A Study On Energy Efficient Routing in Internet of Things

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Abstract: Internet of Things (IoT) enables network connectivity between smart devices at all times, everywhere, and everything. The routing of information from source to sink is the fundamental component of any large scale network. This network enables more reliability by providing congestion free, less packet loss and reduced delay rate. The redundant deployment of network equipment makes the network utilization is relatively low, which leads to a very low energy efficiency of networks. Non-uniform energy consumption and extensive use of limited energy resources are the common reasons behind developing new energy efficient routing algorithms and protocols. This paper focuses on a comparative study of different energy efficient routing mechanisms which can be used in IoT.

Keywords: Internet of Things, Routing in IoT, Clustering Method.

I. INTRODUCTION

Internet of Things (IoT) incorporates concepts from pervasive computing and enables interconnections of everyday objects equipped with ubiquitous intelligence, which becomes an integral part of the Internet. IoT has gained much attention from practitioners and researchers around the world, and spawned a wide variety of smart automated systems, such as smart buildings, smart homes, smart factories, and so on. Internet of things means anything, any object which can connected to the internet and these things can be accessed anywhere from the world at any time.

In Internet of Things most of the devices are battery powered, these battery powered nodes are active a long period, without any human control after the initial deployment. In the absence of energy efficient techniques, a node would drain its battery within few days. Even in communication, large amount of energy is wasted in states, such as collision, control packet overhead, interference etc. To minimize energy consumption and enhancing the network lifetime so many routing protocols are already designed. There are three types of routing methods based on network structure.

The scope of this paper is, Internet of things is the convergence of sensors, actuators and physical objects , which are connected by means of specific routing protocols. These protocols, been specific to Internet of things need to take care of efficiency in terms of energy.

Session2 presents routing factors. Session3 discusses about the routing protocols, whereas Session4 presents comparative analysis of routing methods based on different parameters. Session5 is the conclusion.

II. ROUTING FACTORS

Factors effecting of routing protocols

- Devices: May be of similar type or dissimilar types
- Manufactures: The manufacturers of these devices may be same or different.
- Network: The source and the destination may exist on the same or different networks.
- Connectivity: Connectivity between any two devices may be constant or intermittent.
- Resources Insufficient resources: Cooperation in data relaying Non-cooperation of devices due to resource constraints.
- Communication: Process changing mode of communication e.g. single hop or multi hop.
- Network topology: Frequently changing network topology due to mobile devices and resource constraints.
- Communication range: Variety of communication ranges among devices manufactured by different vendors.

III. ROUTING PROTOCOLS

- There are mainly two classes of routing protocols namely reactive and proactive. In case of a proactive protocol routing paths and states are setup before a demand for routing traffic arises. Paths are maintained even there is no traffic flow at that time. Reactive routing protocols on the other hand, trigger routing actions when data needs to be sent and disseminated to other nodes. Here paths are setup on demand when queries are initiated.
- Routing protocols are also classified based on whether they are destination-initiated or source initiated. Starting from the source node, routing paths are set up by a source initiated protocol up on the demand of the source. On the other hand, destination initiated protocol initiates path setup from a destination node.
- Routing protocols are also classified based on sensor network architecture are as follows

3.1 Location based routing

Location based routes are set by node locations. The space is divided into quadrants. Each node knows its position in its space. Because of application context, utilization of GPS is un realistic, consequently, sensors need to self-organize a coordinate system. The entire sensor network location algorithms impact principally three basic stages.
They are,

- Distance Estimation
- Position Computation
- Localization Algorithms

3.1.1 Location Based Protocols

A. Geographic Adaptive Fidelity (GAF)

Geographic adaptive fidelity [1],[4] is an energy aware routing protocol. The outline of GAF is focused around the energy model that contains energy consumption during the transmission and reception of packets as well as during idle time. State transition diagram of GAF consists of three states. They are active, sleep and discovery. In sleeping state sensor will turn off its antenna for energy savings. In discovery state a sensor trades exchange messages to look into other sensors in the same lattice. Even in the active state the sensor occasionally shows its discovery message to inform proportionate sensors about its state. The time used in each of the state will be depending upon few components like its needs and sensor mobility. Network lifetime is expanded by the GAF with a state where each grid is made of an active sensor around specific ranking rules. The highest rank will handle routing within their respective grids.
Advantages:

- Optimize the performance.
- Highly Scalable
- Maximize the network lifetime
- Limited energy conservation

Disadvantages

- High overhead
- Doesn’t take care of QoS during data transmission.
- Limited mobility
- Limited power management

B. Geographic and Energy-Aware Routing (GEAR)

GEAR [5] makes use of energy aware and geographically informed neighbor selection for performing routing of packets towards destination. The number of interests in directed diffusion is restricted by considering a specific region rather than the whole network. With this, GEAR is capable of conserving more energy. Every node in GEAR keeps the estimated and learning costs for reaching the corresponding destination. The estimated cost is the combined effect of residual energy and the average distance from the destination. A refinement of the estimated cost that accounts for routing around holes in the network is taken as the learned cost. When a node does not have any closer neighbor to the target, a hole occurs. When the network contains no holes the estimated cost is equal to the learned cost.
Advantages

- Increase the Network lifetime

- Reduces Energy consumption

Disadvantages

- Limited Scalability and Limited Mobility
- Limited Power management
- High overhead.
- Doesn't take care of QoS

C. Coordination of Power Saving with Routing(SPAN)

Coordination of Power Saving with Routing (SPAN) [6] is a type of protocol which is proposed primarily for MANETs and later it can also be applicable to WSNs as its aim is to reduce energy consumption. The design of SPAN is motivated from the fact that wireless networks are the most power consumable devices. Even though span doesn't require the sensors to know their location information it runs well with the geographic forwarding protocol. When the geographic forwarding protocol is used the Span selection rule requires every sensor to display its status to the neighbors and also to its coordinators.

Additionally, when it receives a packet, a coordinator forwards the packet to a neighboring coordinator if any, which is the closest to the destination or to a non- coordinator that is closer to the destination. Span adaptively elects coordinators from all nodes in the network, and stay awake continuously and perform multi-hop packet routing within the ad hoc network, while other nodes remain in power saving mode and periodically check if they should wake up and become a coordinator.

Advantages

- Reduces the energy consumption of nodes
- Less overhead and Supports data aggregation

Disadvantages

- Scalability is limited
- High overhead

No Quality of Service

D. Minimum Energy Communication Network (MECN)

The basic concept behind MECN [7] is the establishment of a Sub-network where the number of nodes is less and less power is needed for the transmission of data between nodes. MECN routing scheme works on the concept of relay region. A relay region is developed in the surroundings of each node. Relay nodes are the intermediate nodes present in between the source and the destination. MECN uses these relay nodes in order to reach the destination. A region is selected so that there are less nodes and less energy is required for transmission.

MECN works in two steps:

1. Sparse graph construction.

2. Optimal links search.

Advantages

- Maintains energy network with low power
- Fault tolerant

Disadvantages

- Fault tolerant depends upon specific application

E. Small Minimum Energy Communication Network (SMECN)

SMECN [7] [20] is a routing protocol used as an improvement to MECN. Here, a minimal graph is regarded as the minimum energy constraint. This property implies that for any pair of sensors in a graph associated with a network, a minimum energy-efficient path is present between them. In this protocol, using some initial power constraint, each sensor discovers its immediate neighbors by broadcasting a neighbor discovery message.

Advantages

- Less Energy than MECN 2.Links maintenance cost is less

Disadvantages

- Maximum power usage
- Number of broadcast messages is large

Table 1. Comparison of location based Routing

SL. No	Routing Technique	Advantages	Disadvantages
1	GAF[1] [4]	1.Highly Scalable 2.Maximize the network Lifetime 3.Limited energy conservation	1.High Overhead 2.Doesn't take care of Qos during data transmission 3.Limited Mobility 4.Limited power management
2	GEAR[5]	1.Increase the network lifetime 2.Reduces energy consumption	1.Limited Scalability 2.Limited Mobility 3.Limited Power management 4.High Overhead 5.Doesn't take care of Qos
3	SPAN[6]	1.Reduce the energy consumption of nodes 2.Support data aggregation	1.Scalability is limited 2.High overhead 3.No quality of service
4	MECN[7]	1.Maintains energy of network with low power 2.Fault tolerant	Fault tolerant depends upon specific application
5	SMECN[7] [20]	1.Less energy than MECN 2.Link maintenance cost is less	1.Maximum power usage 2.Number of broadcast message is large

3.2 Flat Based Routing

In flat network routing, nodes communicate in an ad-hoc way and they reach the base station (BS) by multi-hop routing. If a far node tries to reach the sink it needs to find an optimal or efficient (context routing) path. Information/ Data is centralized at the BS.

3.2.1. Flat Based Routing Protocols

A. Sensor Protocols for Information via Negotiation (SPIN)

Sensor Protocols for Information via Negotiation (SPIN) [2] [8] is an adaptive protocol that disseminates all the information at each node to every node in the network assuming that all nodes in the network are potential BSs. These protocols make use of the property that nodes in close proximity have similar data, and hence there is a need to only distribute the data to other nodes that do not possess. The SPIN family of protocols uses data negotiation along with resource-adaptive algorithms. Those nodes which run SPIN are assigned with a high-level name for describing their collected data and to perform metadata negotiations before data transmission. This ensures that no redundant data is sent in the network. The semantics of the meta-data format is application-specific, not specific to SPIN.

Advantages

- Save energy

- Metadata Negotiation Disadvantages

- Lack of proper delivery of Data

Disadvantages

- Lack of proper delivery of Data

B. Directed Diffusion

Directed diffusion [9] is a data-centric paradigm where all data generated by sensor nodes is named using a pair of attribute and value. The main idea of this is to combine the data coming from different sources in-network aggregation by minimizing redundancy and number of transmissions, hence saving energy and prolonging the lifetime. In contrast with traditional end-to-end routing, this mechanism finds routes from multiple sources to a single destination that allows in-network consolidation of redundant data.

In directed diffusion, as the interest is propagated throughout the network, gradients are set up to draw data which satisfies the query. Each sensor after the reception of the interest sets up a gradient for the sender. This process continues till full gradients are set up from the sources to the base station.

Advantages

- Lowest average dissipated energy
- Scalability

- Possible retransmission

Disadvantages

- Total energy communication is high
- Setup phase is expensive
- Periodic broadcast leads to reduced network lifetime

C. Rumor Routing

Rumor routing [10] is similar to directed diffusion, and it is aimed for applications for which geographic routing is not possible. Long-lived packets called agents are employed for flooding the events. When an event is detected, the node adds the event to its local table, called events table, then it generates an agent.

Agent travels the network to transit information regarding local events to all nodes. The nodes that know the route may respond to the query, when a node generates a query for an event. Hence, there is no need to broadcast the entire network, reducing the cost. On the other hand, rumor routing maintains only one path between source and destination. Rumor routing can achieve significant energy savings compared to event flooding and can also handle a node's failure.

Advantages

- No need to flood the event
- Low communication Cost

- Better energy saving

Disadvantages

- Suitable for small number of event condition

D. Gradient-based routing

Gradient Based Routing [11] is a variant of directed diffusion. GBR memorizes the number of hops when the interest is diffused in the entire network. Likewise, each node calculates the height of the node, (minimum number of hops to reach the BS). The difference between a node's height neighbor's heights is taken as the gradient of the link. A packet is forwarded through the link with maximum gradient. When multiple paths exist, the relay node combines data according to a function. The main objective of this scheme is to get a balanced distribution of traffic in the network.

Advantages

- Balanced distribution of traffic
- Increase network Lifetime
- Better total communication Energy than Directed Diffusion

Disadvantages

- Number of transmissions are high

E. COUGAR

COUGAR [12] [20] views the network as a huge distributed database system. The key idea is to use declarative queries in order to abstract query processing from the network layer functions such as selection of relevant sensors and so on. COUGAR makes use of in-network aggregation of data for obtaining more savings in terms of energy. It is achieved by a separate query layer between the network and application layers. The architecture provides in-network computation ability for the provision of energy efficiency when generated data is huge. It also provides a independent method for data query.

Advantages

- Network data aggregation
- More energy saving
- Provides Network layer independent method

Disadvantages

- Overhead in Memory storage and Energy Consumption

F. Energy Aware Routing

Energy-Aware Routing [13] protocol is a destination initiated reactive protocol, is to increase the network lifetime. Although this protocol is similar to directed diffusion, it differs in the sense that it maintains a set of paths instead of maintaining or enforcing one optimal path at higher rates. These paths are maintained and chosen by means of a certain probability. The value of this probability depends on how low the energy consumption is that each path can achieve. By having paths chosen at different times, the energy of any single path will not deplete quickly. This can achieve longer network lifetime as energy is dissipated more equally among all nodes. The protocol initiates a connection through localized flooding, which is used to discover all routes between a source/ destination pair and their costs, thus building up the routing tables. High cost paths are discarded, and a forwarding table is built by choosing neighboring nodes in a manner that is proportional to their cost. Then forwarding tables are used to send data to the destination with a probability inversely proportional to the node cost.

Advantages

- Increases Network Lifetime
- Maintain a set of path instead of one optimal path
- Better energy efficiency

Disadvantages

- Require gathering of location information and setting up of addressing mechanism- leads to complicate route setup

Table2. Comparison of flat based routing

SL. No	Routing Technique	Advantages	Disadvantages
1	Flooding	Simple Protocol	1.Implosion 2.Resourse Blindness 3.Overlap 4.Hgh energy consuming
2	Gossiping	Better energy efficiency than flooding	Increased propagation delay
3	SPIN[2] [8]	1.More energy saving than gossiping	Lack of proper delivery of data

		2.Metadata negotiation	
4	Directed Diffusion[9]	1.Lowest average energy dissipation 2.Scalability 3.Retransmissions are possible	1.Total energy for communication is high 2.Setup phase is expensive 3.Periodic broadcast leads to reduced network lifetime
5	Rumor Routing[10]	1.No need to flood the event 2.Low communication cost 3.Better energy saving	Suitable for small number of event condition
6	COUGAR[12] [20]	1.Network data aggregation 2.More energy saving 3.Provide network layer independent method	Overhead in memory storage and energy consumption
7	Energy Aware Routing[13]	1.increases network lifetime 2.maintain a set of path instead of one optimal path 3.Better energy saving	Require gathering of location information and setting up of addressing mechanism

3.3 Hierarchical Based Routing

In hierarchical networks, nodes cannot communicate directly. They are all controlled by a local base station called cluster head (CH). Large networks can be divided into clusters and interconnect through CH. Paths are defined by CHs. This is a managed service complete with full infrastructure.

3.3.1 Hierarchical Based Routing Protocols

A. Low-Energy Adaptive Clustering Hierarchy (LEACH)

Low Energy Adaptive Clustering Hierarchy (LEACH) [3] [14] is the first energy efficient routing protocol for hierarchical clustering. The LEACH protocol forms clusters in the sensor networks and randomly selects the Cluster-heads for each cluster. Non cluster-head nodes sense the data and transmit to the cluster-heads. The cluster-heads aggregate the received data and then forward the data to the sink. The basic principle is that it assigns overall energy consumption of the network uniformly to each sensor node through periodically selecting different nodes as cluster-head. This results in survival time of nodes being very close to the lifetime of network. This reduces the energy consumption and the lifetime of the entire network is prolonged. In the steady-state phase, the data from non-cluster heads are transmitted to the sink. The sensor nodes communicate to the cluster-heads using TDMA schedule. The nodes communicate to the cluster-head only in their allotted slots. It avoids collision. The cluster-heads are selected randomly for every round.

Advantages

- Incorporates data fusion into routing protocols
  *Amount of information to base station reduced
- Prolonging network lifetime due to effective communication over direct

Disadvantages

- Only single hop clusters formed
  *Might lead to large number of clusters
- No discussion on optimal CH selection

B. Power-Efficient GAthering in Sensor Information Systems (PEGASIS)

The main idea in PEGASIS [15] is that each node receives from and transmits to close neighbors. This approach helps in distributing the energy load evenly amongst the sensor nodes using the greedy algorithm. Alternatively, it computes the chain and broadcast it to every node. This chain is constructed by assuming all the nodes are having the global knowledge regarding the whole network.

Aadvantages

- PEGASIS improves on LEACH by saving Energy in several steps

1. In the Local gathering ,the distances the most of the nodes transmit are much less compared to transmitting to a cluster head in LEACH

2. Only one node communicates to the Base station in each round of communication.

Disadvantages

- As it uses Greedy Algorithm for the formulation of data chain will result a long chain.
- Consuming more energy due to which node die. Data transmission will produce time delay.

C. Threshold sensitive Energy Efficient sensor Network protocol (TEEN)

A reactive network protocol called TEEN [16] is Threshold-sensitive Energy Efficient sensor Network. In Reactive Networks, sensor nodes continuously sense the environment and transmit the value as soon as the sensed parameter exceeds a user specified threshold value. This enables time critical data1 to reach the user almost instantaneously, making such a network most suitable for time critical applications. TEEN protocol has been developed specifically for such networks. However, if the thresholds are not reached, the user cannot determine the state of the network, making it inadequate for applications that require periodic data from the network. In this scheme, at every cluster change time, in addition to the attributes, the CH broadcast the following message to its members:

1. Hard threshold (HT)

2. Soft threshold(ST)

Advantages

- Suited for time critical data sensing applications.
- Energy consumption is less than in the proactive network, because data transmission is done less frequently.
- Soft threshold can be varied, a smaller value of the soft threshold gives a more accurate picture of the network

Disadvantages

- If the thresholds are not reached, the user will not get any data from the network at all and will not come to know even if all the nodes die.

This scheme practical implementation would have to ensure that there are no collisions in the cluster.

D. Adaptive periodic threshold sensitive energy efficient sensor network (APTEEN)

Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network Protocol (APTEEN) [17] is introduced for hybrid networks. There are applications in which the user wants time critical data and also wants to query the network for analysis of conditions other than collecting time critical data. None of the above sensor networks can do both jobs satisfactorily since they have their own limitations. APTEEN is able to

- Combine the best features of proactive and reactive networks while minimizing their
- Limitations to create a new type of network called a hybrid network. In this network, the
- Nodes not only send data periodically, they also respond to sudden changes in attribute values.

Advantages

- Combines both proactive and reactive policies.
- Offers a lot of flexibility by allowing the user to set the CT interval
- The threshold values for energy consumption can be controlled by changing the CT as well as the threshold values.

Disadvantages

- Additional complexity required to implement the threshold functions and CT.
- Overhead and complexity of forming Clusters.

E. Energy Efficient Clustering Scheme protocol (EECS)

EECS [18] [21] is a clustering scheme, where the network is divided into a number of clusters with one cluster head each. Communication between cluster head and BS is single-hop. During network deployment phase, the base station broadcasts a message with a certain power level. By this way each node can compute the approximate distance to the BS based on the received signal strength. It helps to select the proper power level to communicate with the BS. It will use this distance to balance the load among cluster heads. During cluster head election, cluster heads are elected with small control overhead.

Advantages

- EECS produces a uniform distribution of cluster heads across the network through localized communication with little overhead.
- EECS prolongs the network lifetime
- Total energy is efficiently consumed

Disadvantages

- In large network the single hop communication will result overhead and complex.

F. Hybrid Energy Efficient Distributed Clustering Protocol (HEED)

HEED [19],[22] extends the basic scheme of LEACH using residual energy as the main parameter along with network topology features like degree of the node, distance to neighbors etc used as secondary parameters. Cluster head selection is dependent on the residual energy of individual nodes. Since the energy consumed for sensing, processing, and transmission is known, residual energy can be estimated. Intra cluster communication cost is considered as the secondary parameter to break the ties. A tie indicates the chance for a node falling in the range of separate cluster heads. When there are cluster heads, the cluster head with lower intra-cluster communication cost is selected.

Advantages

- Balanced clusters
- Low message overhead
- Uniform & non-uniform node distribution
- Inter cluster communication explained
- Out performs generic clustering protocols on various factors

Disadvantages

- Repeated iterations
- Complex algorithm
- Decrease of residual energy
  * Smaller probability
  * Number of iterations increased
- Nodes with high residual energy one region of a network

Table 3. Comparison of Hierarchical based routing

SL .No	Routing Technique	Advantages	Disadvantages
1	LEACH[3],[4]	1.Incorporates data fusion into routing protocols 2.Prolonging network lifetime due to effective communication over direct	1.Only single hop clusters formed 2.Optimal CH selection is not discussed 3.All CHs should directly transmit the data to the sink
2	PEGASIS[15]	1.PEGASIS improves on LEACH by saving energy in several steps * Transmission distance is less as compared to LEACH * Only one node communicate to the base station in each round of communication	1.As it uses Greedy it will result a long chain. 2.Consuming more energy due to which node die. 3.Data transmission will produce time delay
3	TEEN[16]	1.Suited for time critical data sensing applications 2.energy consumption is less than in the proactive network, because data transmission is done less frequently. 3.A smaller value of the soft threshold gives a more accurate picture of the network.	1.If the thresholds are not reached, the user will not get any data from the network at all and will not come to know even if all the nodes die. 2.This scheme practical implementation would have to ensure that there are no collisions in the cluster
4	APTEEN[17]	1.Combines both proactive and reactive policies 2.Offers a lot of flexibility by allowing the user to set the critical time interval. 3.The threshold values for energy consumption can be controlled by changing the critical time as well as the threshold values.	1.Additional complexity required to implement the threshold functions and critical time. 2.Overhead and complexity of forming the clusters
5	EECS[21]	1.A uniform distribution of cluster heads across the network 2.Prolongs the network lifetime 3.Total energy is efficiently consumed	In large network , the single hop communication will result overhead and complex
6	HEED[22]	1. Balanced Clusters 2. Low message overhead 3. Uniform and non-uniform node distribution 4. Inter cluster communication explained 5. Out performs generic clustering protocols on various factors	1.Repeated iterations 2.Complex algorithms 3.Decrease of residual energy * Smaller probability * Number of iterations increased 4.Node with high residual energy on one region of a network.

IV. COMPARATIVE ANALYSIS

The comparative analysis of three different types of routing algorithms are given below

4.1 Parameter based Comparative Analysis based on the Location Based Routing

Table 4. Parameter based comparative analysis on the Location based routing

Routing	Classification	Mobility	Power	Data	Over	Scalability	Multi	Network	Energy

Technique			Usage	Aggregation	head		path	Lifetime	Consumption
GAF	Location	Limited	Limited	NO	Medium	Yes	NO	High	Limited
GEAR	Location	Limited	Limited	NO	Medium	Yes	NO	Medium	Limited
SPAN	Location	Limited	Medium	Yes	Low	Yes	Yes	Medium	Medium
MECN & SMECN	Location	Limited	Medium	NO	Low	Yes	NO	Low	Medium

4.2 Parameter based Comparative Analysis based on the Flat Based Routing

Table 5. Parameter based Comparative Analysis based on the Flat Based Routing

Routing Technique	Classification	Mobility	Power Usage	Data Aggregation	Over head	Scalability	Multi path	Network Lifetime	Energy Consumption
SPIN	Flat	Possible	Limited	Yes	Low	Yes (Limited)	Yes	Medium	Medium
Directed Diffusion	Flat	Limited	Limited	Yes	Low	Yes (limited)	Yes	Medium	Medium
Rumor Routing	Flat	Very Limited	Medium	Yes	Low	No	No	Low	Low
GBR	Flat	Limited	Limited	Yes	Medium	No	No	Medium	Limited
	Flat	Limited	Medium	No	High	Yes	Yes	Medium	Medium

4.3 Parameter based Comparative Analysis on Hierarchical Based Routing

Table 6. Parameter based Comparative Analysis based on the Hierarchical Based Routing

Routing Technique	Classification	Mobility	Power Usage	Data Aggregation	Over head	Scalability	Multi path	Network Lifetime	Energy Consumption
LEACH	Hierarchical	Fixed BS	Maximum	Yes	High	Good	No	High	High
PEGASIS	Hierarchical	Fixed BS	Maximum	No	Low	Good	No	High	High
TEEN & APTEEN	Hierarchical	Fixed BS	Maximum	Yes	Medium	Good	No	Low	Low
SEP	Hierarchical	Fixed BS	Limited	Yes	High	Good	No	Low	Low
EECS	Hierarchical	Fixed BS	Minimum	No	Low	Low	No	Low	Low
HEED	Hierarchical	Fixed BS	Maximum	Yes	Medium	Good	No	Medium	High

V. CONCLUSION

Internet of Things is the collection of large number of devices. Routing of data from source to destination have greater impact on the communication. Because of limited energy recourses , energy efficient routing have an important role. In this paper, proposing a comparison of different routing techniques. By comparing with all of the routing methods, hierarchical based clustering are more energy efficient than others. This can improve the life time and performance of the network.

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