6V-2 Loop-Based Source Routing Protocol for Mobile Ad-hoc Networks *

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1 Introduction

Recently, mobile computers have become widely available. In an ad-hoc network, there is no base station and only mobile computers are connected to the network. Due to a bounded transmission range of a mobile computer m, m does not always exchange a message directly with another mobile computer m'. Thus, all mobile computers are engaged in routing of a message and multi-hop transmission is required to exchange a message between m and m'. Here, a routing protocol for supporting mobility of computers is required. That is, a mobile computer is required to serve a role of a router. Since not only m and m' but also intermediate mobile computers change locations, a routing protocol has to achieve a currently available route.

Until now, many kinds of ad-hoc routing protocols have been proposed such as AODV and DSDV. In these protocols, it is assumed that a message transmission range of mobile computers are the same and stable. That is, most of communication links are bi-directional and uni-directional links are omitted in these routing protocols. However, due to limited battery capacity, transmission power of mobile computers is not the same and changes. Hence, it is required for multi-hop transmission to detect a route including uni-directional links for achieving higher probability to detect a route. Though DSR (Dynamic Source Routing) [1] has this property, the protocol uses two independent floodings and communication overhead is high.

This paper proposes a novel ad-hoc routing protocol by which looped routes including a source mobile computer are detected and detection of target route is achieved by combination of a single flooding and multiple unicast message transmissions.

2 Ad-hoc Routing Protocols

A mobile ad-hoc network $\mathcal{N} = \langle \mathcal{V}, \mathcal{L} \rangle$ is composed of a set $\mathcal{V} = \{M_1, \ldots, M_m\}$ of mobile computers and a set $\mathcal{L} \subseteq \mathcal{V}^2$ of communication links. A communication link $\langle M_i, M_j \rangle$ is uni-directional. Some of conventional ad-hoc routing protocols are based on an assumption that all available links are bi-directional, i.e. mobile computers M_i and M_j directly exchange messages only if $\langle M_i, M_j \rangle \in \mathcal{L}$ and $\langle M_j, M_i \rangle \in \mathcal{L}$ are satisfied. AODV is such a kind of protocol. Here, if a destination mobile computer D gets a route $R_{S\to D}$, D also finds a reverse route $R_{D\to S}$ is available. Hence, by transmitting a message including $R_{S\to D}$ through $R_{D\to S}$, S achieves $R_{S\to D}$ and start to transmit application messages through $R_{S\to D}$. However, probability that $R_{S\to D}$ is detected is low. On the other hand, the other protocols are based on an assumption that a transmission range of a mobile computer is not the same and changes. Here, even if a destination mobile computer D finds a transmission route $R_{S\to D}$, $R_{D\to S}$ is needed to transmit $R_{S\to D}$ to S.

In most of on-demand routing protocols, *flooding* is used to detect a transmission route from a source mobile computer S to a destination mobile computer D. Most of wireless communication media on which wireless LAN protocols depend is broadcast-based. A message broadcasted by a mobile computer M is received by all mobile computers within a transmission range of M. Suppose that a mobile computer S broadcasts a message mes to all mobile computers in a transmission range of S. If each mobile computer M_i which receives mes broadcasts mes to all mobile computers in a transmission range of M_i, all mobile computers with which S communicates by multi-hop message transmission receive mes. In DSR, in order to find a route from S to D, *Rreq* message is transmitted by flooding. In addition, in order to inform the detected route of S, *Rrep* message is also transmitted by flooding.

3 LBSR protocol

In an ad-hoc network including only bi-directional communication links, by detection of $R_{S\to D}$, $R_{D\to S}$ is achieved as a reverse route of $R_{S\to D}$. However, for achieving higher probability of success of detecting a transmission route between S and D, uni-directional communication links are also used to transmit messages. In DSR as discussed in the previous section, $R_{S\to D}$ and $R_{D\to S}$ are detected independently. In LBSR, S detects a looped route $R_{S\to D} + R_{D\to S}$ containing both S and D. While detecting the looped route, S finds other looped routes which contain not D but S. These routes are used to transmit *Lreq* message back to S with unicast transmission to reduce communication overhead caused by broadcast transmissions.

1. A source mobile computer S broadcasts an *Lreq* message where $Lreq.seq \leftarrow \langle S \rangle$ to all mobile computers M_i within a transmission range of S.
2. On receipt of an *Lreq* message, a mobile computer M_i ($\neq S$) processes the message as follows:
   - If $stop\_flag_i = true$, M_i discards the *Lreq* message.
   - If $M_i = D$ and $req\_flag = true$, M_i discards the *Lreq* message.
   - If $req\_flag_i = false$ and $stop\_flag_i = false$, $req\_flag_i \leftarrow true$ and M_i broadcasts the *Lreq* message to all mobile computers within a transmission range of M_i after appending an address of M_i to the end of $Lreq.seq$.
   - If $req\_flag_i = true$ and $stop\_flag_i = false$,
     - if $next_i = null$, M_i suspends the processing for the *Lreq* message. On receipt of an *Lconf* message, i.e., on storing an address to $next_i$, M_i resumes the processing from the beginning of step 2.
     - otherwise, i.e., an address has been stored in $next_i$, M_i appends M_i to the end of $Lreq.seq$ and transmits the *Lreq* message to a mobile computer whose address is $next_i$.
3. On receipt of an *Lconf* message, a mobile computer M_i ($\neq S$) processes the message as follows:
   - If $next_i = null$, M_i stores an address which is just after an address of M_i in $Lconf.seq$ and a number of addresses after an address of M_i in $Lconf.seq$ into $next_i$ and $hops_i$, respectively, and transmits the *Lconf* message to a mobile computer whose address is just after an address of M_i in $Lconf.seq$.
   - Otherwise, i.e., an address has been stored in $next_i$,
     - if $hops_i$ is larger than a number of addresses after an address of M_i in $Lconf.seq$, M_i stores an address which is just after an address of M_i in $Lconf.seq$ and a number of addresses after an address of M_i in $Lconf.seq$ into $next_i$ and $hops_i$,

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respectively, and transmits the *Lconf* message to a mobile computer whose address is just after an address of M_i in $Lconf.seq$.
  - otherwise, M_i transmits the *Lconf* message to a mobile computer whose address is just after an address of M_i in $Lconf.seq$.
4. On receipt of an *Lstop* message, a mobile computer M_i ($\neq S$) sets *stop_flag* as $true$.
5. On receipt of an *Lreq* message, a source mobile computer S appends an address of S to the end of $Lreq.seq$ and processes the message as follows:
   - If $detect\_flag = false$,
     - if an address of a destination mobile computer D is included in $Lreq.seq$, S sets *detect_flag* as $true$ and transmits an *Lconf* message where $Lconf.seq \leftarrow Lreq.seq$ to a mobile computer whose address is just after an address of S in $Lconf.seq$.
     - otherwise, S transmits an *Lconf* message where $Lconf.seq \leftarrow Lreq.seq$ to a mobile computer whose address is just after an address of M_i in $Lconf.seq$.
   - Otherwise, S transmits an *Lstop* message where $Lstop.seq \leftarrow Lreq.seq$ to a mobile computer whose address is just after an address of M_i in $Lconf.seq$.

□

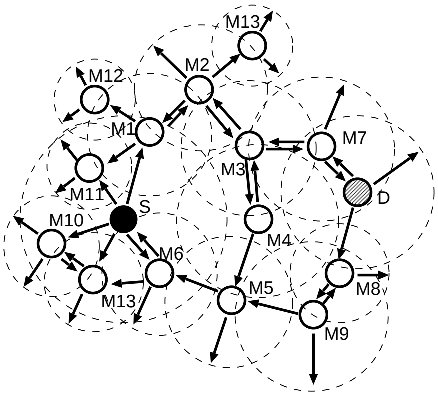

Figure 1: Flooding of Lreq in LBSR.

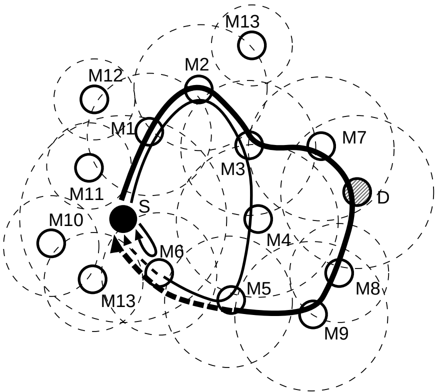

Figure 2: Unicasting of Lconf in LBSR.

4 Evaluation

For detection of a transmission route from S to D in DSR, two independent floodings are required. In a single flooding, messages are transmitted through all the communication links. Therefore, the maximum number of required messages is the same as the number of links $|\mathcal{L}|$. Hence, the maximum total number of messages is $2|\mathcal{L}|$. On the other hand, in LBSR, a single flooding and a number of unicast messages for transmitting *Lconf* messages are required. Let l_i be a number of mobile computers included in the ith loop route. Thus, the total number of messages in LBSR is $|\mathcal{L}| + \sum l_i$.

Figures 3 and 4 shows a simulation results. Here, a simulation area is 500m × 500m and a distribution of diameter of a wireless transmission range is uniform between 20m and 200m. As show in Figure 3, the number of broadcast messages in LBSR is half of that in DSR. Figure 4 shows total numbers of messages. In LBSR, many unicast messages, i.e. Lconf messages, are transmitted. Especially, through a wireless communication link near S, an Lconf message is transmitted each time a looped route containing the link is detected.

However, by the procedure of route detection, S detects a route for every destination mobile computer which is reachable from S by multi-hop transmission by using LBSR though only a route between S and D is detected in DSR. Hence, if S transmits messages to n destinations between two successive procedures of LBSR route detection, only $1/n$ overhead is required.

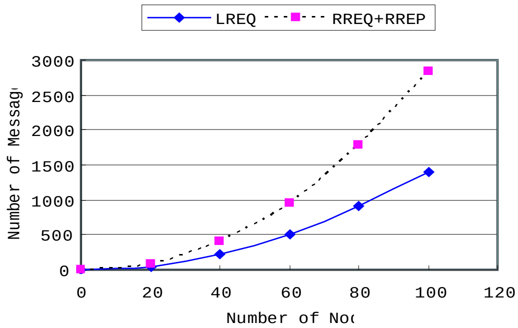

Figure 3: Number of Broadcast Messages.

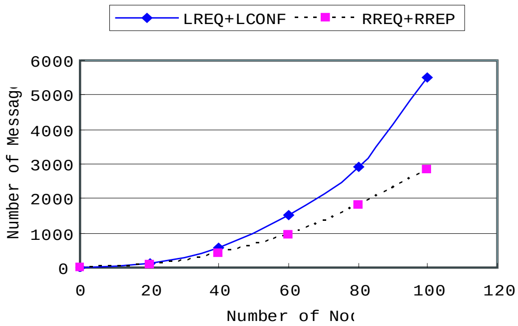

Figure 4: Number of Messages.

5 Concluding Remarks

This paper has proposed a novel ad-hoc routing protocol LBSR in which looped routes are detected to get a route from a source mobile computer to a destination one and to reduce communication overhead caused by broadcast message transmission. Here, a single flooding and unicast message transmission are used instead that two flooding are used in DSR. In future work, the authors will evaluate the performance of LBSR in simulation and a prototype system.

References

[1] David, B., David, A., Hu, Y.C., Jorjeta, G. and Jetcheva, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks," Internet Draft, draft-ietf-manet-dsr-07.txt (2002).