters and Bayesian inference can be implied into the OGMs and hop counts. These, on the bases of the Bayesian analysis, can make decisions through the conditional probability in Bayesian Inference.

D. *HSLS*

Hazy Sighted Link State protocol (HSLS) is a wireless mesh network routing protocol and is based on features of reactive, proactive and suboptimal approaches. Main features of this protocol are:

Meant for: Wireless mesh networks.

Working: The routing information here is link-state update and TTL. The link state update contains the sender’s information, the next immediate node and sequence number. It uses this information to produce the best route for information sending. This protocol is used for controlling the LSU based on the network topology on the basis of the scope and frequency of the link state broadcast message [8].

Flooding Avoidance: It does not flood the network with link state information. Link state information is advertised through the network optimally.

Scalability: HSLS is a scalable link state routing protocol which is designed for maintaining a consistent and coherent view of the network.

Limitations: Distant updates in HSLS are sent infrequently due to which the nodes do not receive information from the distant nodes which may no longer be present. With HSLS, one can't disambiguate between a node that is still present 10 hops away and a failed node until former neighbors send long-distance announcements.

Hazy sighted link state routing protocol is a hybrid routing protocol in which the nodes are not that far away and the routing protocol does not have much information about the whole network topology in order to make a good next-

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hop decision. Thus, propagation of each link state change is avoided.

Selection Parameters: Link state update and TTL

USE OF BAYESIAN INFERENCE: HSLS is a limited radius protocol in which the nodes do not have information about faraway nodes and are only concerned about their close neighbors. Stating briefly, HSLS limits the propagation of link-state updates so that timeliness of the information is a linear function of the number of hops [9]. HSLS basically works on the hop count for its specific functional radius and on link state for link selection and hence the Bayesian network is inefficient to be implemented over this protocol.

E. *Fish Eye State Routing Protocol*

Main features of this protocol are:

Meant For: Ad-hoc wireless networks

Working: As the name suggests, it works on the principle of fish eye viewing technique. A fish eye detects the objects near its focal point with high details; but as it gets away from it, the image gets less particular. In Fish Eye State (FSR), the nodes closer to each other exchange more information as compared to the far off nodes in the network. FSR keeps the overhead low without compromising route computation accuracy when the destination is near. FSR uses the concept of scopes to divide the nodes strength according to their respective distance from the source. This distance is computed using the hop count, such that all one hop away nodes are considered to be in the same scope. Similarly, nodes that are two hops away come in the premises of the second scope. Figure 3 illustrates this phenomenon.

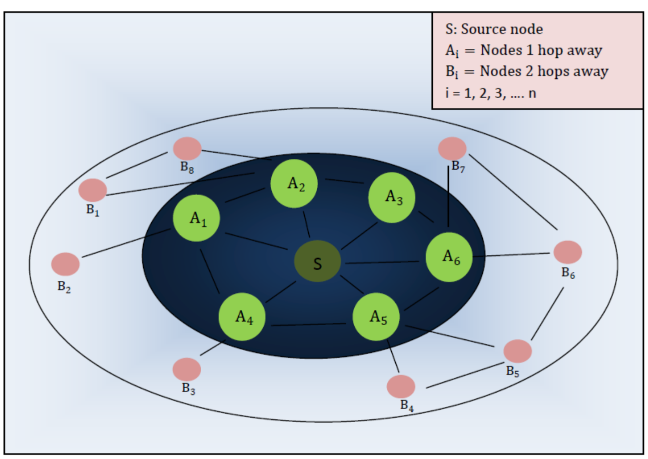

Fig 3. Scopes of FSR view of a MANET

Route Discovery Mechanism: First, it discovers its neighbors and establishes relationships. Then route computation is done through the Link State Packets (LSPs) information. LSPs do the job of spreading the information about the neighbors.

Less Routing Overhead: This protocol uses the technique of fisheye to reduce the routing overhead. It is a link state protocol and has the ability to see the objects when they are proximal to the focal point. The nodes only exchange topology information with their near-neighbor nodes so the nodes have accurate information only about the nearer nodes. Each node has a unique identifier. The nodes can move freely and can change the direction independently. Two nodes are connected when the distance between them becomes less than or equal to the transmission range.

Routing Tables: For each node, three tables along with the list of neighboring nodes are maintained. These tables are:

1. Topology Table
2. Distance Table
3. Next hop Table

Bandwidth Efficiency: Different frequencies are used in link state information. Higher frequency is used for smaller scope exchanges and vice versa. So the exchanges in smaller scope are more frequent. This makes the information of the nearer node more precise than the farther ones. This property of FSR reduces the bandwidth and routing overhead and also the topology messages size can be reduced.

USE OF BAYESIAN INFERENCE: As described in [14], simulation results have shown that FSR performs well when the destination is nearer and mobility is low. Inaccuracy in the FSR algorithm increases with increased mobility and destination distance. The Bayesian solution to this shortcoming in FSR has been suggested in section III.

F. *OLSR*

OLSR is basically a mobile ad-hoc network routing protocol but can be used in other wireless ad-hoc networks too. Main features of this protocol are:

Multipoint Relays: In this protocol, routes to all destinations within the network are known and maintained before use. It is based on the concept of Multi Point Relays (MPRs). Nodes within the network announce their selected MPRs. Only these MPRs forward the broadcast messages. Timeout values and validity information is contained within the messages. Working of MPRs makes OLSR unique [10]. Figure 4 depicts the working of these MPRs.

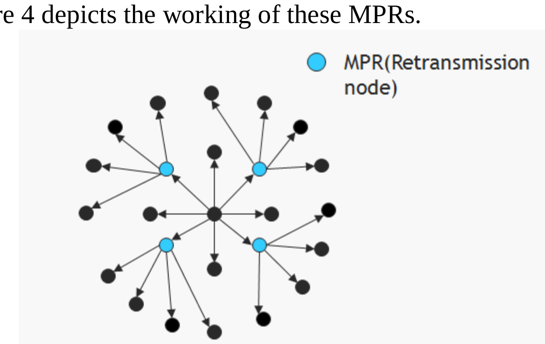

Fig 4: Routing information flooding by elected MPRs

Working: OLSR is designed to work independently from other protocols and OLSR does not make any assumption about the underlying layers of the OSI reference model.

Fast OLSR: It has the capability of detecting fast moving nodes within the ad-hoc network and is thus termed as Fast OLSR, which is an extra privileged feature for these nodes detected through the fast change in the neighbors. Fast OLSR

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and normal OLSR can coexist in a network; while, later on when the fast moving node becomes static, it's again brought back to the original state [11].

USE OF BAYESIAN INFERENCE: OLSR uses hop count as the selection parameter. After scrutinizing the literature on this protocol, a challenge has been recognized in it. This is the control messages overhead problem as compared to other protocols like FSR and distance vector based protocols. This problem has been addresses from a conditional probability viewpoint in section III.

G. *EIGRP*

EIGRP (Enhanced Interior Gateway Routing Protocol) is a Cisco propriety routing protocol based on several parameters. It constitutes the following main features:

Algorithm: EIGRP uses DUAL (Diffusing update Algorithm) algorithm instead of DBF (Distributed Bellman-Ford) algorithm for path selection. EIGRP is a loop free routing protocol because of the DUAL algorithm it uses.

Selection Parameters: EIGRP is dependent on bandwidth, delay, load utilization and link reliability. It does not make use of hop count because of its loop free algorithm [12].

USE OF BAYESIAN INFERENCE: Bayesian network can be efficiently implemented over EIGRP because of its multi-metric nature for path selection. These metrics are bandwidth, delay, load utilization and link reliability.

H. *HSR*

Hierarchical State Routing (HSR) protocol has the following main features:

Multilevel Clustering: These are distributed multi-level hierarchical routing protocols that use the concept of multilevel clustering. This clustering is organized in levels having a 'leader' in each cluster.

Physical level clustering: In Physical level clustering, the nodes have one-hop wireless link between them.

Local level clustering: Locally, the nodes are linked on certain relations. Every node of the cluster has information about topology of the network and the status regarding it. This information circulates within the network periodically. The 'leader' broadcasts information about the hierarchical topology of the network to all the lower level nodes. The address of each node in the network is saved in the table of HSR; these tables are updated by the routing update packets.

Route Establishment: Routes are established according to the rule of hierarchy that packets should be forward to the node which is higher in position than the source. Then this packet should be sent to the highest node in the hierarchy of the destination, thus in this way the packets are forwarded from source to the destination. This process can reduce size of routing tables but can lead to problems too in exchanging the information and electing the leader node.

USE OF BAYESIAN INFERENCE: Bayesian inference can be implemented in electing the 'leader node'. Furthermore, implementing it in each node can avoid circulation of information about the topology unless a change in topology occurs.

I. *Babel Routing Protocol*

Babel is a distance vector protocol (a form of DSDV) that avoids loops. A robust and efficient loop avoiding distance vector routing protocol; Babel is based on the concept of AODV, DSR and EIGRP and makes a hybrid implementation of these protocols.

Meant for: Both flat routing (in mesh networks where routes are not arranged properly) and prefix based routing (where route information is set as prefixes ready to be used) are compatible with this protocol. Babel is suitable for wireless networks because of its loop free nature even if mobility is detected within the network and during convergence after the mobility is detected.

Loop management in prefix based routing: If a prefix is provided by one router only and not by many, there never occurs a loop for that prefix. If the same prefix is provided by many routers (which might mean that they are a subnet) then Babel lets the loop originate for some time and that time is called the Garbage Collection time (GC time). After this time, there never occurs a loop for that prefix again.

Limitations of Babel: Babel needs periodic updates in its routing tables and therefore consumes energy and bandwidth.

Neighbour Discovery: It sends Hello messages to its neighbors and those who acknowledge it they do it by sending IHU (I Heard U) messages to it. With that it calculates the cost between it and the neighbors and then goes for the least cost route.

Selection Parameters: Babel basically depends not only on the Expected Transmission count (ETX) for congestion but also on the Link Cost for reliability.

Convergence mechanism: Babel converges faster than DSDV. What DSDV does is that whenever there occurs some topology changes, it waits for the fresh information to come; i.e., it waits until the new sequence number is sent in the normal periodic interval as its set. Babel acts hybrid over here. It reactively collects fresh information on the spot rather than waiting till the entire interval. It reactively requests the new sequence numbers and the waiting interval are avoided so convergence is done faster and flooding of new routing information is avoided.

Metric computation strategies: Babel allows multiple link cost and route metric computation strategies. Babel is based on distance vector routing and uses the ETX than simple hop count and is thus more intelligent and reliable. Babel uses history sensitive routes selection which minimizes the impact of route flap and also it generates a reactive update when it observes link failure [13].

USE OF BAYESIAN INFERENCE: We can use Bayesian network in the Babel protocol to increase its adaptability so that it can decide whether to adjust the hello and IHU TLVs intervals for a node or not, according to the mobility changes in a network.

Babel is a hybrid protocol having provisions for link quality estimation and fairly arbitrary metrics. When configured suitably, Babel can implement shortest-path routing, or it may use a metric based, for example, on

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measured packet loss. Bayesian network can be implemented over Babel for path selection criteria where the task of the Bayesian network is to use the ETX and also the hop count of the Babel protocol and make the selection of the Path more intelligent. This provision has been described as the proposed adaptive-Babel protocol in section III.

TABLE 1: LIST OF SELECTION PARAMETERS USED IN THE REVIEWED PROACTIVE PROTOCOLS

Routing protocol	Selection parameter 1	Selection parameter 2
DSDV	Hop count	-------
IARP	Link state	-------
B.A.T.M.A.N	Hop count	-------
HSLS	Link state	TTL
FSR	Link state	-------
OLSR	Hop count	-------
EIGRP	Bandwidth, Link reliability	Load utilization, Delay
HSR	Hop count	-------
Babel	ETX	Link cost

III. PROPOSED SOLUTIONS FOR VARIOUS ROUTING PROTOCOLS

A. *Adaptive-FSR using Bayesian Inference*

As discussed in section II, FSR outperforms the conventional link state protocols in the sense that it keeps a low overhead for control messages. Furthermore, the source node deals well with nodes closer (one to two hops away). If the destination is within this range, FSR algorithm works sound enough. However, when the destination is far off and mobility of the nodes is high, then FSR performance degrades. This has been illustrated in the simulation results by Pei, Gerla & Wei [14] that have also stated the trend in FSR inaccuracy w.r.t mobility. Their results show that as mobility increases, FSR view of the source needs to have scopes with higher radii. We have utilized this observation to devise a Bayesian inference based plan for an adaptive FSR. Selection metric of FSR, i.e. Link state is used as the learning parameter to compute conditional probability on the source node. Figure 3 is used as the system model for this algorithm.

Figure 5 represents the proposed adaptive-FSR algorithm. Here, it is assumed that nodes mobility is high (which is one reason adaptive-FSR shall be used). Moreover, other characteristics have considered similar to the work done in [14]. The system model as shown in Figure 3 consists of two scopes, hence, the algorithm is also proposed for a two scope scenario.

B. *Adaptive-OLSR using Bayesian Inference*

OLSR excels in providing updated routing information via its MPR nodes. This comes with the cost of resources, as OLSR does this even when the network is idle. The challenge that comes with this protocol is that it does not remain silent. It keeps updating routing information even when there is no or less traffic in the network. This happens when routing is anageable with less control messages but OLSR, due to its proactive nature still keeps the MPRs engaged. Such a scenario demands OLSR to be intelligent enough to make decision as to whether to behave proactive or to become hybrid when needed. This is a great deal of flexibility that can be achieved if we have some useful information at hand. We chose the selection metric, hop count as the learning parameter for this purpose. With the help of this little datum, we propose the adaptive-OLSR algorithm described in Figure 6. The purpose is to utilize the concept of MPRs as the intelligent decision makers. This brings in a nested decision-making; first at the source node and then internally at all MPRs.

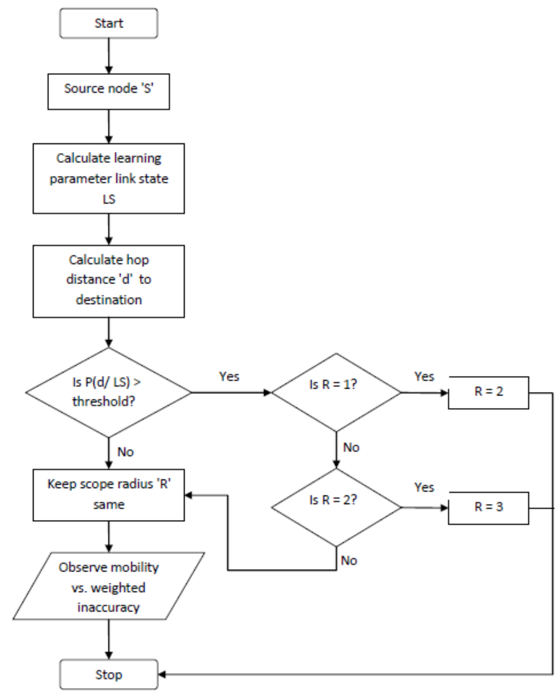

Fig 5: Flowchart of the adaptive-FSR algorithm

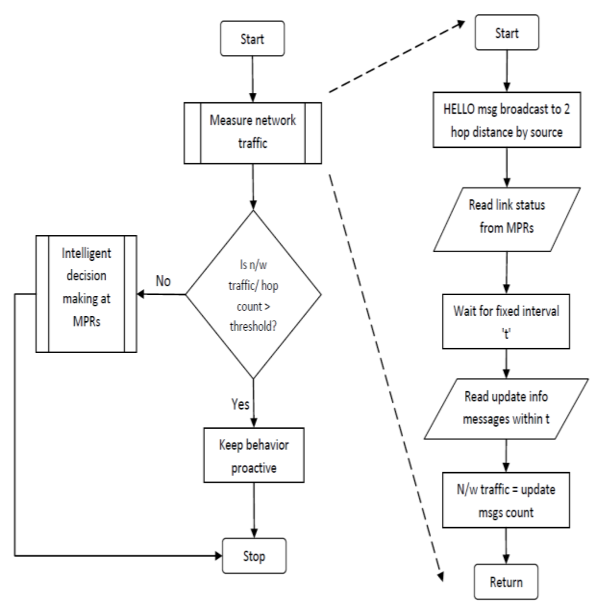

Fig 6: Flowchart of the adaptive-OLSR algorithm

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C. *Adaptive-Babel using Bayesian Inference*

In the race of competent routing in distance vector based routing protocols, Bellman-Ford algorithm was the pioneer. After it, researchers brought the DSDV protocol with loop avoidance using the concept of sequence numbers. Still the problem of wait interval was there, for which Babel was proposed as a solution. How does it cope with the problem of wait interval, this has already been discussed in section II.

Presently, we propose a conditional probability based solution for some challenges that are still there in Babel routing protocol: First, Babel creates traffic problems because it is based on periodic routing table updates that create overhead, and therefore, consumes energy and bandwidth. But we want better communication first and it is still less energy consuming than the DSDV. Second, implementing Bayesian Inference would result in efficient utilization of resources which will ultimately pay back the bandwidth and energy consumed.

When the same prefix is routed by many routers, Babel takes time to acquire its initial properties and to avoid the loops. This makes it unsuitable for mobile networks, as mobile networks cannot afford to have system breakdown even for seconds.

Apart from this, Babel is built for low end devices, and implementing Bayesian inference in it will require computations. But this issue can be attuned since between the time Babel was made and now there's a wide difference in the computation costs.

The proposed algorithm is a form of an add-on in the existing Babel protocol. The flow of this process is diagramatically shown in Figure 7. It works in the following way:

- Bayesian congestion check is performed on all nodes in the network to find out the nodes that are less participating than the others and to perform the suggested operations on those nodes.
- First, the specific node to start at is selected. It is named in the Figure 7 as Node Xi since the same steps will be performed on all the nodes for i= 1 to the total number of nodes in the network.
- The parameter used for applying Bayesian inference in Babel, i.e. ETX is calculated at the specific node to serve as the learning parameter for finding the conditional probability via Bayesian Inference.
- When ETX is known then a congestion check is performed. The calculated ETX is matched with a pre-defined threshold. This threshold is set according to the QoS for the network as per the requirement.
- If the congestion measure (as given by the calculated ETX) is greater than the threshold then this indicates that the route followed by packets sent from this node is too crowded for a QoS enabled delivery. This route needs to be changed and some other more appropriate route linked to a more actively participating node should be discovered.
- For this, the update interval for this node is increased by pre-defined duration of 't'.
- In the case if the ETX measured at the node gives congestion less than the threshold set, then performance of this node is good as per the criterion set by this algorithm and its update intervals need not be altered as they are already giving quality route selection.
- The same check is performed for other nodes as well and the algorithm stops when all the nodes have been checked.

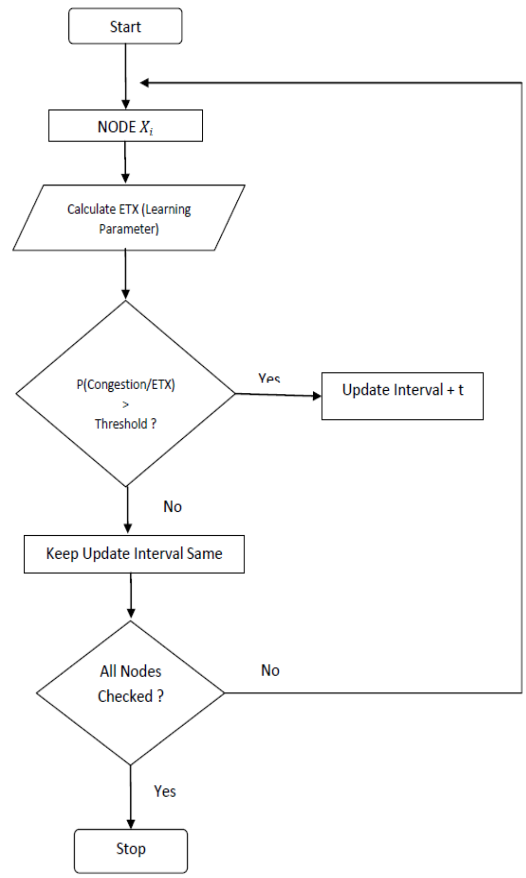

Fig 7: Flowchart of the adaptive-Babel algorithm

IV. CONCLUSION AND FUTURE WORK

Proactive routing protocols are best suited in networks where route discovery needs freshly updated information frequently. In such a scenario, the proactive protocols in use are constantly being updated to outlive the challenging demands of route discovery. We have made an innovative effort in this work, to bring in solutions based on Bayesian inference for meeting these challenges. We have thoroughly studied various proactive routing protocols and identified the key parameters therein for the Bayesian inference. The accomplishment of algorithms based on Bayesian networks has stimulated the literature review for this work. The prime intention was to use the joint probability based principles from Bayesian inference to resolve situations where smart decision making is required from the protocols. To sum up in a nutshell, this work serves as a pilot study for researchers working in both Bayesian inference and proactive routing protocols domains. The algorithms presented in this work will be implemented and evaluated with the existing schemes in our future work.

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