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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

Access networks – In premises networks

Centralized metric-based source routing
Amendment 1

Recommendation ITU-T G.9905 (2013) – Amendment 1



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Recommendation ITU-T G.9905

Centralized metric-based source routing

Amendment 1

Summary

Recommendation ITU-T G.9905 specifies centralized metric based source routing (CMSR), a proactive, layer 2 multi-hop routing protocol. CMSR is a proactive routing protocol which can find and maintain reliable routes considering the link quality of both directions. The routing control packet overhead of CMSR is quite low compared to existing proactive routing protocols such as optimized link state routing (OLSR), so that it can be applied for large-scale networks even on narrow band power line communication (PLC) networks.

Amendment 1 adds the following features: a PAN-INFO sub-message in the Hello message to notify information on the coordinator or network status, message formats for non-6LoWPAN networks, and a procedure for inter-node communication and upstream source routing.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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FOREWORD

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The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

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Recommendation ITU-T G.9905

Centralized metric-based source routing

Amendment 1

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.9905 (2013).

1 Scope

This Recommendation specifies centralized metric based source routing (CMSR), a proactive, layer 2 multi-hop routing protocol.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T G.9903] Recommendation ITU-T G.9903 (2014), *Narrowband orthogonal frequency division multiplexing power line communication transceivers for G3-PLC networks*.
- [IETF RFC 4944] IETF RFC 4944 (2007), *Transmission of IPv6 Packets over IEEE 802.15.4 Networks*.
- [IETF RFC 6282] IETF RFC 6282 (2011), *Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

- 3.2.1 1WAY link:** A link between neighbour nodes for which only the incoming link cost is available.
- 3.2.2 2WAY link:** A link between neighbour nodes for which both incoming and outgoing link costs are available.
- 3.2.3 Hello message:** A message transmitted by each node in order both to notify its existence and to exchange link cost and route information with neighbour nodes.
- 3.2.4 LC incoming:** The cost of a one-way link from a neighbour node.
- 3.2.5 LC outgoing:** The cost of a one-way link toward a neighbour node.

3.2.6 link: A link between two nodes exists if either can receive control messages from the other, according to this specification.

3.2.7 link cost (LC): The cost of a link between a pair of nodes, calculated from bidirectional link quality. The LC value used is the greater of "LC incoming" and "LC outgoing".

3.2.8 LOST link: A broken link where communication is no longer possible.

3.2.9 node: Communication equipment, including the personal area network (PAN) coordinator, which communicates using the CMSR protocol according to this specification.

3.2.10 provisional route cost: The provisional route quality between a node and the coordinator, equal to the sum of the route cost from a neighbour node to the coordinator and the LC incoming from the neighbour node.

3.2.11 route cost: The total route quality between a node and the coordinator, equal to the sum of all link costs in the route from the node to the coordinator.

3.2.12 topology report message: A message transmitted to the coordinator (using unicast) that contains route and neighbour node information.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CMSR	Centralized Metric based Source Routing
LC	Link Cost
MAC	Media Access Control
NSDU	Network Service Data Unit
PAN	Personal Area Network
PLC	Power Line Communication

5 Protocol overview

Multi-hop routing protocols are a key feature of communication for advanced metering applications over power line communications (PLCs). For a large-scale PLC network, e.g., PLC deployment in a large-scale apartment building, a robust and low overhead routing protocol is required in order to achieve reliable metering.

This Recommendation addresses the following main objectives:

- Perform mesh-under proactive routing on 6LoWPAN in IPv6 networks, and communicate using 16-bit short addresses used by 6LoWPAN.
- Discover a bidirectional route between a node and a coordinator, taking bidirectional link quality into account.
- Establish and maintain multiple reliable routes in case route break occurs.
- Generate control packets which increase as only $O(N)$ for route discovery and maintenance (with N being the number of nodes present in the network).
- Deliver data packets with source routing and/or hop-by-hop routing.

5.1 Outline of operation

CMSR performs mesh-under routing basically on 6LoWPAN in IPv6 networks, and communicates using 16-bit short addresses used by 6LoWPAN, but it can also work in a network without 6LoWPAN. The usage for non-6LoWPAN networks is defined in Annex B. In order to perform

neighbour node detection and route discovery, a Hello message is used for exchanging route and link quality information between nodes, whereas a topology report message is used to notify the coordinator. The coordinator and nodes maintain neighbour tables for storing information on neighbour nodes, and route tables for storing route information. Each node determines an optimal route based on the link quality and the number of hops to the coordinator.

5.1.1 Route discovery

Route discovery is carried out with the three steps shown in Figure 5-1.

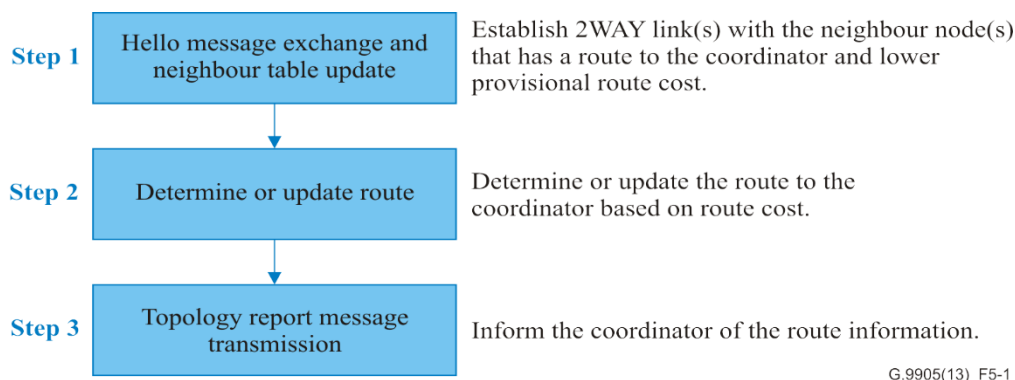


Figure 5-1 – Overview of route discovery steps

Step 1: Hello message exchange and neighbour table update

Each node periodically transmits the Hello message as a 1-hop broadcast message with the interval of HELLO_INTERVAL (or HELLO_INTERVAL_FAST as mentioned in clause 8.1.1). In order to avoid a permanent collision of Hello messages, each node randomly shifts the transmission timing. The maximum timing shift is defined by HELLO_JITTER.

For route discovery, the node establishes a 2WAY link with the node which already has a route to the coordinator. Figure 5-2 shows how the 2WAY link is established. The node that receives the Hello message stores the information included in the Hello message in the neighbour table. When the node receives a Hello message from its neighbour node for the first time, the link between the nodes is considered as a 1WAY link (meaning that the node has measured the LC incoming from that neighbour node but does not know the LC outgoing to that neighbour node). The receiving node calculates the provisional route cost as the sum of the route costs in the received Hello messages and the measured LC incoming. The status, LC incoming and provisional route cost are recorded in the neighbour table (first phase in Figure 5-2).

The node selects the neighbour nodes based on the provisional route costs, i.e., neighbour nodes with lowest provisional route costs. Up to LINK_MAX_PREFERRED neighbour nodes may be selected. The node sends a Hello message with the link request (LINK_REQ sub-message) to the selected neighbour nodes to obtain the LC outgoing. Upon reception of the LINK_REQ sub-message, the neighbour nodes record the LC incoming and LC outgoing according to the received message (second phase in Figure 5-2).

The neighbour nodes transmit LINK_REP sub-messages including the LC incoming to the originator of the LINK_REQ. The originator node stores the LC incoming in the received LINK_REP sub-message as LC outgoing, and sets the link status as "2WAY" (third phase in Figure 5-2).

Note that the LINK_REQ and LINK_REP sub-messages are transmitted in the Hello message that is periodically transmitted with the interval of HELLO_INTERVAL (or HELLO_INTERVAL_FAST).

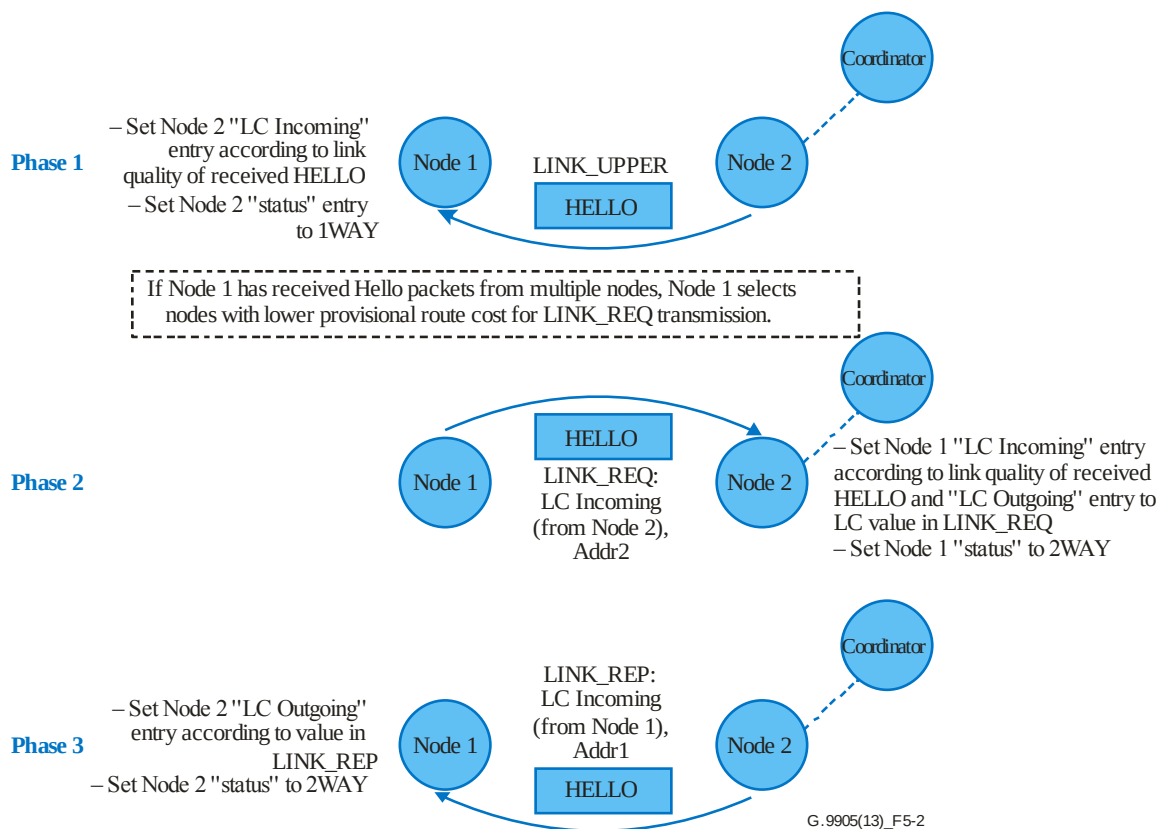


Figure 5-2 – Establishment of 2WAY link using LINK_REQ/LINK_REP sub-messages

Step 2: Route determination/update

The node may receive LINK_REP sub-messages from more than one neighbour node in Step 1. The node calculates the route cost associated with each neighbour node based on the link cost (i.e., greater of LC incoming and LC outgoing) and the route cost information in the LINK_REP sub-message from the neighbour node. The node selects the route with the least route cost. Other routes may be selected as candidates for route recovery. The route information, i.e., relay node addresses and each link cost, is stored in the route table.

If the node already has the route to the coordinator and it finds a better route, the route may be updated.

Step 3: Topology Report message transmission (route update for the coordinator)

The Topology Report message is used to inform the coordinator of the routes used by each node, 2WAY links associated with each node and broken links associated with each node. The node periodically transmits a Topology Report message toward the coordinator. The coordinator updates the route table for each node based on the received Topology Report messages. Note that the coordinator does not transmit the Topology Report message.

The above steps are repeated and each node updates the route based on the Hello messages and the Topology Report messages periodically transmitted by other nodes.

5.1.2 Fast mode operation

Fast mode is used to shorten the route discovery time. The node in fast mode transmits the Hello message with an interval of HELLO_INTERVAL_FAST. If the node does not currently have a route to the coordinator, the node operates with the fast mode and may request its neighbour nodes to operate in fast mode by setting the fast mode flag in the Hello message. Any node which receives a Hello message with fast mode flag set to "enable" shall operate with fast mode for a certain period.

5.1.3 Route recovery

CMSR allows a node to maintain alternative routes in case broken links occur.

For upstream communication, each node has the route to the coordinator and possibly an alternative route. If the node stores an alternative route, it changes the route immediately.

For downstream communication with source routing, the node reports the failure to the source node (i.e., coordinator), which allows the coordinator to select an alternative route.

5.1.4 Packet delivery

5.1.4.1 Unicast packet

The coordinator and the nodes send upper layer packets using the discovered route.

In upstream communication (from a node to the coordinator), the node shall select one of two methods – source routing or hop-by-hop. In hop-by-hop, a source node sends packets only to an upstream destination neighbour node. In order to facilitate rapid route recovery, the route to the coordinator is not included in these packets. Each node relays the packet to the uplink in a hop-by-hop manner. In source routing, the node specifies the entire route to the final destination and the CMSR source route header is attached to the packet.

In downstream communication (from the coordinator to a node), the coordinator shall select one of two methods – source routing or hop-by-hop. In source routing, the coordinator specifies the entire route to the final destination and the CMSR source route header is attached to the packet. This is necessary as, in order to reduce memory resource usage, nodes do not hold route information to other nodes. In hop-by-hop, the coordinator transmits the packet to the next hop, and the relay node forwards the packet based on the route information stored in the route table. These methods can be selected according to system requirements.

In inter-node communication (from a node to a node), the node shall select one of two methods – source routing or hop-by-hop. The originator node sends packets according to the upstream communication procedure. In each node, the route to the coordinator is defined as the default route. If the node (originator node or relay node) has the route to the destination node, it transmits the packet based on the route to the destination. If not, it may discard the packet or transmit the packet based on the default route, i.e., the route to the coordinator. When the coordinator receives the packet destined for a node, the coordinator relays it to the destination node according to the downstream communication procedure.

5.1.4.2 Broadcast packet

Only a limited number of nodes forward a broadcast packet in order to avoid congestion in a large-scale network. Only nodes which are listed in the LINK_UPPER sub-message of the Hello messages from the different nodes are enabled to forward a broadcast packet.

5.2 Table overview

The necessary protocol state is recorded in the route table and the neighbour table. Every node has its own tables.

The route table contains tuples of destination short address, route cost, hop count and short address list of relay nodes to the destination. The node updates the route table when it finds or updates the route based on received Hello messages or when it receives a Topology Report message from a node.

The neighbour table contains tuples of neighbour node address, node type, link status, link cost incoming, link cost outgoing, link cost of relay link, short address list of relay nodes and the route cost. The node updates the neighbour table according to Hello messages received from neighbour nodes.

5.3 Signalling overview

This protocol generates and processes the CMSR message and the source route header. The CMSR message includes three types of messages, Hello message, Topology Report message and Route Error message.

5.3.1 Hello message

The Hello message is used by nodes to notify their existence and status to each other in the route discovery process, and is also used to deliver coordinator information or network status. The Hello message contains one or more of the following ~~five~~^{four} sub-messages.

LINK_UPPER sub-message: Used to notify the route from the node to the coordinator and each link cost within the route. This sub-message contains the list of relay node addresses and the link cost of each link.

LINK_REQ sub-message: Used to request a neighbour node to feedback the link cost from the node to the neighbour node. This sub-message also indicates to the neighbour node that the link between the node and the neighbour node is a 1WAY link. This sub-message contains one or more sets of the target node address and its link cost.

LINK_REP sub-message: Used to respond to the LINK_REQ sub-message received from a neighbour node. This sub-message contains one or more sets of the target node and its link cost (i.e., outgoing link cost for the neighbour node).

LINK_LOST sub-message: Used to notify the existence of a broken link. This sub-message contains one or multiple sets of the target node and its link cost (must be zero). LINK_LOST is determined by the lack of reception of a Hello message from a node for a period given by HELLO_MAX_COUNT multiplied with HELLO_INTERVAL.

PAN_INFO sub-message: This is optionally used to notify coordinator information or network status information, and it contains one or more attribute types. One of the attribute types is coordinator reboot count e.g., to notify encryption key update due to coordinator reboot and encourage nodes to trigger re-authentication for a key update.

For reliable message delivery, more than one transmission of LINK_REQ, LINK_REP and LINK_LOST sub-messages addressed to a certain neighbour node may be conducted. The number of transmissions is given by NOTIFY_MAX_COUNT.

5.3.2 Topology Report message

The Topology Report message contains information on the route to the coordinator and link status with neighbour nodes. Each node generates a Topology Report message based on the route table and the neighbour table, and periodically sends it to the coordinator. A Topology Report message contains one or more of the following three sub-messages.

LINK_UPPER sub-message: Indicates the route information from the node to the coordinator and each link cost. This sub-message contains the list of relay node addresses and the link cost of each link.