A Simulative Analysis of Routing Protocols for LR-WPAN

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Abstract: IEEE802.15.4 standard specifies two PHYs: an 868/915 MHz direct sequence spread spectrum (DSSS) PHY and a 2450 MHz DSSS PHY. The 2450 MHz PHY supports an over-the-air data rate of 250 kb/s, and the 868/915 MHz PHY supports over-the-air data rates of 20 kb/s and 40 kb/s. The PHY chosen depends on local regulations and user preference. In this paper main focus is on analyzing and finding suitable routing protocol for low rate wireless personal area networks (LR-WPAN). A simulative approach is used to evaluate performance of routing protocols for LR-WPAN (IEEE802.15.4) using different scenarios. Ns-2 is used for the same as it supports IEEE802.15.4. AODV, AOMDV and MDART protocols were selected for experimentation. MDART outperforms others for Energy used, PDR and Throughput for network of moderate size. But it shows higher delays because of table driven approach.

Keywords: LR-WPAN, AODV, AOMDV and MDART.

I. INTRODUCTION
A Low Rate Wireless Personal Area Network (LR-WPAN) is a simple, low-cost communication network that allows wireless connectivity in applications with limited power and relaxed throughput requirements. The main objectives of an LR-WPAN are ease of installation, reliable data transfer, short-range operation, extremely low cost, and a reasonable battery life, while maintaining a simple and flexible protocol.

A system conforming to IEEE 802.15.4 consists of several components. The most basic is the device. A device can be an RDF or an FFD. Two or more devices, within a POS communicating on the same physical channel constitute a WPAN. However, a network shall include at least one FFD, operating as the PAN coordinator. An IEEE 802.15.4 network is part of the WPAN family of standards although the coverage of an LR-WPAN may extend beyond the POS, which typically defines the WPAN.

A well-defined coverage area does not exist for wireless media because propagation characteristics are dynamic and uncertain. Small changes in position or direction may result in drastic differences in the signal strength or quality of the communication link. These effects occur whether a device is stationary or mobile as moving objects may impact station-to-station propagation (Zheng et al. 2006).

Establishing optimal route between source and destination is a significant problem in any network. Work is going on to provide solution to this problem for LR-WPAN. Several routing protocols are developed till date for the same. But they compromise in at least one of the QoS measures. Finding suitability of routing protocol for any network is prevailing issue. In this paper performance of selected routing protocols is analyzed on network simulator (ns-2) to cater the current research issues.

II. RELATED WORK
A lot of IEEE standards are there but IEEE802.15.4 is important because it can provide ZigBee like features for wireless PAN. From related literature available few are mentioned below.

The authors of Koubaa et al. (2005) presented an overview of the technical features of the physical layer and the medium access control sub-layer mechanisms of the IEEE 802.15.4 protocol that are most relevant for wireless sensor network applications. They also discussed the ability of IEEE 802.15.4 to fulfill the requirements of wireless sensor network applications.

In Kohvakka et al., (2006), the authors analyzed the performance of IEEE 802.15.4 Low-Rate Wireless Personal Area Network (LR-WPAN) in a large-scale Wireless Sensor Network (WSN) application. To minimize the energy consumption of the entire network and to allow adequate network coverage, IEEE 802.15.4 peer-to-peer topology was selected, and configured to a beacon-enabled cluster-tree structure. This analysis was consisted of models for CSMA-CA mechanism and MAC operations specified by IEEE 802.15.4. Network layer operations in a cluster-tree network specified by ZigBee are included in the analysis. For realistic results, power consumption measurements on an IEEE 802.15.4 evaluation board were also included. The performances of a device and a coordinator were analyzed in terms of power consumption and goodput. The results were verified with simulations using Wireless Sensor Network Simulator (WISENES).

A new protocol named Kademia-based Dynamic Source Routing (KDSR) was developed by authors of Zhao et al. (2009), which integrates the functionality of a DHT and Dynamic Source Routing (DSR) at the network layer to provide an efficient indirect routing primitive in MANETs. KDSR organizes mobile nodes into a XOR-based metric topology. This topology has the property that every message exchanged conveys useful routing information, which facilitates route discovery and route maintenance. Simulation results show that KDSR achieves better packet delivery ratios at significantly lower overhead than DSR.
In Caleffi (2009), a DHT-based routing protocol was proposed, which integrates at the network layer both traditional direct routing, i.e. MANET routing, and indirect key-based routing, i.e. P2P routing. The unique feature of such a proposal is the ability to build an overlay network in which both the logical and physical proximity agree, improving so the P2P performances. In addition, it outperforms traditional routing protocols for MANET communications whenever the number of nodes grows, assuring satisfactory performances also for large networks operating in presence of hostile channels and moderate node mobility.

The authors of Caleffi and Paura (2011) proposed a Distributed Hash Table (DHT)-based multi-path routing protocol for scalable ad hoc networks. They proposed a multipath-based improvement to a recently proposed DHT-based shortest-path routing protocol, namely the Dynamic Address RouTing (DART). The resulting protocol, referred to as multi-path DART (M-DART), guarantees multi-path forwarding without introducing any additional communication or coordination overhead with respect to DART.

In Zhang and Shao (2011), the authors proposed four mobility models for simulating different scenarios of mobile ad hoc networks and to know which protocol is better than another in different mobile network scenarios. Also a byte-based energy consumption evaluation methodology is introduced for the protocol assessment. The experiment built upon mobility models, shows that TORA can cause too much energy consumption on large-sized network and is fit for the mobile adhoc network with low node mobility, while AODV, DSR, and especially DSDV performs well on energy consumption for the mobile ad hoc network with high node mobility.

The authors of Bhat et al., (2011) implemented a small subset of the IEEE 802.15.4 protocol to achieve a point to point communication. The implemented protocol uses 802.15.4 MAC compliant data and acknowledgment packets. Current consumption is measured while doing one data packet transmission. Measurements are compared with existing work. IEEE 802.15.4 protocol implementation is done using Verilog language. Code implementation is done in such a manner so that it can be ported to any platform with minimal changes. It can also be modified to suit any special experimental setup requirements.

In Naseer et al. (2011) multiple topologies were analyzed such as Cluster-Tree, Mesh and Star in various scenarios to compare different performance metrics (Throughput, traffic sent, traffic received, Load, End-to-end Delay and etc). In this analysis they found that Cluster-Tree topology is best as compared to Mesh and Star topology because it take 20% and 45% load greater as compared to Mesh and Star Topology respectively. Similarly its throughput, Traffic Sent, Traffic Received and Delay was better than the other two topologies.

The relationship between QoS and superframe parameters was in Yong Lan et al., (2014) through analytic mathematical model and simulation method in order to find the QoS performance of slotted CSMA/CA mechanism in beacon-enabled IEEE802.15.4.

A comparative analysis of a new ADAPT algorithm for sensor networks to analyze the energy consumption in different scenarios was presented in Santhi et. al., (2015). Results showed that proposed algorithm is better than other algorithms.

The authors of Choudhury et al. (2016) in proposed an improved ZigBee algorithm by employing neighbor tables and link quality indicator (LQI). Keeping in mind the low complexity of traditional ZigBee protocol, priority based approach was implemented by using two reserved bits as priority bits in route selection. Opnet Simulator was used for the simulation purpose along with Visual Studio 2005 for C++ compiler. Simulation results showed that the proposed priority based routing protocol perform better than the classical ZigBee tree algorithm, and thus can be claimed as an enhanced ZigBee protocol.

In Saraswala et al. (2017), the authors implemented the AODV routing protocol in True Time 2.0 which is a Simulink based software used in MATLAB. A Path loss is the most important element that effects the design and the analysis of the wireless communication system. They studied the impact of path loss exponent on transmission range and the hop count. Also soft computing technique named Fuzzy logic was used for deciding the optimum path loss exponent.

III. ROUTING PROTOCOLS

Routing protocols differ in the approach used for discovering a new route and maintaining a route when nodes move. These can be classified into following three categories:

1) Proactive routing protocols
2) Reactive routing protocols
3) Hybrid routing protocols

Other than the above criteria routing protocols are also classified based on being either centralized or distributed and also on being static or adaptive.

AD-HOC ON DEMAND DISTANCE VECTOR (AODV)

Ad hoc on Demand Distance Vector (AODV) is a modified form of highly dynamic destination sequenced distance vector routing protocols DSDV routing algorithm. The main task of DSDV is to reduce the number of broadcast message sent throughout the network. AODV is an on demand routing protocol having the feature of facilitating the changes occurred due to the link conditions. If the link fails, notifications are sent only to the nodes affected due to link failure. Because of on demand nature of the protocol there is minimal routing traffic in the network and does not allow nodes to keep the routes. AODV creates and maintain routes only whenever it is required, as it is a reactive protocol. More important the information from neighbors is also received. Whenever route breaks, neighbors can be notified. When two nodes in an ad hoc network want to communicate with each other, AODV will build multi hop routes between these nodes. AODV is loop free protocol; this is one of the key features of the protocol.

AOMDV (ADHOC ON DEMAND MULTIPATH DISTANCE VECTOR)

AOMDV is a multipath extension to its single path predecessor AODV. AOMDV’s intelligence lies in its
multipath algorithm, which utilizes the already present information in the routing packets. Unlike AODV every time when a link breaks AOMDV doesn’t have to reinitiate a route discovery rather it utilizes the next available path in its routing table to forward data packets. Figure shows the state diagram representation of AOMDV Routing algorithm. Starting from idle state when a node generates a data packet it first traverses through its routing table to find a entry for the desired destination, if it finds a appropriate route entry it looks up for a valid path with a valid next hop and on finding the same it goes into the data forwarding state however if the node is an intermediate node instead of a source and somehow receives a data packet it will as well look through the route table and if it doesn’t find an appropriate entry it goes into the route maintenance state wherein it generates a RERR and send it to the upstream node, and the upstream nodes as well as the source on arrival of the RERR packet deletes the next hop from the path entry. The node goes in to local connectivity maintainer phase when in receives a hello message from one of it neighbor. In this phase the node updates its neighbor table and it routing table as per the hello message received. The AOMDV protocol also has a route purging state which a node can reach in one of the two ways firstly when the MAC layer reports a link failure or secondly due to the inbuilt timer route_purge timer on expiry of which the node removes all stale routes. A node comes into route building state when it receives a RREQ/RREP packet. In this phase the node either forwards a RREQ packet or sends back a RREP towards the source depending on route availability in its routing table and rules mentioned in (Marina and Das, 2001).

**M-DART (Multi path DART)**

The M-DART extends the DART protocol to proactively discover all the available routes between a source and a destination. In this section, we first present an example of how the MDART’s multi-path approach improves the tolerance of the address space overlay against mobility as well as channel impairments. Then we give an overview of how M-DART is capable to implement a multi-path routing strategy without introducing any communication or coordination overhead. Finally, we provide a detailed description of the multi-path data forwarding strategy and a polynomial bound on the on the routing table size.

M-DART shares several characteristics with DART. It is based on the distance vector concept and it uses the hop by hop routing approach. Moreover, M-DART also resorts to the dynamic addressing paradigm by using transient network addresses. The main difference between DART and M-DART lies in the number of routes stored in the routing table: the former stores no more than l entries, one for each sibling, while the latter stores all the available routes toward each sibling. The core of M-DART protocol lies in ensuring that such an increase in the routing state information stored by each node does not introduce any further communication or coordination overhead by relying on the routing information already available in the DART protocol. In particular, it does not employ any special control packet or extra field in the routing update entry (Figure 1) and, moreover, the number of entries in the routing update packet is the same as DART: l. No special coordination action is needed by nodes and the node memory requirements constitute the only additional overhead in M-DART relative to DART.

![Figure 1: M-DART routing update entry](Image)

These valuable characteristics are obtained by means of blind route notification that is by notifying neighbors only about the presence of routes towards a sibling without detailing the paths that the packets will be forwarded through. Although such a strategy allows us to avoid introducing any communication or coordination overhead, a major issue arises when a blind route notification is used in multi-path hierarchical routing. In fact, in such a case the cost associated with a path is not enough to single out the best route among multiple ones (Caleffi and Paura, 2011).

**IV. SIMULATION RESULTS**

Parameters used for performing simulation and evaluating performance of different routing protocols are listed in Table 1. These parameters are used in Tcl scripts to vary no. of sensor nodes, routing protocols and obtain the relative results.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of sensor nodes</td>
<td>5, 11, 15, 21 and 25</td>
</tr>
<tr>
<td>Simulation duration</td>
<td>100 s</td>
</tr>
<tr>
<td>Scheduling types</td>
<td>AODV, AOMDV and M-DART</td>
</tr>
<tr>
<td>Simulator</td>
<td>ns-2.35</td>
</tr>
<tr>
<td>MAC</td>
<td>IEEE 802.15.4</td>
</tr>
<tr>
<td>Traffic</td>
<td>Mix (CBR and Exp)</td>
</tr>
</tbody>
</table>

In first scenario three routing protocols are considered namely AODV, AOMDV and MDART. AOMDV and MDART are multipath in nature whereas an MDART protocol is table driven. Simulation setup for this is already mentioned in Table 1. Observations were made after performing simulation experiments and are listed in Table below.

<table>
<thead>
<tr>
<th>Nodes</th>
<th>PDR</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AODV</td>
<td>AOMDV</td>
<td>MDART</td>
</tr>
<tr>
<td>5</td>
<td>0.856027</td>
<td>0.849032</td>
<td>0.997636</td>
</tr>
<tr>
<td>11</td>
<td>0.982917</td>
<td>0.754875</td>
<td>0.947664</td>
</tr>
</tbody>
</table>

Table 2: Average PDR for MDART, AOMDV and AODV.
Comparison graph shown in Figure 2 made it clear that for a network of size upto 20 nodes MDART is giving more promising PDR results as compare to AODMV and DSDV because of DHT paradigm. However difference is not significant for bigger network.

Table 3: Average Throughput for MDART, AOMDV and AODV

<table>
<thead>
<tr>
<th>Nodes</th>
<th>AODV</th>
<th>AOMDV</th>
<th>MDART</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2036</td>
<td>1868</td>
<td>2367</td>
</tr>
<tr>
<td>11</td>
<td>1406</td>
<td>1863</td>
<td>1573</td>
</tr>
<tr>
<td>15</td>
<td>1418</td>
<td>1513</td>
<td>1835</td>
</tr>
<tr>
<td>21</td>
<td>1026</td>
<td>884</td>
<td>1933</td>
</tr>
<tr>
<td>25</td>
<td>2509</td>
<td>2540</td>
<td>126</td>
</tr>
</tbody>
</table>

As shown in Figure 3, MDART behaves similar as that of AODV and AOMDV protocols and is showing higher throughput for sensor network size of 15 and 20. This is because of table driven criteria of MDART, once routing table is ready packets can be delivered quickly on available routes. But MDART compromises for bigger network because of absence of routes in table as there was no sufficient time to complete the table for bigger networks.

We have consider another performance parameter called Energy efficiency for which following observations were made (See Table 4). Energy used decides network life time.

Table 4: Energy Used of MDART, AOMDV and AODV

<table>
<thead>
<tr>
<th>Nodes</th>
<th>AODV</th>
<th>AOMDV</th>
<th>MDART</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4.871965</td>
<td>4.765745</td>
<td>4.719595</td>
</tr>
<tr>
<td>11</td>
<td>5.099611</td>
<td>5.657821</td>
<td>6.586331</td>
</tr>
<tr>
<td>15</td>
<td>8.741791</td>
<td>12.38392</td>
<td>6.957452</td>
</tr>
<tr>
<td>21</td>
<td>11.87142</td>
<td>15.82022</td>
<td>12.559521</td>
</tr>
<tr>
<td>25</td>
<td>7.635433</td>
<td>13.99373</td>
<td>7.738353</td>
</tr>
</tbody>
</table>

As shown in Figure 4 AODV and AOMDV are consuming comparatively more energy while MDART is consuming less.
energy comparatively because of its DHT approach and is good for achieving high Quality of Service for sensor networks.

Table 5: Delay of MDART, AOMDV and AODV

<table>
<thead>
<tr>
<th>Nodes</th>
<th>AODV</th>
<th>AOMDV</th>
<th>MDART</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.004723</td>
<td>0.004726</td>
<td>0.004963</td>
</tr>
<tr>
<td>11</td>
<td>0.004800</td>
<td>0.004802</td>
<td>0.004816</td>
</tr>
<tr>
<td>15</td>
<td>0.004629</td>
<td>0.004638</td>
<td>0.004800</td>
</tr>
<tr>
<td>21</td>
<td>0.004659</td>
<td>0.004662</td>
<td>0.004800</td>
</tr>
<tr>
<td>25</td>
<td>0.004645</td>
<td>0.004643</td>
<td>0.004800</td>
</tr>
</tbody>
</table>

From graph 5 it is clear that because of table driven approach of MDART delay is more whereas other protocols are reactive and shows lesser delay comparatively.

V. CONCLUSION

In this research work we evaluated and compared the performance of routing protocols for WSN. In our experimentation single path and multipath routing protocols were considered i.e. AODV AODMV and MDART respectively. Simulation of these protocols has been carried out on NS-2.34 and performance has been evaluated based on Packet Delivery Ratio (PDR), Throughput Delay and Energy Used.

It was observed that M-DART has higher PDR and Throughput for network size less than or equal to 20. It is also consuming comparatively lesser Energy. We can conclude that M-DART is suitable for WLAN (IEEE 802.15.4) for networks of moderate size. M-DART is proposed for scalable networks but shows higher delays.

REFERENCES


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