Bulletin of Networking, Computing, Systems, and Software – www.bncss.org, ISSN 2186-5140
Volume 6, Number 1, pages 5–7, January 2017

Dynamic Temperature Aware Routing Protocol over Ad hoc Networks at Fire Sites

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***Abstract*—In this paper, we present the issue of exploiting the temperature aware routing protocol which is widely used for especially high temperature environments such as fire and disaster sites. Since the highly tempered atmosphere by the fire makes it difficult to provide reliable packet transmissions and routing path, we propose a novel routing protocol, called DTAR (Dynamic Temperature Aware Routing), which monitors the current temperature of each node to identify its own temperature and melt-down symptom according to the predefined threshold value, and then dynamically performs route discovery procedure for avoiding the heated route. This new protocol is highly compatible with any conventional on-demand based routing policy. We also expect that the proposed protocol is suitable for mitigating the wireless link failures in fire sites thanks to the reliable route discovery.**

Keywords—Mobile Ad Hoc Network; High Temperature; Routing Protocol; Fire Sites

I. INTRODUCTION

Recently, thanks to the advancement of IoT (Internet of Things) technology, various intelligent devices and mobile terminals can be connected to one another by using wireless medium. In particular, the Mobile Ad hoc Network (MANET) [1] technology provides self-organized networking services by the fact that it does not rely on a pre-existing infrastructure, such as gateways in wired networks or APs (Access Points) in managed (infrastructure) wireless networks. Instead, every wireless node of MANET participates in routing process by forwarding data for neighbor nodes, so the determination of which nodes forward data is made dynamically according to network connectivity and topology. In this network, the nodes are highly free to move and can create and join networks anywhere and anytime. There are numerous service opportunities for exploiting MANETs in a wide range of military, security, healthcare and etc. In addition, disaster response service is also one of major fields for adopting MANETs because each mobile node can keep the end-to-end connectivity even in extreme conditions such as collapse and fire occurrence.

Despite the promising applications for MANETs, when the WSN is deployed at fire sites, the mobile devices and radio antenna can be easily melted down due to high temperature caused by fire. Although there are many kinds of network protocols to support ad hoc networks, the conventional on demand (reactive) routing protocols such as AODV [2] and DSR [3] do not consider the high temperature atmosphere and related physical failures. They merely provide the shortest routing path and its network connectivity regarding efficiency only. Furthermore, when the particular data traffic is concentrated on a certain intermediate node which is located in shortest path to the destination node under extreme high temperature caused by fire, the radio antenna or internal circuit are burned down and then, the wireless link will be disconnected. This unexpected link failure also causes long end-to-end delay and severe packet losses. Finally, such performance degradations will prevent suitable disaster prevention and response activities at fire sites. In order to resolve the aforementioned problem, a lot of the state of the art protocols such as TARA [4], LTR [5], ALTR [6], LTRT [7], TSHR [8] are proposed. However, these protocols are based on the table driven (pro-active) routing scheme, which is not suitable for disaster environments where the network topology is constantly and dynamically changing. Hence, in this paper, we propose a new Dynamic Temperature Aware Routing protocol (DTAR) based on reactive scheme to avoid the highly heated areas during the routing process.

II. PROPOSED PROTOCOL

In this section, we introduce the detailed operations of the proposed scheme, named DTAR, to explore high temperature problems during the routing process in ad hoc networks at fire sites. In order to provide the best performance of proposed protocol, DTAR basically assumes following preconditions. First, all wireless nodes are equipped with identical Radio Frequency (RF) specifications and routing algorithm to transmit and receive the data packet in same ad hoc network. Second, all nodes are equipped with temperature sensor to measure the current temperature of current spot. Third, all nodes use on-demand routing scheme such as DSR and AODV where each node exchanges RREQ (Route Request), RREP (Route Reply), and RERR (Route Error) control packets for establishment and maintenance of routing path.

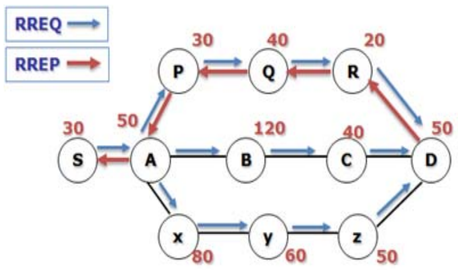

Fig. 1. Route Discovery Procedure of DTAR

In route discovery procedure of DTAR, the source node S generates and broadcasts the RREQ packet to its neighbor nodes in order to find a fresh route for destination. This RREQ contains the current temperature value of node S. Although the temperature unit or format are various (e.g. Celsius and Fahrenheit), DTAR assumes that all participating nodes use an identical unit. In addition, the temperature value can be measured either from atmosphere or radiant heat by fire. That is, the obtained value is calculated either external temperature or direct contact heat. In general, since most device failures and malfunctions are caused by radiant heat, DTAR assumes that all nodes measure this radiant heat at the fire site. The measured temperature values are shown in figure 1. In case of source node S, its temperature is 30 degree. When an intermediate node receives the RREQ packet, it sums and attaches its own temperature information, then rebroadcasts the RREQ packet to neighbor nodes until the destination node receives it. In figure 1, when node A receives RREQ from node S, it attaches the value of 80 degree (add 30 to 50) to RREQ. When the destination receives the RREQ packet by iterating rebroadcast operations, the destination chooses the lowest total temperature value. Then, it immediately transmits a RREP packet to the source node by using unicast scheme. If the source node receives this RREP, it starts to transmit its data packets to the destination node. Figure 1 describes the entire route discovery procedure between source node and destination node. Note that the broadcasted RREQ packets are delivered to destination node D along the three separate routes. At this time, the destination node chooses the route of S-A-P-Q-R-D where the total temperature value is 220 degree, while the values of route S-A-B-C-D and S-A-X-Y-Z-D are 290 and 320, respectively. Hence, the source node transmits its data packets more reliably by avoiding the most heated route.

It is important to note that if a specific node has extremely high temperature even though the total value of the route is small, the node will be broken down shortly. In this case, such highly heated node should be excluded from the routing path. Otherwise, the route will be also broken because of the node's failure. In order to tackle this problem, DTAR defines two kinds of threshold values, which are TH_{max_temp} and TH_{time}. TH_{max_temp} denotes the maximum threshold temperature and TH_{time} denotes the duration time threshold. When the node's temperature is increased to the maximum threshold and its value is persisted for threshold time, the node is excluded from the routing path. For this, the intermediate node simply drops the RREQ packets or the destination node deliberately excludes the route from candidates. Finally, the destination node chooses another route which is more safe from link failures. In order to determine the optimal value of each threshold, the sensor device shall consider its thermal resistance and hardware material, which is quite variable with the target environments. Thus, the most simple approach is to consider the general thermal resistance value of the electric circuit, which is approximately 80 Celsius.

Meanwhile, another important issue of the proposed protocol is that DTAR does not allow intermediate nodes to transmit their RREPs regarding their own route caches since all RREQ packets carrying the accumulated temperature values need to be delivered to the destination node.

For verification of the performance of the proposed protocol, we have conducted extended simulation via NS2 [9] and compared the temperature results with conventional On-demand protocol based on minimum hop routing policy. The compared result is shown in figure 2.

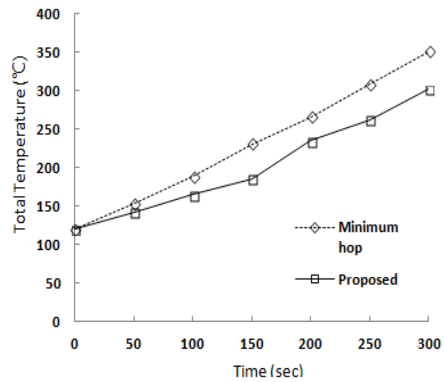

Fig. 2. Performance comparision between DTAR and legacy protocol

According to figure 2, as the time goes on, the proposed protocol can avoid the heated route and keep a lower-thermospheric communication rather than legacy protocol with minimum hop policy. Thus, we expect that DTAR surely provides more reliable networking service at real fire sites.

III. CONCLUSION

In this paper, we present a temperature aware routing protocol called DTAR over mobile ad hoc networks especially at fire sites where the wireless communication tends to be failed due to high heat. To do this end, DTAR periodically monitors its temperature and defines temperature threshold value. Then, if the node wishes to transmit a data packet, it dynamically performs the route discovery procedure by using RREQ and RREP packets. Finally, the source node establishes a reliable routing path which can avoid the most heated node and path. For future works, we plan to develop a real test-bed equipment to perform a field test at real fire sites.

ACKNOWLEDGMENT

This research was supported by the Fire Fighting Safety & 119 Rescue Technology Research and Development Program funded by the Ministry of Public Safety and Security of Korea (NEMA-Next Generation-2014-58). It also supported by the DGIST R&D Program of the Ministry of Science, ICT and Future Planning (16-IT-02).

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