View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Proceedings of the Asia-Pacific Advanced Network

Proceedings of the Asia-Pacific Advanced Network 2013 v. 36, p. 65-73.
http://dx.doi.org/10.7125/APAN.36.9
ISSN 2227-3026

Path Recovery in 6LoWPAN Routing Protocol

Gee Keng Ee, Chee Kyun Ng*, Nor Kamariah Noordin, Fazirulhisyam Hashim and Borhanuddin Mohd Ali

Department of Computer and Communication Systems Engineering, Faculty of Engineering, Universiti Putra Malaysia, UPM Serdang, 43400 Selangor, Malaysia.

E-Mails: darrow_keng@yahoo.com, {mpnck, nknordin, fazirul, borhan}@eng.upm.edu.my

---

Abstract: 6LoWPAN has become a new technology to provide the Internet connectivity to the traditional wireless sensor network (WSN). In order to route the delivered packet from originator to destination nodes, the simplified Ad-hoc On-Demand Distance Vector (AODV) routing protocol for 6LoWPAN with 6LoWPAN Ad-Hoc On-Demand Distance Vector Routing (LOAD) has been introduced. However, the conceptual LOAD routing protocol has yet proposed any path recovery mechanism in 6LoWPAN. In this paper, an originator recognition (OR) path recovery mechanism is proposed for the 6LoWPAN LOAD-based routing protocol. In this proposed mechanism, the participated nodes will memorize the originator address attached within data packet during the data transmission. When a link break happens on destination path, the LOAD protocol message will be amended by inserting an identity key, which is a memorial of originator address, in the generated route error (RERR) message before transmitted towards the originator for the failure notification. This identity key is then used by the originator to initialize path recovery in order to retransmit the failed data packet to the unreachable destination node. Instead of using MAC address in the LOAD routing protocol, IP address is used in the proposed Originator Recognition (OR) path recovery mechanism (OR-LOAD) routing protocol which is designed for the global routing. The proposed OR-LOAD routing protocol has been examined under noisy 6LoWPAN environment in Qualnet simulator. Its performance is then evaluated and compared to AODV routing protocol in terms of packet delivery ratio and average energy consumption. The simulation results show that the proposed OR-LOAD outperforms AODV with packet delivery ratio of 19.4%, and with comparable average energy consumption in both routing protocols.

Keywords: Path recovery; 6LoWPAN; AODV; LOAD; RERR; Qualnet simulator.

---

1. Introduction

Internet protocol version 6 (IPv6) over low power wireless personal area network (6LoWPAN) has been defined by Internet Engineering Task Force (IETF) as a technique to deploy the Transmission Control Protocol and Internet Protocol (TCP/IP) protocol into wireless sensor network (WSN) [1]. Thus, 6LoWPAN enables IPv6 connectivity over the IEEE 802.15.4 standard compliant devices by introducing an adaptation layer between the network and MAC layers. This adaptation layer performs header compression, packet fragmentation and reassembly functions to succeed the delivery of IPv6 packet from the network layer to the MAC layer [2]. As 6LoWPAN adaptation layer focuses on enabling the IPv6 packet, routing issue has become one of the main research topics in 6LoWPAN.

A routing protocol defines the mechanism to route a data packet from source node (also known as originator) to destination node. There are two routing schemes in 6LoWPAN such as mesh-under and route-over. The mesh-under approach uses either 16-bits or 64-bits MAC address to perform non-IP routing within LoWPAN, while the route-over approach uses IP address to perform IP routing within or outside the LoWPAN. Currently, there are two IETF working groups working for the 6LoWPAN routing protocol, Routing Over Low-power and Lossy networks (ROLL) [3] and Mobile Ad hoc Network (MANET) [4]. ROLL introduces the IPv6 Routing Protocol for Low-power and Lossy networks (RPL) [5] for route-over routing protocol in 6LoWPAN. The RPL uses the directed acyclic graphs (DAGs) to perform IPv6 forwarding mechanism among routers, hosts and edge routers [6]. Instead of creating a new 6LoWPAN routing protocol as is done by ROLL, MANET has proposed to simplify the existing IETF routing protocols for 6LoWPAN [7].

The Ad-hoc On-Demand Distance Vector (AODV) [8] routing protocol is widely used in MANET. Due to its low routing overhead, AODV routing protocol is considered as a strong candidate for 6LoWPAN. This routing protocol has been suggested to support the network mobility of sensor network in 6LoWPAN. A survey, which has been conducted by ROLL working group, shows the AODV routing protocol should be used without fragmentation in 6LoWPAN. Unfortunately, it is impossible to use the existing AODV routing protocol without modification [9]. Some simplification has been suggested in AODV routing protocol for 6LoWPAN such that only route request (RREQ) and route reply (RREP) control messages are used during the AODV routing [10]. This simplified and modified version of AODV routing protocol is named as 6LoWPAN Ad-Hoc On-Demand Distance Vector Routing (LOAD) routing protocol [11]. LOAD routing protocol is a reactive routing protocol which uses MAC addresses to route the data packet from originator to destination node. It has proposed to use RREQ and RREP messages for the route discovery, and exploits the route error (RERR) message for path recovery when a link break happens during the data transmission. Nevertheless, none of the research work has been proposed for path recovery mechanism in the LOAD routing protocol.

Previously when a link break happens in the original AODV routing protocol, precursor list in the routing table is used to forward the RERR message in order to notify the originator about the link failure. The originator will then initialize a path recovery mechanism to find an alternative path to the unreachable destination node [8]. However, in the conceptual LOAD routing protocol, there is no precursor list in its routing table. In the case of link failure, the RERR message is sent to previous nodes towards the originator because it is assumed to contain the originator address. Since the RERR message does not contain the originator address in the conceptual LOAD routing protocol, it cannot report the originator without precursor list as in AODV routing protocol. Thus, the originator is not able to find an alternative path to the currently unreachable destination. Moreover, it may keep sending the packets without realizing packets have been dropped. This situation will degrade the performance of LOAD routing protocol. Furthermore, by using MAC addresses to support mesh-under routing scheme in 6LoWPAN as proposed in the conceptual LOAD routing protocol [11], it will limit the packet routing within the LoWPAN only, and thus scales down the range of packet route. The packet can only be routed among the LoWPAN devices only.

In this paper, a new path recovery mechanism named as Originator Recognition (OR) path recovery mechanism is designed and developed for the conceptual LOAD routing protocol. The LOAD routing protocol with Originator Recognition path recovery mechanism (OR-LOAD) is proposed to be used for route-over instead of mesh-under as proposed in the conceptual LOAD routing protocol. There are three defined operation states in the proposed OR path recovery mechanism; memorizing state, encryption state and recognition state. During the memorizing state, the participating nodes will memorize the originator address of a forwarding data packet. When a link break happens during data transmission, the node that notifies broken link will initiate the encryption state in order to encrypt the memorized originator address in RERR message. This originator address is actually served as an identity key in the RERR message. The recognition state will be initialized during the RERR message forwarding. The involved nodes will identify the destination of received RERR message, where this destination is the originator of the failed data packet. After the originator receives the RERR message, it will stop sending the data packet to the unreachable destination node. Then, it will re-initialize a route discovery process in order to find a new path to the currently unreachable destination node.

The developed OR-LOAD routing protocol has been examined under noisy 6LoWPAN environment in Qualnet simulator. Its performances are evaluated and compared with AODV routing protocol in terms of packet delivery ratio and average energy consumption. The simulation results show that the proposed OR-LOAD routing protocol outperforms AODV routing protocol with packet delivery ratio of 19.4%, and with comparable average energy consumption in both routing protocols. It is because the OR path recovery mechanism in the OR-LOAD routing protocol lessens the packet loss which caused by irreparable broken link. Thus, it depicts the OR-LOAD routing protocol has a higher reliability than AODV routing protocol.

2. OR Path Recovery Mechanism in OR-LOAD Routing Protocol

Since the existing conceptual LOAD routing protocol fulfils the routing requirements, it is chosen as a candidate for 6LoWPAN routing protocol development. Originally, the conceptual LOAD routing protocol does not suggest any path recovery mechanism for a broken link during the data packet transmission. Thus, an OR path recovery mechanism is proposed to the conceptual LOAD routing protocol and has been named as OR-LOAD routing protocol. Unlike the conceptual LOAD routing protocol that only focus on the 6LoWPAN mesh-under routing, the proposed OR-LOAD routing protocol targets on the route-over routing to support both inter-PAN and intra-PAN routing. It replaces the existing link-layer addressing scheme of conceptual LOAD routing protocol with IP addressing scheme and has been developed at network layer. There are three operation states involved in the proposed OR path recovery mechanism; memorizing state, encapsulation state and recognition state. Figure 1 shows the operation of proposed OR path recovery mechanism in OR-LOAD routing protocol.

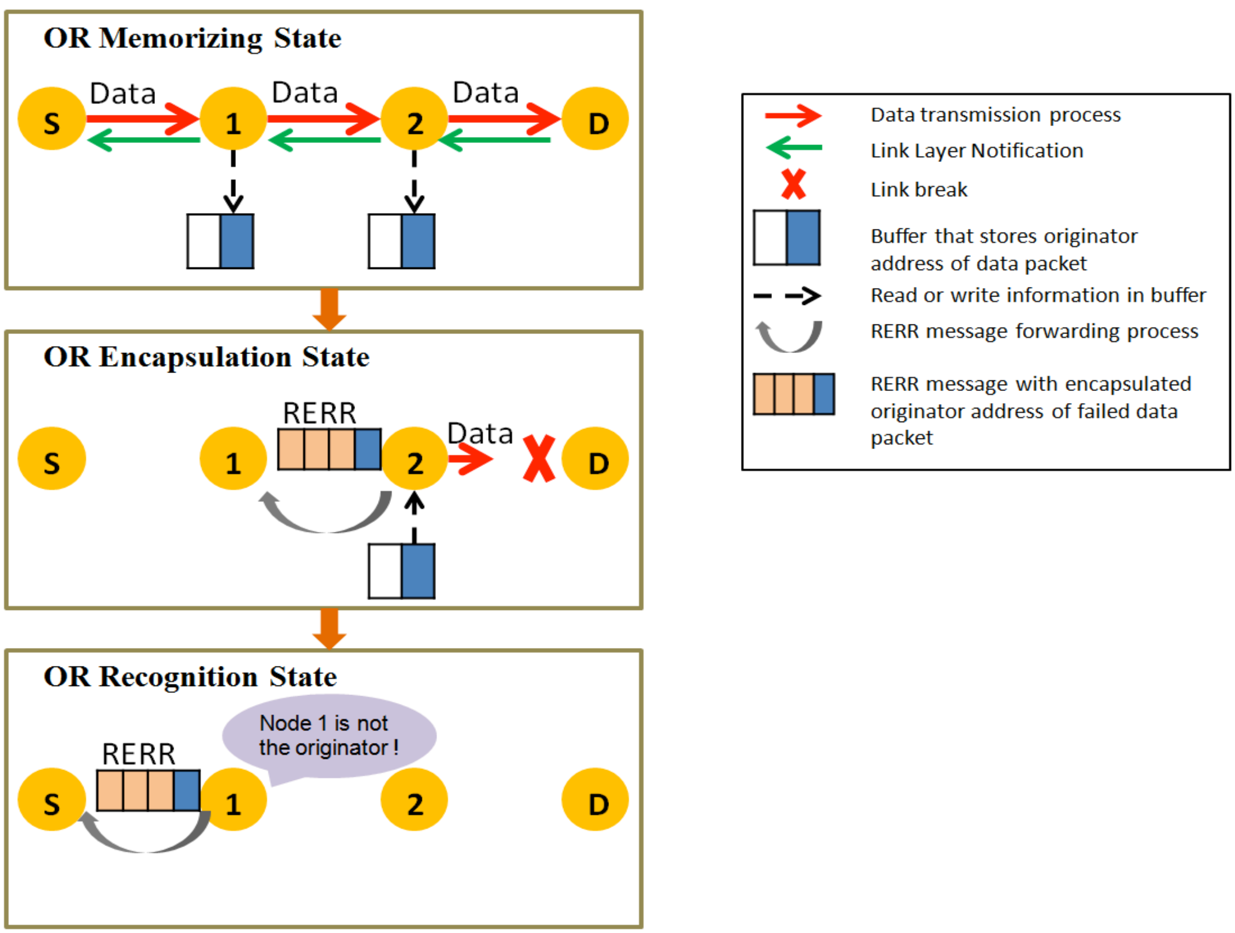

Figure 1. Operation states in OR path recovery mechanism.

During the memorizing state, the intermediate node will memorize the originator address header field information from a buffered data packet. This header field information is then stored into a new temporary buffer. When a link between two nodes is broken where the local repair is fail, the generated RERR message will trigger the encapsulation state. In the encapsulation state, the memorized originator address header field in the temporary buffer is encapsulated into the generated RERR message. The added originator address header field acts as an identity key for the receiving node of RERR message. During the RERR message forwarding towards the originator, recognition state will be initialized. In this state, each previous hop that receives the RERR message from the next hop towards a destination will use the added originator address header to identify the destination of received RERR message, where the destination of RERR message is the originator of the failed data packet. In the case that the receiving node of RERR message is the originator of the failed data packet, the originator will reinitiate a new route discovery process for a new alternative path to the currently unreachable destination, if there is a data packet still needed to be transmitted to the destination. In contrast, if the receiving node of RERR message is not the originator of the failed data packet, the previously buffered data packet for the unreachable destination as indicated in the RERR header field will be dropped. Then, the received RERR message will be forwarded to the previous hop unicastly toward the originator of the failed data packet.

3. Performance Evaluation of Proposed OR Path Recovery Mechanism in 6LoWPAN

Since the existing conceptual LOAD routing protocol fulfils the routing requirements, it is chosen as a candidate for 6LoWPAN routing protocol development. Originally, the conceptual LOAD routing protocol does not suggest any path recovery mechanism for a broken link during the data packet transmission. Thus, an OR path recovery mechanism is proposed to the conceptual LOAD routing protocol and has been named as OR-LOAD routing. In order to simulate and analyze the performances of the proposed OR-LOAD routing protocol under a particular condition, the important simulation parameters as shown in Table 1 are set accordingly during the Qualnet simulation. The other Qualnet simulation parameters that are not mentioned in this table will use the default value as provided in Qualnet simulator. During the 6LoWPAN simulation, the constant bit rate (CBR) data traffic is used. This is because the CBR fully uses the limited capacity channels with the constant maximum bit rate which is defined in the IEEE 802.15.4 standard. There are total 200 CBR traffic packets which will be sent from originator to destination node. The simulation start time is set as 1s to ensure that all the node configuration and initialization processes are done before any packet transmission. For each packet transmission, the interval time is set as 1s. The end time of CBR packet transmission is set as 0 to ensure that all 200 CBR packets are sent within 250s simulation time. The simulation is run under the increasing interference environment with node deployment scalability up to 50 nodes.

Table 1. List of simulation parameters.

Parameter	Value
Radio Type	802.15.4 Radio
MAC Protocol	802.15.4
Network Protocol	IPv4
IP Fragmentation Unit	1280 bytes
Routing Protocol	AODV or OR-LOAD
Number of Nodes	5, 10, 15, 20, 25, 30, 35, 40, 45, 50 nodes
Scenario Dimension	500 meters x 500 meters
Simulation Time	30 minutes
Packet Size	1280 bytes
Node Placement Model	Random
Application Protocol	CBR

Figure 2 depicts the performance evaluation of the packet delivery ratio against total number of nodes. It can be seen that the packet delivery ratio of both OR-LOAD and AODV routing protocols are decreased with the increasing number of nodes. However, the proposed OR-LOAD routing protocol has higher packet delivery ratio compared to the AODV routing protocol under 6LoWPAN environment. The OR-LOAD routing protocol achieves packet delivery ratio about 7% higher than the AODV routing protocol at 10 nodes. With the increasing number of nodes, the OR-LOAD routing protocol achieves packet delivery ratio about 100% better than the AODV routing protocol. Moreover, the OR-LOAD routing protocol performs an average of 19.4% higher packet delivery ratio than the AODV routing protocol. This is because the link breaks happen more frequently when the number of nodes is increased, where the proposed OR-LOAD routing protocol shows its significance in path recovery compared to the AODV routing protocol. Finally, the results show that the OR-LOAD and AODV routing protocols reach the common point when 50 nodes are used in the particular network.

Figure 3 shows the average energy consumption with increasing number of nodes in the network. It can be seen that the average energy consumption for both OR-LOAD and AODV routing protocols almost same. With the increasing number of nodes, the average energy consumption is increased. This is because more nodes are involved in the data transmission. However, for the number of nodes more than 35 nodes, the OR-LOAD routing protocol consumes slightly higher energy than the AODV routing protocol. It is about maximum 0.34% higher than the AODV routing protocol. The neglect able value is due to the link break happened more frequently with the increasing number of nodes.

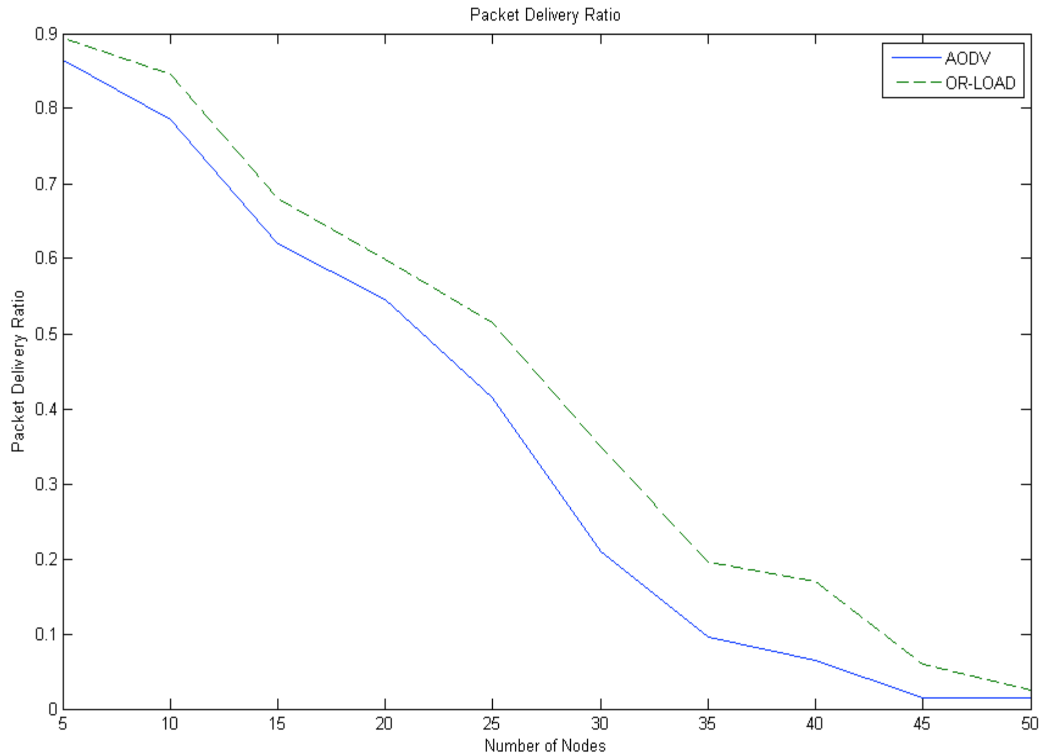

Figure 2. Packet delivery ratio between OR-LOAD and AODV routing protocols.

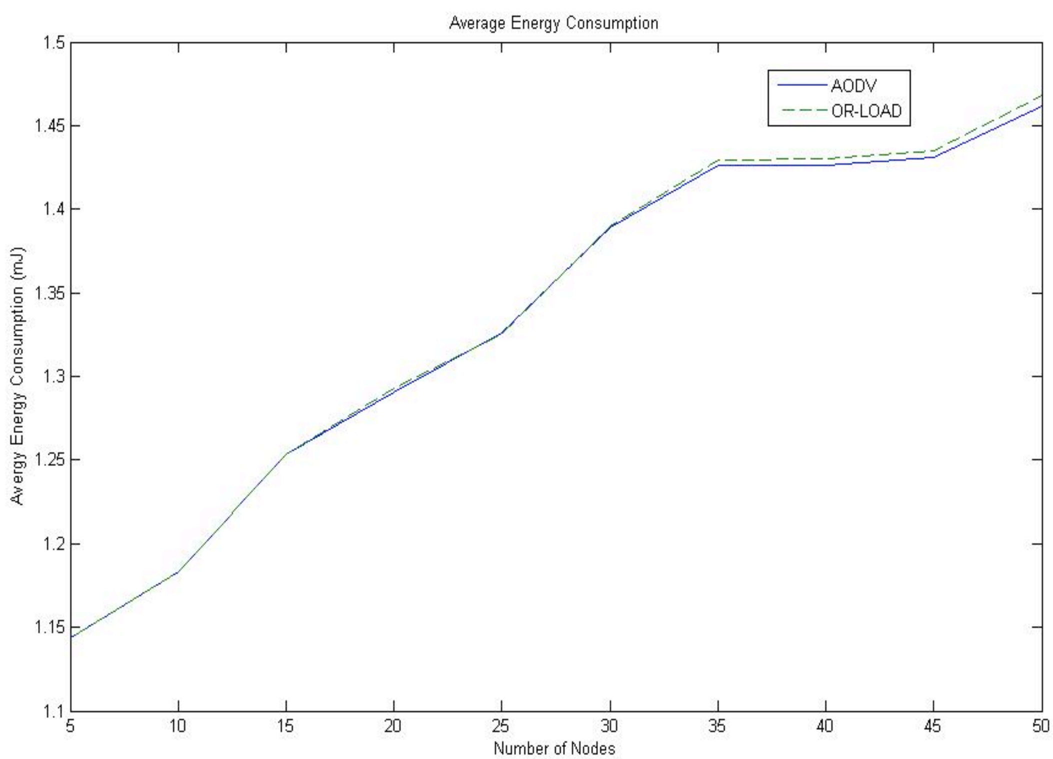

Figure 3. Average energy consumption between OR-LOAD and AODV routing protocols.

4. Conclusions

In this paper, the proposed OR-LOAD routing protocol has been evaluated in the Qualnet simulator. The simulations are run with the increasing number of node in order to examine the network scalability under the increasing interference environment. The performances of OR-LOAD routing protocol are compared with the AODV routing protocol under the 6LoWPAN environment. It can be seen that OR-LOAD routing protocol outperforms AODV routing protocol with average of 19.4% in terms of packet delivery ratio. This is because the OR-LOAD routing protocol provides a more reliable route to a particular destination during the data packet transmission. The insignificant drawbacks of OR-LOAD routing protocol is the slightly higher average energy consumption. Therefore, it can be concluded that the OR-LOAD routing protocol outperforms than AODV routing protocol with some minor tradeoffs under the noisy 6LoWPAN environment.

References

1. Kushalnagar, N.; Montenegro, G.; Schumacher, C. IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals. RFC 4919, IETF, 2007.
2. Montenegro, G.; Kushalnagar, N.; Hui, J.; Culler, D. Transmission of IPv6 Packets over IEEE 802.15.4 Networks. RFC 4944, September 2007.
3. IETF ROLL Working Group. http://tools.ietf.org/wg/roll
4. IETF MANET Working Group. http://tools.ietf.org/wg/manet
5. Winter, T.; Thubert, P.; Brandt, A. RPL: IPv6 Routing Protocol for Low Power and Lossy Networks. draft-ietf-roll-rpl-19, Internet Draft, March 2011.
6 Gomez, C.; Paradells, J. Wireless Home Automation Networks: A Survey of Architectures And Technologies. *IEEE Communications Magazine*, 2010, vol. 48, no. 6, pp. 92-101.
7. Oliveira, L.M.L.; Sousa, A.F.; Rodrigues, J.J.P.C. Routing and Mobility Approaches in IPv6 Over LoWPAN Mesh Networks. *International Journal of Communication Systems,* Wiley Online Library, 2011, vol. 24, no. 11, pp. 1445-1466.
8. Perkins, C.; Belding-Royer, E.; Das, S. Ad Hoc On-Demand Distance Vector (AODV) Routing. RFC 3561, July 2003.
9. Levis, P.; Tavakoli, A.; Dawson-Haggerty, S. Overview of Existing Routing Protocols for Low Power and Lossy Networks. draft-ietf-roll-protocols-survey-07, Internet Draft, April
10. Montenegro, G.; Kushalnagar, N. AODV for IEEE 802.15.4 Networks. draft-montenegro-lowpan-aodv-00, Internet Draft, July 2005.
11. Kim, K.; Park, S.D.; Montenegro, G.; Yoo, S.; Kushalnagar, N. 6LoWPAN Ad Hoc On-Demand Distance Vector Routing (LOAD). daft-daniel-6lowpan-load-adhoc-routing-03, Internet Draft, June 2007.

© 2013 by the authors; licensee Asia Pacific Advanced Network. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/3.0/).