A COMPARATIVE STUDY OF ROUTING APPROACHES FOR ENERGY CONSTRAINED DEVICES IN IOT

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Abstract
Internet of Things (IoT) is a self organized network of power and bandwidth constrained devices that continuously produce and capture data. Some of the application areas of IoT network include inaccessible areas such as battle field, dense forests, space etc., The nodes in these areas do not have a proper recharge system to charge them. So a major concern is to elongate battery life of the nodes to increase the overall life time of the system. The data produced by these nodes is transmitted to a receiver through a path computed using routing algorithms. Routing algorithms requires processing at each node which consumes considerable amount of energy, which has attracted the concern of many researchers. The main motivation of this paper is to study the energy consumption in proactive and reactive routing approaches and further propose an energy efficient hybrid routing mechanism for IoT system.
Keywords: AODV, Energy Efficient, Hybrid routing, OLSR, ZHLS

I. INTRODUCTION

The routing protocols are used to route the packets from the source node to the destination in the IoT environments. The efficiency of a routing protocol is measured in terms of delivering the quality of service (QoS), reliability and minimizing the energy consumption in nodes [13]. These data, which are highly dimensional, redundant, and noisy, become a huge challenge for current network infrastructure to transmit [2].

The devices in IoT have different requirements such as:

- Environment interaction
- Heterogeneous devices and scalability
- Diversity of applications and areas
- Energy and resource constraints
- Mobility
- Data exchange
- Self configurability
- Security and privacy issues

Fig. 1 shows a typical scenario of routing in IoT. The source node requires certain service A so it generates a discovery process to find such a service. Each intermediate node forwards the request till it reaches destination node, this is the discovery process flow which is shown by black arrows. The destination node is the element of the network that can supply the required service. A route has to be established between the requesting node and destination node using a routing protocol. Several metrics are normally used to determine the quality of routes, such as hop count distance, end-to-end delay, and throughput. Due to mobility of nodes the topology of the system frequently changes, the routing protocol should be capable of identifying the changing topology and re-computing paths among available nodes. This frequent re-computation consumes considerable amount of node energy. Another issue of this discovery process is the huge number of request packets that are exchanged or forwarded between nodes. The main requirement of to prevent these problems is to reduce the number of redundant packets in the discovery process of routing protocols. Various routing approaches are:

1. Proactive approach

Proactive protocol maintains a list of destination nodes along with their routes in the routing table. These tables are exchanged throughout the network at regular intervals.

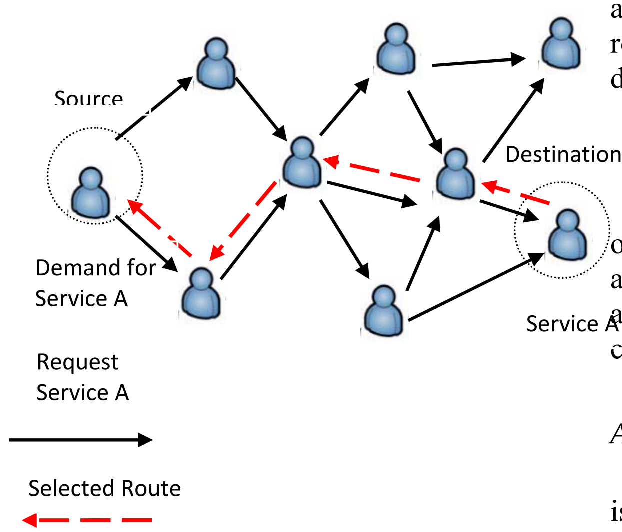

Fig. 1 Routing in IoT [5]

The drawback of this method is slow reaction to failures and huge amount of maintenance data. Examples of proactive algorithms include Optimized Link State Routing Protocol (OLSR), and Destination Sequence Distance Vector (DSDV).

2. Reactive approach

Reactive protocol determines a path to a node only when a route request (demand) packet to this node has been received. These request packets are flooded into the network. When a neighboring node receives this packet it responds by sending its routing table. Some of the examples of reactive algorithms include Ad hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR).

3. Hybrid approach

Hybrid protocol combines the techniques of proactive and reactive routing approaches. The initial anticipated route is computed using proactive algorithm and then serves the demand from additionally activated nodes through reactive flooding. Some of the examples of hybrid algorithms are Zone Routing Protocol (ZRP) and Zone-based Hierarchical Link State Routing Protocol (ZHLS).

The rest of this paper is organized as follows. In Section II, we present an overview on proactive and reactive routing approaches. Section III presents different power metrics that are used in the evaluation of best routing algorithm. Section IV shows how hybrid routing algorithms are better compared to proactive and reactive method. Finally, the conclusion is drawn up in section V.

II. RELATED WORK

Energy consumption in a network can be obtained by measuring various parameters such as energy consumed during transmit, receive and idle modes, total average energy, energy cost per packet, and packet delivery ratio.

A. *Proactive Routing*

Optimized link state Routing protocol (OLSR) is an optimization over the classical link state protocol, designed specially for mobile ad hoc networks. OLSR was proposed to improve QoS, load balancing and energy consumption [4]. OLSR does not require a central entity for computing paths. Each node sends control messages periodically and can face some reasonable loss, since OLSR does not use a reliable transmission mechanism. Paths are computed using a modification of Dijkstras algorithm, there are two main phases of the algorithm:

(i) Topology sensing, and

(ii) Route computation.

During the topology sensing phase the neighboring nodes and active links between them are discovered. This is done by periodic exchange of HELLO and TC messages. In the Route Computation phase nodes calculate paths from source to other nodes in the network. OLSR is a table driven protocol and exchanges topology information with other nodes of the network regularly. Each node selects a set of nodes as 'multi-point relays' (MPR) as shown in Fig. 2 below. Only nodes, selected as such MPRs, are responsible for forwarding control traffic, intended for diffusion into the entire network [5]. MPRs provide an efficient mechanism for controlled flooding by reducing the number of transmissions required and hence saving the energy in nodes.

B. Reactive routing AODV

In the reactive routing which is an on-demand approach, a route from a source to a destination is maintained only when a demand is generated and nodes do not discover each other unless the source node wants to communicate with the destination. When the local connectivity of the mobile node is of interest each mobile node can become aware of the other nodes in its neighborhood by the use of several techniques such as local broadcast of hello messages. The algorithms primary objectives are [9]:

• To broadcast discovery packets only when necessary
• To distinguish between local connectivity management neighborhood detection and general topology maintenance.
• To disseminate information about changes in local connectivity to those neighboring mobile nodes that are likely to need the information AODV uses a broadcast route discovery mechanism.

During the discovery phase a source sends a route request packet to its neighboring nodes requesting for path information. Each receiving nodes either responds by sending a route reply packet to the source which contains the required path information or continue forwarding the request packet to its neighbors. Each node receives a particular request packet only once; if a redundant copy of the request packet is received it simply drops it and saves energy by not forwarding duplicate request packets. Along with forwarding the request/reply packets the node keeps tracking the path information to build up forward and reverse path. Although the route discovery process is performed frequently, more so with increased node mobility, this approach generates low control overhead traffic in comparison to the proactive protocol.

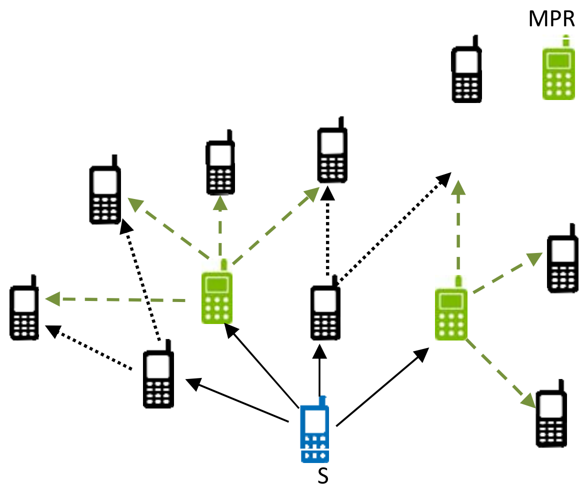

Fig. 2 MPR election in OLSR protocol

A mobile node maintains a route table entry for each destination of interest. Each route table entry contains the following information:

- Destination
- Next Hop
- Number of hops
- Metric
- Sequence number for the destination
- Active neighbors for this route
- Expiration time for the route table entry

AODV uses distance vector algorithm for selecting the path from source to destination. AODV does not incorporate any congestion control scheme, due to which its performance drops as the network scales. It also does not provide load balancing.

III. POWER RELATED ROUTING METRICS

The efficiency of a routing protocol in terms of power consumption can be improved using various power related metrics, which can also increase the lifetime of the network [6]. The depletion of a node’s energy can interrupt communication and, even worse, can cause network partitioning. Power-aware routing protocols typically use one or more power-related metrics to assess and select the optimal path in IoTs.

The node in a wireless network at any given time can be in one of the four states: transmit, receive, idle, and sleep. Moreover, each state consumes a different energy level. The total energy consumption for a node to transmit and receive a packet can be calculated as follows

$E\ total = E\ trans + E\ rec + E\ idle$ (1)

Where:

$E\ trans = P\ transmit * t$ (2)

$E\ rec = P\ receive * t$ (3)

$E\ idle = P\ idle * t$ (4)

t : is the duration of time for transmitting a packet

The following evaluation metrics were used:

(a) Energy consumption: The metric gives the average of energy consumed by each node in different states (transmit, receive and idle).

(b) Total Average Energy: The metric determines the total of the average consumed energy by each node at the end of the simulation. The total average consumed energy can be calculated as shown in (1).

(c) Energy Cost per Packet: This metric gives the ratio between the total consumed energy over the number of successfully received packets at the destinations.

(d) Packet delivery ratio: The ratio of the data packets successfully received at the destination

IV. PROPOSED SYSTEM

In the proposed system we use a hybrid routing protocol but instead of considering all active nodes in the network, the proposed system select nodes whose residual energy is greater than the threshold value. Where the threshold value indicates the energy required to keep the node active for some interval 't'. A mobile node which is close to depletion (i.e. node's residual energy < threshold) can soon become inactive and change the network topology, restarting the discovery process and wasting the computation done so far. Once the nodes are selected we apply a hybrid protocol such as ZHLS to compute routing paths. The overall life time of the network is increased by these two considerations.

(a) Node Level Topology

(b) Zone Level Topology

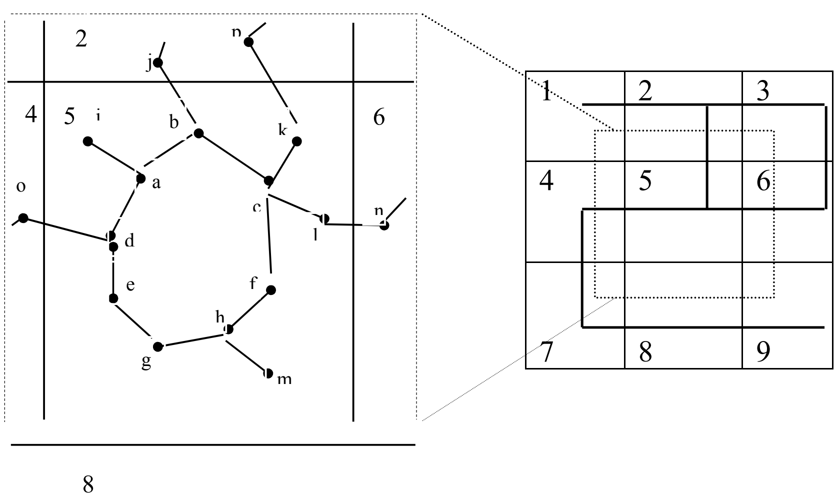

Fig. 3 ZHLS Network

ZHLS (Zone Based Hierarchical Link State Routing Protocol)

ZHLS is a hybrid routing protocol, which divides the network into various zones. Each node maintains intra-zone routing table and each zone has inter-zone routing table. ZHLS contains two topologies, a node level topology and a zone level topology as shown in Fig. 3 (a) and (b) respectively with an example network [12]. Fig. 3(b) shows division of network into 9 zones and the connection between various zones. Fig. 3(a) shows zone 5's node level topology. Nodes d, b, k and l act as gateways for zone 5, which forward packets between zones.

Node d broadcast a link request packet in the network for which the neighboring nodes o, e and a responds by flooding their NodeLSPs in the zone. When d receives all NodeLSPs it constructs an intra-zone routing table which is shown in Table 1. After each node receives all NodeLSPs from other nodes it constructs a ZoneLSP. ZoneLSPs are flooded to the entire network by gateway nodes.

ZoneLSP of node 5 in Fig. 3 is flooded by nodes k, b, d and l to zones 2,4and 6 respectively. When all nodes receive ZoneLSPs from all zones an inter-zone routing table is constructed as shown in Table 2. This reduction in the number of packet processing and controlled flooding significantly reduces the energy at each node.

Destination	Next-Hop Node
a	a
b	a
e	e
4	o
.	.
.	.

Table 1. A part of intra-zone routing table of node d

Destination Zone	Next Zone	Next-Hop Node
4	4	o
7	4	o
2	2	a
6	6	a
.	.	.
.	.	.

Table 2. A part of inter-zone routing table of node d

V. CONCLUSION

In Summary a node's energy consumption directly depends on the amount of processing carried out in it. In OLSR because of the proactive nature too many packets are exchanged and processed which reduces the lifetime of the network. In case of AODV based on reactive nature packets are exchanged only based on demand. Which in contrast reduces the no of control packets and performance of the network in terms of lifetime is better. However AODV does not scale well with the increasing size of the network. ZHLS overcomes the issues of both OLSR and AODV due to its hybrid nature. Even in case of large networks the intra-zone and inter-zone LSPs are less. Therefore it is more energy efficient and increases lifetime of the network. Hybrid algorithms are an excellent choice for energy constrained nodes in non reachable areas.

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