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High efficiency AODV routing protocol based on link availability prediction in MANETs

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Abstract: To cope with the problem of low protocol efficiency of the standard ad hoc on-demand distance vector (AODV) routing protocol with the periodic Hello message broadcast mechanism, a new link availability prediction based strategy is introduced to reduce the amount of Hello messages. In this strategy, a novel wireless link availability prediction model under line-of-sight (LOS) propagation environments is proposed based on which the parameter of Hello Interval in AODV can be dynamically adjusted to achieve the goal of changing the frequency of Hello message broadcasts under different link stability degrees. Simulation results demonstrate that, compared with the standard AODV with the periodic Hello message broadcast mechanism, the proposed protocol effectively reduces unnecessary control message overhead and greatly improves the performance in terms of end-to-end delay and efficiency.

Key words: Hello message; link availability; ad hoc on-demand distance vector; routing protocol; ad hoc

In MANETs without centralized infrastructures, mobile nodes communicate with each other over multi-hop wireless links if they are out of wireless transmission range. It means that each node should commit itself to forward data packets from a neighboring node to another until a final destination is reached. Although this new approach of networking brings a great flexibility to the world of wireless communications, it imposes some strong requirements with regard to the routing functionality because of the wireless connectivity nature of MANETs, such as a high degree of mobility, absence of a centralized administration and limited resources. Macker et al. gave some basic rules in designing ad hoc routing protocols[1], among which protocol efficiency is considered as an important issue. The protocol should have low control message overhead in order to preserve limited bandwidth and power resources by minimizing route setup and maintenance messages.

As one of the most popular routing protocols for MANETs, the ad hoc on-demand distance vector (AODV)[2] has been extensively studied since it was first proposed by Perkins. To our knowledge, however, few works which address how to reduce the control message overhead in AODV have been published. In this paper, a novel method is proposed to reduce the amount of control overhead by dynamically updating the environment parameters of Hello Interval.

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1 Introduction of AODV

In AODV, when a source node wishes to send a packet to a destination node for which it has no routing information in its table, it initiates a route discovery process to locate its interlocutor node by broadcasting a route request (RREQ) packet. On receiving a RREQ packet, each node first creates or updates a reverse route for itself back to the source node, and if it is neither the destination nor has a fresh enough route to the destination, it rebroadcasts the packet. Otherwise, a route reply (RREP) packet is generated and unicasted back to the source node along the reverse route. When the RREP finally reaches the source node, the discovery period is terminated and the newly established route can now be used to send the data packets waiting on the buffer.

Once a route toward a particular destination is created, each node along the particular path should use some available link or network layer mechanism to perform route maintenance. In AODV, route maintenance is usually performed by requiring nodes to send periodic Hello update messages, usually one per second. Failure of a node to receive two consecutive Hello messages assumes that the link to its neighbor is down. Subsequently, a route error (RERR) message is initiated to notify the earlier nodes down the path of such a breakage, and the corresponding entries in the routing table of affected nodes will be invalidated.

2 Improvement for Standard AODV

AODV is an on-demand dynamic routing protocol, which means route enquiries are initiated on an on-demand basis and a node only creates and maintains routes that it really needs. This on-demand approach potentially leads to an increase in traffic exchange delay. To cope with this, AODV introduces a local connectivity management mechanism, namely periodic Hello message broadcasts to collect information of topology changes in a timely fashion. Although this mechanism helps the protocol to react quickly to changes in routes, it has negative affects on network congestion and battery lifetime because it inevitably increases the routing load of the network.

How to reduce the amount of Hello messages is an interesting issue. An AODV improvement protocol with the Hello message mechanism is presented in which the function of the Hello message is expanded to all the transmission procedures of data service and management information[3]. In other words, any transmission procedure of packets including RREQ, RREP, RERR and data packets, can be regarded as an advertisement of the presence of the transmitting node. Intuitively, this improvement can greatly reduce the amount of Hello messages in scenarios with heavy traffic load, because, in this case, a great amount of data packets act as the role of Hello messages, and a Hello message is needed only when the interval period between two packets is longer than the preconfigured Hello Interval. However, in scenarios with light traffic load, there are still a large number of periodic Hello messages generated to perform connectivity management.

2.1 Concept of dynamically adjusting Hello Interval

As described above, AODV introduces a periodic Hello message broadcast mechanism to perform local connectivity management. In fact, the essence of this mechanism is to maintain a local connectivity map which is periodically updated to monitor the actual state of wireless links between a node and all its neighbors. Fig. 1 shows two typical local connectivity maps of node *I*. It is obvious that in the left map, neighboring nodes far away from *I* are more likely to move out of the radio coverage range, while in the right one, because those neighbors are very close to *I*, the corresponding links may remain available for relatively long periods. So it can be concluded that the right local connectivity map is stabler than the left one. Therefore, when the local connectivity map of node *I* is in a relatively stable state, Hello messages should be broadcasted with relatively long intervals. Otherwise, node *I* should broadcast Hello messages with relatively short intervals so as to react rapidly to possible link breakages. If we introduce the concept of dynamically adjusting Hello Interval according to the current distribution state of the network to each node, the amount of Hello messages is expected to be further reduced because unnecessary Hello messages are avoided when the local connectivity map of the considered node is in a stable state.

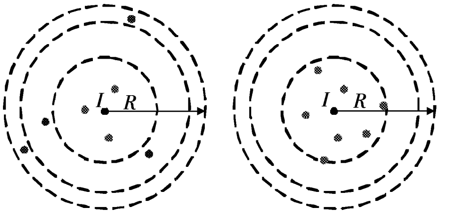

Fig. 1 Local connectivity maps of *I*

2.2 Prediction of lifetime period of wireless links

In order to implement this concept in AODV, a link availability prediction model should be used to predict the lifetime period of wireless links based on which Hello interval can be dynamically updated. In recent years, with the rapid development of global positioning system (GPS) technology, designing routing protocols for MANETs with the aid of GPS has become a hot research topic. Similarly, we can also use the position information provided by GPS to predict the lifetime period of wireless links.

For simplicity of analysis, here we assume a line-of-sight (LOS) propagation model in which the path loss of signal transmission is determined by

$$L_s = L_O + (\gamma_o + \gamma_w)d, \quad L_f = 32.44 + 20\lg d + 20\lg f \tag{1}$$

where L_f is the path loss in free-space propagation[4]; d is the transmission range; f is the central wavelength of the signal; γ_o and γ_w are the absorption coefficients of oxygen and water vapor, respectively. Once a packet is received, the distance between the sender and the receiver, and the path loss can be easily calculated according to the location information included in the packet and its received radio signal strength. Then we can determine the value of $\gamma_o + \gamma_w$ according to Eq. (1). Note that since γ_o and γ_w are usually regarded as constant values in a given LOS environment, $\gamma_o + \gamma_w$ only needs to be calculated once. Then for given transmission power P_{tx} and receiving power threshold P_{rx}, the effective radio transmission range d is given by

$$20\lg d + (\gamma_o + \gamma_w) d = P_{tx} - P_{rx} - 20\lg f - 32.44 \quad (2)$$

From Eq. (2), we find that the path loss solely depends on the distance to the transmitter in an LOS environment. If the distance between two nodes is no more than the effective radio transmission range, we can say that the corresponding wireless link is available. Now we consider a simple scenario with two moving nodes, A and B, as illustrated in Fig. 2. With the help of GPS, both the nodes can acquire their position information of location, moving speed and direction periodically. Then the lifetime period of the link between A and B is given by[5]

$$T'_L(B, A) = \frac{-(ab+cd) + \sqrt{(a^2+c^2)R^2 - (ad-bc)^2}}{a^2+b^2} \quad (3)$$

where $a = v_i\cos\theta_i - v_j\cos\theta_j$, $b = x_i - x_j$, $c = v_i\sin\theta_i - v_j\sin\theta_j$, $d = y_i - y_j$, and R is the effective radio transmission range determined by Eq. (2).

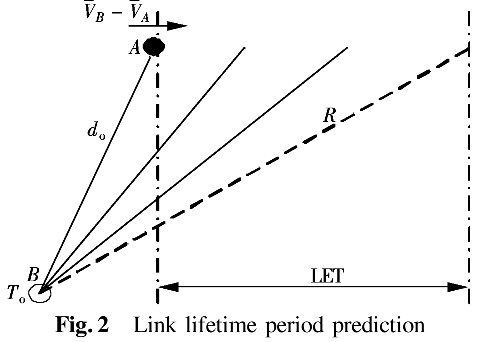

Fig. 2 Link lifetime period prediction

2.3 Link availability prediction based AODV

For a considered node, if the Hello Interval is selected according to Eq. (3), it is sure that the corresponding wireless link between the two nodes will not break due to node movements. Nevertheless, the interval between two Hello messages should not be very long. Otherwise, the protocol cannot respond quickly in the case of node power off or its moving into the coverage of unknown nodes. So the lifetime period of the wireless link between two nodes can be selected according to the following subsection function:

$$T_L(i,j) = \begin{cases} 1 & T'_L(i,j) < 1 \\ T'_L(i,j) & 1 \leqslant T'_L(i,j) \leqslant T_{th} \\ T_{th} & T'_L(i,j) > T_{th} \end{cases} \quad (4)$$

where T_{th} is the upper limit of the Hello message broadcast interval. Intuitively, the period of the Hello message broadcast is mainly determined by the link with the shortest lifetime period. So, we propose a simple model to determine the Hello Interval for a considered node i:

$$T_h(i) = \min\{T_L(i,j)\} \qquad j \in N_i \quad (5)$$

where N_i is the neighbor set of node i.

In order to implement the link availability prediction based Hello message mechanism in AODV, some modifications must be added to the standard AODV routing protocol. The pseudo-code of modifications to standard AODV routing protocol is illustrated as follows:

```
Hello Interval initialization in current node i:
{Set the Hello timer Th(i) to expire after current time plus Tth to schedule the first Hello broadcast event}
Wait until an event interrupt occurs:
if (EVENT_INTRPT_TYPE = = HELLO_TIMER_EXPIRE)
{Schedule another Hello broadcast event by resetting Th(i) to expire after current time plus Tth}
elseif (EVENT_INTRPT_TYPE = = PK_ARVL_FROM_MAC)/* A packet arrives from MAC layer. */
{Get the position information of neighboring node j from the received packet;
Calculate TL(i,j)—the lifetime period of the link between i and the neighbor j according to Eq. (4);
/* Resetting Th(i) timer to TL(i,j) if the latter is less than the period of current Th(i) timer expires. */
if (TL(i,j) < Th(i))
Th(i) = TL(i,j);
Func. Packet_Process (PK_ARVL_FROM_MAC);/* Processing the packet received */
}
elseif (EVENT_INTRPT_TYPE = = PK_ARVL_FROM_APPL)/* A packet arrives from MAC layer. */
{Func. Packet_Process (PK_ARVL_FROM_APPL);
Schedule another Hello broadcast event by resetting Th(i) to expire after current time plus Tth}
else return;
```

3 Simulation Model and Results

In this section, a series of simulation experiments in an OPNET[6] network simulator are conducted to perform an evaluation analysis on the performance ability of AODV with the three discussed mechanisms, namely periodic Hello message based (SAODV), the function expanded Hello message based (EAODV), and the link availability prediction based (PAODV).

3.1 Simulated network scenario and model

All simulations are conducted for 50 s of simulation time in a network scenario with 30 nodes uniformly distributed in an area of 1 500 m × 1 500 m. Each node moves within the area, with a random direction and a random velocity uniformly distributed between 0 and a maximum value of 10 m/s. And for simplicity, the parameter T_{th} is set to 4 s in our simulations.

As the IEEE 802.11 standard is widely used in test beds and simulation platforms, the distributed coordination function (DCF) of IEEE 802.11 is used as the MAC layer protocol in our simulations. The PHY model is modeled as a shared-media radio with a rate of 1

Mbit/s and a radio transmission range of 300 m. Finally, the background traffic is modeled by 30 source nodes generating packets with inter-arrival times uniformly distributed between 0 and a maximum value of 8. 0 s, and the packet size is 256 bytes.

Two important performance metrics, namely average end-to-end delay (latency) and normalized routing protocol efficiency are chosen to assess the improved AODV protocol. Latency includes all possible delays introduced when sending a packet from the source to the destination. While normalized routing protocol efficiency is defined as the amount of data traffic generated (in bits) per total traffic delivered (in bits), including data traffic and control traffic messages (RREQ, RREP, RERR and Hello).

3. 2 Simulation results and technical analysis

This subsection presents the simulation results and analysis of the relative performance of AODV with the three mechanisms discussed above.

Fig. 3 shows the relative latency performance of the three different versions of AODV. From this figure, we can see that PAODV gives the best latency performance, followed by EAODV and SAODV. It is because PAODV further reduces routing overhead and performs the local connectivity management in a more efficient way, compared to its counterparts.

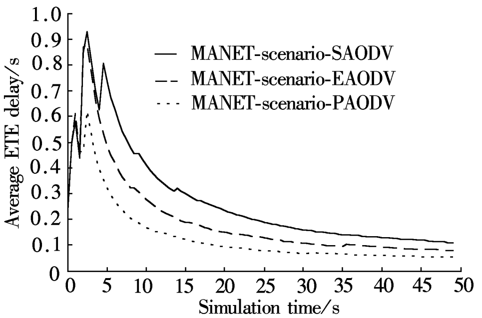

Fig. 3 Variation in average end-to-end delay

Fig. 4 shows the variation in the normalized routing protocol efficiency of AODV with the three different mechanisms, respectively. We observe that, PAODV has the best protocol efficiency performance, while SAODV has the worst, followed by EAODV. It can be explained by the fact that the periodic Hello message broadcast in SAODV considerably increases the routing load in the network, and thus severely degrades the protocol efficiency. EAODV expands the function of the Hello message to all the transmission procedures of data service and management information, so the routing load is greatly decreased. In PAODV, a link availability prediction algorithm is added to AODV to predict the lifetime period of a wireless link based on which a Hello period can be dynamically selected, so the routing load is further decreased, thus resulting in higher protocol efficiency.

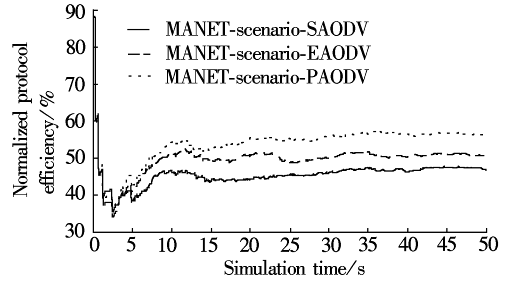

Fig. 4 Variation in normalized protocol efficiency

Fig. 5 shows the variation of protocol efficiency performance of AODV with three different mechanisms when the average packet generating interval ranges from 0. 25 to 4. 0 s. We find that when the packet generating interval is large, which means low data packet generating rate, EAODV gives a slightly better routing efficiency performance than SAODV. It is because, in this case, only a few data packets are generated to act in the role of Hello messages. When the packet intertime is small, which means a high data packet generating rate, EAODV and PAODV give an almost similar performance in terms of protocol efficiency. It is because frequent data packet transmission procedures lead to a large number of Hello messages being reduced, and the link availability prediction mechanism can hardly further reduce the Hello messages.

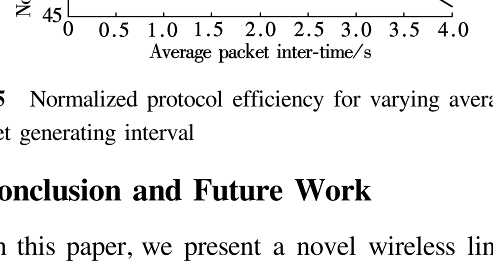

Fig. 5 Normalized protocol efficiency for varying average packet generating interval

4 Conclusion and Future Work

In this paper, we present a novel wireless link availability prediction algorithm based on which Hello Interval can be dynamically adjusted to further reduce unnecessary Hello messages in AODV. It is noted that this algorithm is proposed under an LOS propagation environment, while in a typical wireless environment where the transmitted signal over the wireless channel is subject to multi-path fading, signal attenuation can be modeled as a stochastic process, which determines the complexity of link availability prediction. At present, how to predict the life-time of a wireless link under such a realistic environment is still a very difficult problem, and has not been well addressed. However, our work figures out a novel way to improve the efficiency of routing protocols for MANETs. How to provide a simple, efficient and economic way to make prediction in the context of typical wireless channels is still a challenge, and should be deeply studied in the future.

References

[1] Macker P, Corson M S. Mobile ad hoc networking and the IETF [J]. *Mobile Computing and Communications Review*, 1999, **3**(1): 11 − 13.

[2] Perkins C E, Royer E, Das S. RFC 3561 Ad hoc on-demand distance vector routing [S]. IETF Mobile Ad Hoc Networks Working Group, 2003.

[3] Chen Xiaoshu, Li Xia. Improved high efficiency AODV routing protocol for ad hoc networks [J]. *Journal of Southeast University*: *Natural Science Edition*, 2003, **33**(2): 127 − 130. (in Chinese)

[4] Rappaport T S. *Wireless communications*: *principles and practice*[M]. Prentice Hall, 1995.

[5] Lee S J, Su W, Geral M. Ad hoc wireless networks with mobility prediction [C]//*Proc of IEEE ICCCN'* 99. Boston, MA, 1999: 4 − 9.

[6] OPNET. MIL 3 Inc (university program) [EB/OL]. (2006-01-10) [2006-11-04]. http://www.opnet.com.

MANETs 中基于链路有效性预测的高效 AODV 路由协议

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摘要:针对传统 AODV 路由协议中周期性 Hello 消息广播机制会造成协议效率低下的问题,提出了一种利用无线链路有效性预测来降低 Hello 控制报文的新策略. 首先给出了适用于视距无线传输环境下新的链路有效性预测模型,根据此模型所预测的无线链路生命周期来动态更新 AODV 路由协议中的 Hello Interval 配置参数,从而实现在不同链路稳定性下以不同频率广播 Hello 消息的目的. 仿真结果表明,相比于采用周期性 Hello 消息广播机制的原协议而言,改进协议有效减少了不必要的报文开销,并在平均端到端时延和协议效率这 2 个性能指标上都获得了明显改善.

关键词: Hello 消息;链路有效性;AODV;路由协议;ad hoc

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