Low-Complexity Routing Algorithm for Smart Metering on PLC

Ahmed Elawamry
Faculty of Engineering
Benha University
Cairo, Egypt
ahmedelawamry@bhit.bu.edu.eg

Ahmed ElSanhoury, Ayman M. Hassan
Orange Labs Cairo, LCI Dept.
International Centers, Orange Labs P&S
Cairo, Egypt
ayman.hassan@orange.com

***Abstract*— A routing algorithm is proposed to increase link reliability in smart metering over low-tension power line grid. The algorithm assumes data concentrator (DC) is polling meters connected to the power line to send energy consumption, loading profile and any other crucial data to the utility. The proposed algorithm is designed to keep the needed complexity at the meters at minimum, while moving the intelligence up to the DC. The protocol accounts for asymmetric characteristics of the power line channel, where some nodes couldn't receive data from DC and neighbor nodes (deaf nodes), while its transmission could be received properly. Special packet structure is proposed to minimize algorithm overhead. Performance comparison with AODV protocol in terms of average throughput, reachability, and protocol overhead is in progress.**

Keywords- smart metering; routing algorithm; PLC; AODV

I. INTRODUCTION

Using power grid as a communication medium is an attractive alternative to utilities as it provides low-investment medium for smart grid services including: smart metering, load survey, load shedding and profiling. However, as never been designed with communication aspects in mind, the power line channel introduces tough challenges to the system designer in order to achieve reliable link with acceptable availability, throughput and range. Factors like attenuation, narrow-band and impulsive noise, and impedance variability are among the issues that affect the link quality in power line communication (PLC) systems, and their impact should be mitigated. On the physical layer level, coding, interleaving and noise cancellation are commonly used to enhance the channel quality. Another effective solution to increase the reliability and range of the smart metering system is to use Ad-hoc routing protocols [1]. In this arrangement, intermediate meters act like repeaters to regenerate packets from/to meters that couldn't be reached by the DC directly due to bad channel conditions. The repeating algorithm should be in a controlled manner to avoid network flooding.

II. HISTORICAL OVERVIEW

Applying routing protocols for range extension of PLC system has been addressed in previous studies. The PMR routing protocol mentioned in [2] is on-demand multipath routing algorithm. The protocol tries to find maximally disjoint routes in large-scale networks with Master-Slave structure. The routing protocol is an on-demand source routing protocol that builds multiple routes using request/reply cycles. When the Master needs a route to a given slave without knowing any routing information, it floods the RREQ message to the entire network. Several duplicates that traversed through different routes reach the destination as a result of flooding. Finally, the destination node picks up multiple disjoint routes from arrived RREQ packets and sends ROUTE REPLY (RREP) packets back to the source via the chosen routes.

The IPODV routing protocol proposed in [3] is based on the AODV protocol, with modified RREQ broadcasting mechanism and neighbor table management. The protocols studied in [4] and [5] are based on clustering meters into groups according to the connectivity status of the meter to DC and adjacent meters. Two-state Markov model is used to represent channel state from/to each meter.

In [6], an algorithm based on time-slotted scheme with random back off delay is studied. This algorithm assumes meters send their data using slotted ALOHA instead of the common polling algorithm. Other approaches like the protocol mention in [7] is based on the ant colony algorithm mentioned in [8].

Asymmetric characteristic of the power line channel isn't considered in the preceding protocols, where some nodes are subject to high channel noise due to the household appliances [9]. The behavior of those nodes is like a deaf behavior. i.e. nodes couldn't receive messages from DC although they could transmit to it. The proposed algorithm described in section III tackles this aspect in order to increase the number of meters attached to the DC (reachability); hence improve the performance.

III. DESIGN OF THE ROUTING ALGORITHM

The network comprises DC and several meters connected in star-mesh topology via low-tension power grid. Fig. 1 shows the flowchart of routing algorithm at DC side. The algorithm aims at reducing complexity as much as possible in the meters side hence reduces the meter's cost.

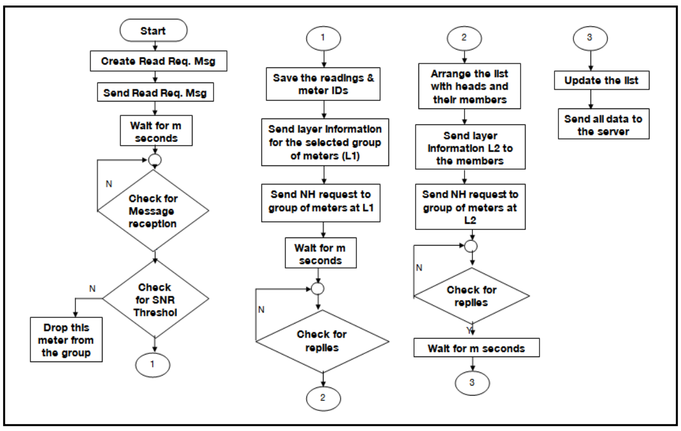

Figure 1. DC flowchart.

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A. Time Line Scenario

The mechanism of the routing algorithm could be summarized as follows:

1. DC broadcasts *read request message* (RREQ) to all meters.
2. Meters receive RREQ properly respond to the DC request. Assume number of responded meters equal N_1.
3. DC selects N_2 meters ($N_2 < N_1$) to be assigned at the first tier. This assignment is done by determining a metric threshold such as signal to noise ratio SNR.
4. DC sends *layer information message* (L_1) to N_2 meters in order to inform them they're selected to be at the first tier/layer.
5. After first tier assignment procedure is accomplished, DC requests from N_1 meters to get their neighborhood through *get neighborhood message* (Get NH).
6. Meters which are in the same tier, will not communicate with each other according to the predefined rule (if $L_H \geq L_N$ then no reply, where L_H is header tier/layer and L_N is the neighbor layer) which is set during L_1 message.
7. Meters at L_1 send their group (list) to DC to create L2.
8. DC arranges the received groups into a list.
9. Repeat step 5 in order to compose tier/layer3.

Meters don't receive RREQ message for more than one hour is classified as "Deaf". Deaf meters will send unconditionally after it timed-out and raise a DF flag associated with their readings in order to inform the header meters and DC by their type. The flowchart for the meter algorithm is shown in Fig. 2.

The header meter which can listen to the deaf meters stores the deaf meter reading, formats the meter reading message as shown in Fig. 3, then sends this reading associated with its reading at the next time slot.

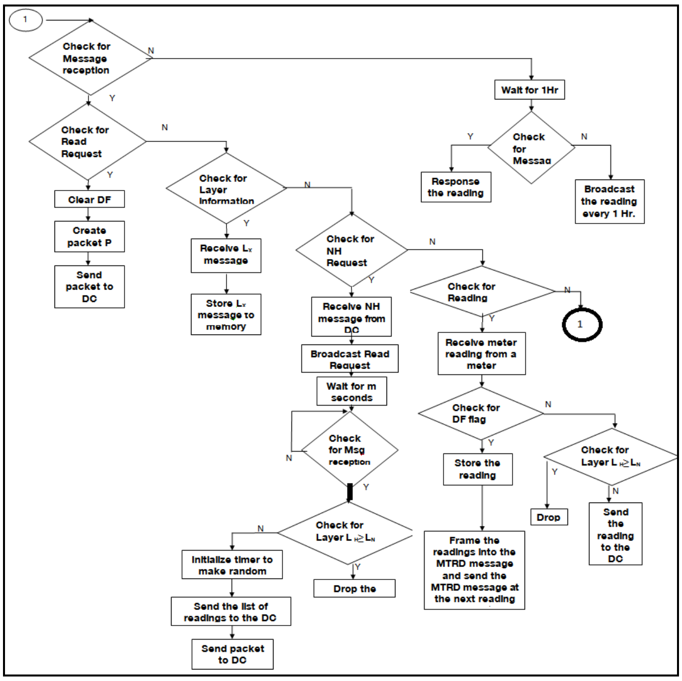

Figure 2. Meter flowchart.

B. Protocol Data Unit (PDU) Design

The PDU is formatted according to the described scenario in the preceding section. The structure of the four messages used for the algorithm is shown in Fig. 3 below.

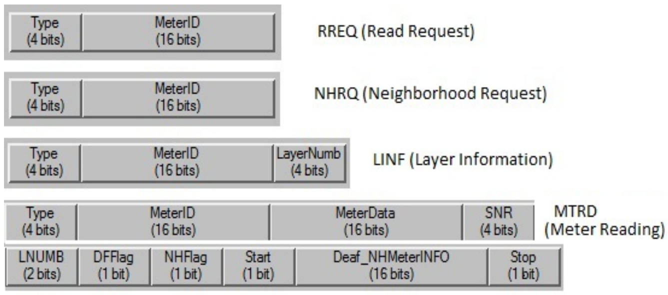

Figure 3. Meter reading message formats.

CONCLUSION

A routing algorithm is proposed to keep complexity at the meters at minimum; hence reducing the meter's cost. Reachability is expected to be improved due to the mechanism adopted with the deaf nodes. Simulation results are going to be analyzed and compared with AODV protocol to verify performance improvement.

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