Local Mobility Perceptual Model Based on Fuzzy Logic in MANET

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Abstract

As a key pattern in wireless communications, ad hoc is able to improve spectrum utilization and network throughput evidently. Data existed in ad hoc network get better security because it will never be transmitted through the public network. However, there are significant gaps, in terms of movement speeds, areas, etc., among multiple devices causing network instability problems, which traditional routing protocols lack necessary considerations about. The obvious influence is performance reduction or transmission failure. Therefore, we propose a perceptual model based on fuzzy logic to obtain degree of mobility in local region. Establishment procedures include motion perception, parameters fuzzification, and output normalization. That is, nodes observe adjacent nodes and calculates topology change rate and average speed of neighbors. Then using membership function fuzzify the relationship between above parameters and mobility level. Finally, acquiring the normalized output with the help of centroid formula. Relevant modifications of a reprehensive protocol are implemented to optimize its robustness in complex situations. Simulation results illustrate that the upgraded protocol can maintain high packet arrival rate and acceptable latency in various experiments, which proves the usability and efficiency of our model in different mobile scenarios.

Keywords: Perception Model, Fuzzy Logic, Adaptability, Ad hoc network

1 Introduction

Mobile Ad hoc Network (MANET) is a group of devices which support transmit data to each other without any communication infrastructure. MANET is widely used to communicate in complex and special environments such as large conferences, battlefields, and disaster scenarios[]. Benefit from Wi-Fi Direct[] and D2D communication[] technology in 5G, more and more devices have ability to form a heterogeneous MANET. This can increase network resource utilization and throughput greatly. Typically, Point-to-point communication can reduce the risk of attacks such as data snooping and stealing, because attackers should be close to communication paths to achieve an attack. Currently, almost everyone has a smart phone which supports cellular communication or Wi-Fi connection, this provides a broader application scenario for MANET, such as indoor interactive games or education which tend to have high privacy.

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There are three classic types of protocols in ad hoc network: table driven protocols which usually called proactive protocols such as DSDV[3],OLSR[2]; on demand protocols or reactive protocols such as AODV[10], DSR[5]; hierarchical protocol which mixed above two types of protocols, for instance, CBRP[8]. Some protocols based on geographic location, such as GPSR[14], have also been proposed. Previous researches[4] declare that proactive routing protocols have optimal performance in small, stable networks. When the mobility of the network increased, reactive routing protocols are considered to have better effects. Furthermore, hierarchical routing protocols is able to support large-scale networks but it does not perform well in scenes where nodes moves at high speed. Location-based routing maintains good efficiency in most scenarios, but nodes must support to measure specific locations.

Self-organizing network improves data leakage but diversified mobility, transmission rate, and processing capacity of devices will result in loss of transmission performance since existing protocols do not consider the problem caused by multi-scenario fusion. Hence, designing an adaptive routing protocol will bring great improvements to MANET. Generally, degree of node association and relative moving speed among devices have a powerful impact on routing performance[1]. In particular, for promoting the robustness to different degrees of mobility in MANET, we propose a model to detect motion state of nodes in local area based on fuzzy logic. A modified protocol was introduced to show how the model brings adaptability to existing protocol. Specific contributions are as follows: (1) This paper propose an intra-area mobility perceptual model. Under this model, the perceptual node collect information of neighbors and outputs judgment of movement level based on fuzzy logic. (2) A modified routing protocol is introduced in detail to illustrate how to apply the model. Meanwhile we evaluated the improved protocol in typical scenarios through NS2, a simple analysis of the results is provided at the end.

The rest of this paper is organized as follows. Section 2 describes main principle and detailed processing steps of proposed model. Section 3 presents an improved protocol using our model. Section 4 shows the performance of modified protocol in two scenarios and makes comparison with other mechanisms. A brief description of related work is given in section 5. Finally, our conclusion and future work are listed in section 6.

2 Proposed model

Frequently, when local topology changes rapidly or nodes move quickly, links among nodes are considered to have a large probability of failure. So if nodes can obtain mobility parameters and switch its routing scheme refer to current situation, the network will be more robust and efficient. However, while the network scale get large, it is extremely difficult for nodes to collect detailed mobile parameters of overall topology. Fortunately, a node can attain motion state of neighbors easily. Since nodes in MANET transmit data hop-by-hop, nodes change routing scheme according to the degree of mobility in local region will make sense. More detailed, nodes can obtain the rate of neighbor changes through periodic HELLO messages, which imply the degree of correlation of node motion trace. Benefit from velocity[9] and dsitance[7] estimation method, the device has the ability to estimate relative speed among neighbors, since that is beyond the scope of this paper, it is not discussed in detail here.

Key parameters such as node relevance and moving speed reflect the mobility of nodes, but there is no accurate quantitative standard currently. As a consequence, it is hard to use Boolean logic to determine the mobility of nodes. On the contrary, Fuzzy logic[15] was initially proposed to solve subjective or imprecise events, using multiple membership functions to fuzzify the problem and use the weighted decision function to calculate output. So it can be used to help make decisions.

Above all, a mobility adaptive model was proposed in this paper. Note that this paper assumes that all nodes have same transmission ability and each node knows its location. In this model, nodes observes other nodes in local area and speculates the availability of links based on fuzzy logic. This requires nodes obtain moving parameters such as neighbors change rate and relative speed between nodes within one hop. Devices switch to suitable routing scheme for current situation according to the model output. The processing steps are as follows:

Step.1 The perceptual node periodically floods HELLO messages to adjacent nodes and counts variation ratio of the neighbors in local area(LVR) and ratio of relative speed to adjacent nodes (SVR). As shown in formula (1), LVR is defined as proportion of the quantity of nodes added or removed to total quantity of nodes within one hop from the monitor. SVR is defined as the proportion of mean node speed within one hop to the upper speed limit. Furthermore, indicators are flexible and scalable. Users of this model can adjust the factors to be suitable to the usage.

$$\begin{cases} LVR = \frac{N_{add}+N_{del}}{N} \\ SVR = \frac{v_{\text{mean}}}{v_{\text{max}}} \end{cases} \tag{1}$$

Step.2 Once the perceptual node obtain real-time LVR and SVR, they map values to corresponding fuzzy sets based on membership functions. The membership function is shown in formulation(2) for example.Φ(x) is defined as fuzzy output of each ratio, x is the input LVR or SVR. Interval(a,b) point out the boundary of membership function. For different indicators, the parameters in the formula are different.

$$\Phi(x) = \begin{cases} 0 & x < a \\ \frac{x}{b-a} & a <= x < b \\ 1 & b <= x \end{cases} \tag{2}$$

Step.3 The normalized output is obtained using the centroid formula, as shown in formula(3), n represents the amount of membership functions, n=2 in this paper. Output is defined as normalized degree of local mobility. Supervisory nodes compares the output with a preset threshold to determine the degree of mobility within the region. We set the same threshold for all nodes but it can be set differently depending on the identity of node.

$$Output = \frac{\sum_{k=1}^{n} \Phi_k(x)^* x}{\sum_{k=1}^{n} \Phi_k(x)} \tag{3}$$

By setting the appropriate threshold and parameters of each membership function, monitoring nodes can judge the motion state of neighbors and switch routing scheme suitably. In next section, we introduced MD-CBRP as an example to illustrate how to apply the model to an existing protocol.

3 Modified protocol

CBRP(Cluster Based Routing Protocol)[8] is a typical hierarchical protocol used in MANET. Compared to flat routing protocols, CBRP provides low latency transmission while also supporting larger networks. However, this scheme needs to maintain local topology information, so that its performance will degrade obviously when the mobility of the network increases. Original CBRP was designed for large-scale networks and its mechanism can be mainly divided into two parts: maintenance cluster and routing process.

Firstly, all nodes periodically send HELLO messages every two seconds to maintain a list of neighbors within two hops, and select the node with the smallest ID number as the cluster head. A node connected to multiple cluster heads is considered as a gateway node. Remaining nodes are members of the cluster. The identity of each node is marked in the neighbor list: cluster head, gateway, and member. The next, CBRP find routes through source routing, it is the same as DSR. Their difference is the way sending requests. CBRP first checks if the destination is in the neighbor list. If the destination is a neighboring node, it will be forwarded directly; otherwise, the message will only be sent to the adjacent cluster head and gateway to search aimed node. However, DSR flood request messages and intermediate node keep route cache.

Selective forwarding methods weaken CBRP support for mobility because the data transmission can only pass through the cluster head and the gateway node, when the actual identity of a certain node changes, other nodes can only discover it after receiving the next HELLO message, which may result in packet loss. Besides, frequent topology changes cause source resend request continuously.

In order to promote the performance of CBRP in high mobility scene, Mobility Detected CBRP(MD-CBRP) is proposed based on the model mentioned in previous section. A judgment module added in cluster head. Cluster heads periodically counts ratio of neighbor changes and speed of adjacent nodes to obtain LVR and SVR. Each entry in the neighbor list maintains a timer and speed record, the timer requires 8 bytes of memory while the speed record requires 1 byte. Maximum duration of the timer is two seconds. When the cluster head receives HELLO message, it calculates distance from the corresponding node and then records estimated speed in the neighbor list.

Every two seconds, the cluster head calculates LVR and SVR then judges the current cluster mobility state through the model output. When the output is below the threshold, nodes in the cluster remain consistent with node which runs CBRP. When the output is beyond the threshold, the cluster is considered to be unstable. All nodes in this cluster maintain only the topology information within one hop and use flooding method to request route since the nodes belong to the cluster no longer trust the head and the gateway can serve as a stable forwarding bridge. In particular, a gateway node that is in both stable and unstable clusters still maintains topology within one hop, but when a routing request is sent from gateway to a stable cluster, the gateway forwards the request directly to the cluster head and other gateways. Moreover, nodes in unstable clusters will keep the route cache. Benefit from the existence of route cache, new link constructed quickly near broken link.

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A tag indicating the status of current cluster will be added to HELLO message. The node attaches this tag to the end of each line of neighbor list, in order to determine the situation of each cluster in which it is located. After receiving the HELLO message from cluster head, members and gateways checks that the label has decided its own routing scheme. Generally, the local area is regarded as stable when label is 0, and in turn when the local area is turbulent, the label should be 1. The TTL of the HEELO package is set to 2 when the cluster is steady, otherwise set to 1. Before node communication begins, nodes first check the flag to decide on the forwarding scheme.

For perceptual model, specifically, we set initial threshold of 0.6 and maximum speed of 50 m/s. For LVR, the fuzzy interval is set to (0.2 0.6); for SVR, the fuzzy interval is set to (0.2, 0.5). We implemented MD-CBRP in NS2 and in next section its performance will be displayed for analysis.

4 Simulation and evaluation

4.1 Simulation setup

In order to evaluate the performance of proposed model and improved protocol in different mobility scenarios, we adopt platform NS2 which is widely used to simulate. We compared MD-CBRP with four protocols which are already existed : AODV, DSR, DSDV, and CBRP.

All protocols were executed with the same simulation parameters. We assumed simulation area to be 600 x 600 m^2, and the mean speed of nodes is set to be 0,10,20,30,40. The duration of each test lasts 150 seconds. The total number of nodes is 30 and nearly 20 nodes are randomly selected to send data with a rate of 5KB and the duration of data transmission did not exceed 80 seconds. The traffic type is CBR applicable for applications with low latency, while the physical layer used the IEEE 802.11 standard for wireless networks with a bandwidth of 2Mbps. After executing simulation 30 times using different seed, we got average results for each scenarios.

Two mobility scenarios Manhattan and RPGM are considered in the simulation. These two movement scenes are representative of random moving and collective moving. In Manhattan scenario, the relative movement speed between nodes is extremely large, and topology changes frequently. There is no obvious correlation between locations of the nodes. However, nodes in RPGM scenario are highly aggregated, relative speed between nodes is almost zero. Moreover, changes of link state rarely occur in this model.

4.2 Simulation results

In this subsection we compare the capability of five protocols in terms of:

• Packet Arrive Ratio : The number of successful data packets arrive at the destination node divided by the number of all data packets sent.

• Average Transmission Delay: The mean time required for data packets transmit from the source to the destination.

• Normalized Routing Overhead: The proportion of routing messages compared to the sum of received data in bytes.

Among them, the first two indicators reflect the performance of network transmission. Whether data can be transmitted on time determines network efficiency and reliability, so it is exceedingly significant to increase packet arrival rate and reduce transmission delay. Routing overhead causes energy consumption, whereas nodes in the MANET have limited power so reducing routing overhead also make sense.

Packet arrival rate is shown in Fig.1, this indicates a more robust performance of MD-CBRP throughout the results. In Figure 1-a, it can be discovered that table driven protocol like DSDV has a poor performance when nodes have high relative velocity. As a hierarchical protocol, the performance of CBRP is also deteriorated because local topology changed fast. Generally, on-demand routing protocols are considered to support for mobility well. However, the performance of AODV is not satisfactory because of the slower reconstruction of route. M-CBRP and DSR performed similarly and achieved best scores. Both protocols demand intermediate node maintain route caches so that they can recovery transmission quickly to handle failure of links easily. For Figure 2-a, package arrival rate of all protocols is above 90% since the logic links between nodes hardly change in RPGM model. Among them, DSR,CBRP, and MD-CBRP all achieved the best performance.

In terms of latency in Fig.2, as a consequence of the proactive protocol transmit data through table

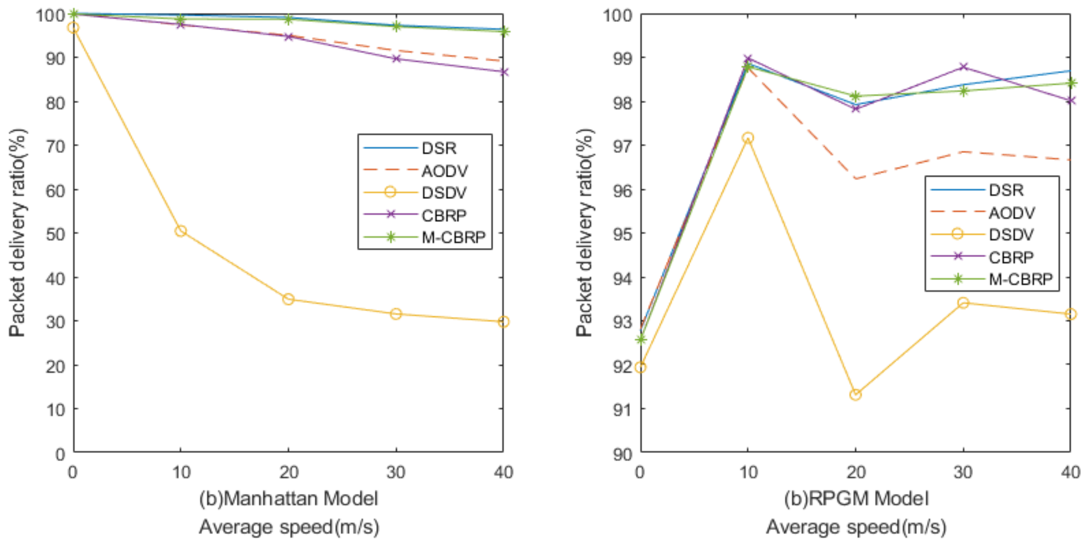

Figure 1: Packet delivery ratio

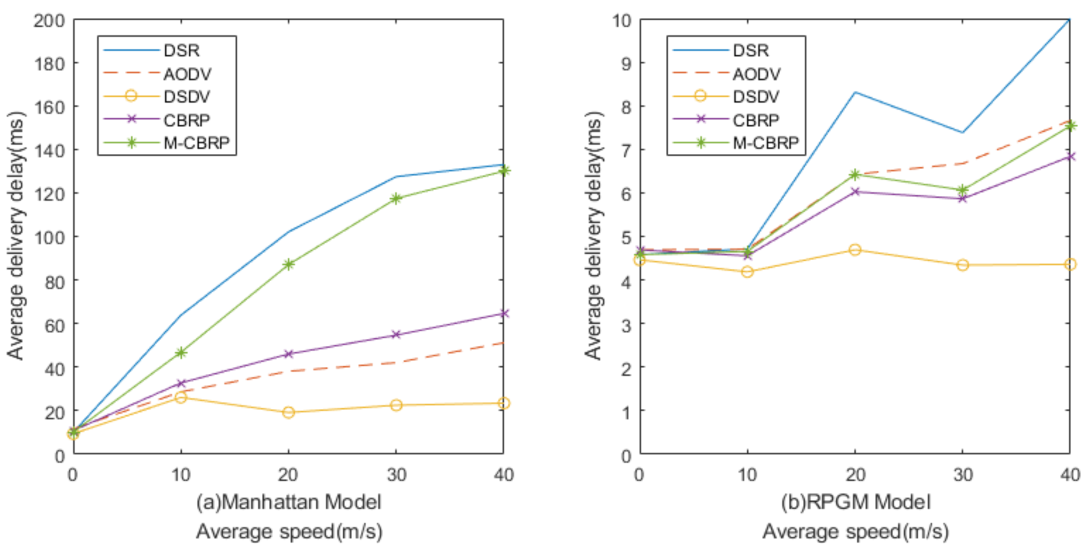

Figure 2: Average transmission delay

without looking for a route, it can be clearly found that DSDV always has the lowest latency. DSR has the worst performance because of source routing. Furthermore, in Fig.2-a, when using DSR and MD-CBRP for routing, the delay is significantly increased, but this is due to rapid changes in topology, some data transmissions will wait for a very long time. So the average delay increased greatly. However, MD-CBRP has similar good results to CBRP in Fig.2-b, this shows that the improved protocol still maintains a low transmission delay when degree of node movement is low.

According to Fig.3, we can find similar trends. On-demand routing protocols have low routing overhead when node mobility is low, but their overhead exceeds proactive or hierarchical protocols as mobility increases. As the network topology changes fast, the routing overhead of DSR and MD-CBRP grow rapidly caused by frequent link disconnection in Fig.3-a. Fig.3-b indicate The routing cost of MD-

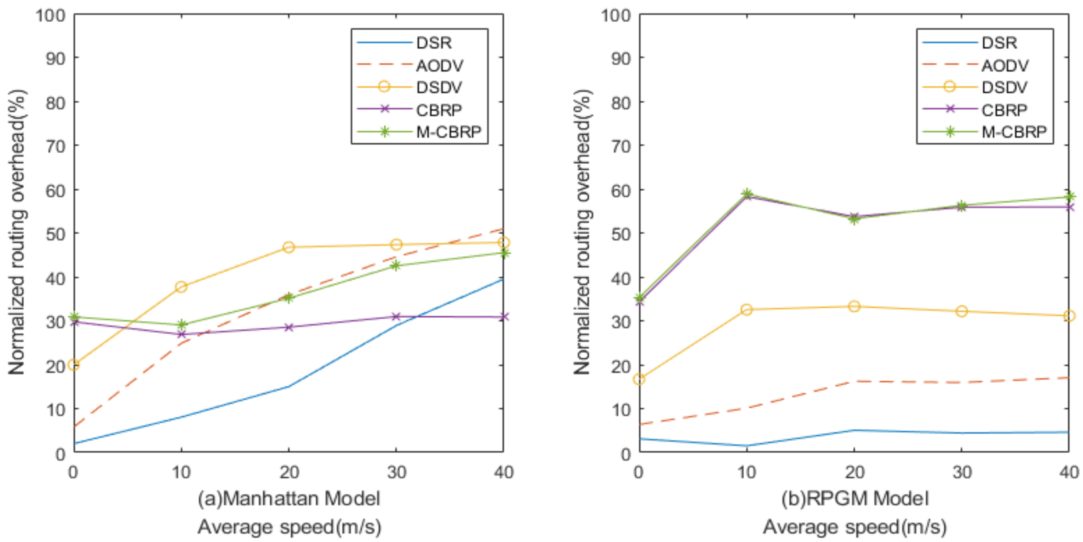

Figure 3: Routing overhed

CBRP in a stable network is slightly higher than that of CBRP.

Above all, the improved protocol guarantees end-to-end packet delivery ratio at scenarios with different degree of mobility. It also keep a low latency when the topology changes slowly. This represents the proposed model did enhance the adaptation of routing protocols to motion diversity.

The disadvantage of MD-CBRP is that its overhead is large, and the cluster head is required to execute extra calculation. Since MANET are often used in special communication occasion, successful data transmission is especially important. And the routing overhead can be effectively reduced by increasing the HELLO packet broadcast interval or reducing its TTL.

5 Related work

5.1 Adaptive routing protocol

Since there is no infrastructure, the requirements for ad hoc network are very different from other networks. Scalability of routing protocols in MANET is related with excessive traffic caused by increase of network size and node mobility. In order to cope with different scenarios, some researches have proposed methods to improve the route adaptability.

Muneer Umar et al.[13] proposed state-aware link maintenance approach to perceive whether traffic passing through node, then divide the node into three states. Active nodes will use table-driven routing while inactive nodes will not maintain link state table, which can reduce routing overhead and improve network efficiency. However, when nodes move quickly, the performance of this protocol will drop dramatically due to frequent link state changes.

Ladas et al.[6] discussed the impact of the node quantity on traditional routing protocols and introduced a hybrid protocol called M-CML. This protocol record the number of nodes in the entire communication area. When the network size is small, the node will adopt an enhanced OLSR protocol. When the number of nodes is large, the node will adopt the AODV protocol. Although this protocol improve routing performance but AODV and OLSR both perform badly in highly mobile scenarios, so their protocols also lack mobility support.

P.Marinho et al.[12] proposed a clustering protocol for high-density areas, which promote network scalability by limiting cluster size and multi-layer clustering. But they only evaluated their protocol in low mobility scenarios. Numerous cluster heads would make it difficult to use in scenarios where nodes move fast.

Above works have as main focus on obtain some key attributes of the network, such as traffic distribution, network size and network density. They get better performance by employing adaptive procedure to improve traditional protocol. However, they are short of consideration for different node moving capacities, the work we have done just makes up for this gap.

5.2 Location assisted routing protocol

The method of positioning, ranging or speed measurement is able to help nodes route, and several methods of geographic location assisted routing have been proposed.

GPSR [14]was presented to support mobile scenes with high-speed mobile nodes. It always has a good performance whether the node move quickly. However, local links may unreachable for a long time because of routing holes. In addition, GPSR requires nodes to have the ability to obtain their detailed location, so some devices cannot support the protocol and some safety issues may appear.

Kumar Rana et al[11]. improved existing Directional LAR mechanism to find the best next-hop and thus reduces unnecessary transmissions. Their experiments show that the new protocol gets less routing overhead and lower latency. Whereas they only considered cars as communication nodes, actually it is hard to support GPS for a long time for small mobile terminals such as smart phones.

In this paper, our goal is to design a light model that can discover the mobility of local topology without GPS. Benefit from this model, we can improve support for nodes with different levels of mobility conveniently.

6 Conclusion

In this paper, we proposed a local mobility perceptual model which can help nodes decide suitable routing mechanism. Two crucial indicators rate of topological change and average speed of neighbor nodes are used to calculate in the model, model output can represent the mobility of local area. We apply this model to a commonly used hierarchical protocol CBRP and evaluated the improved protocol by simulation tool. Finally, simulation results showed that the modified protocol obtain better robustness in two typical scenarios, this proves proposed model does have the ability to help routing protocols adapt to multiple mobility scenarios.

However, due to the variety of scenes, some parameters of our model require empirical settings, so it is inflexible. Future works include considering more network or node attributes and adopt intelligent approaches, such as machine learning, to mine the right parameters automatically.

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