Composite and Hybrid Routing Protocol for Wireless Sensor Networks with Mobility Consideration

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Abstract:- Due to the rapid advancement in Wireless Sensor Network, it is very essential to focus on efficiency in performance of the sensor networks. We design a hybrid routing protocol for wireless sensor network with mobility consideration. The protocol selects the route by three factors; cluster formation, cluster head selection and determining the sink node position based on its load. Cluster head selection is based on the residual status of node regarding load and energy. This protocol improves the network performance and reduces the packet loss by removing the congested and constrained nodes from routing path. Moreover, it improves the network lifetime by dynamically changing the sink node position based on the status of its neighbor node load status. Thus this paper deals with the design and development of hybrid routing protocol for WSN with mobility of sink node in multi hop communication environment.

Keywords: Hybrid Routing Protocol; Mobility; Cluster; Sink Node; Congestion;

I. INTRODUCTION

Wireless Sensor Networks (WSN) is an emerging area of research and development as it is being implemented in large number of applications. WSN has interconnected devices operated by battery with low power signal processing and wireless transceiver. Basically WSNs are comprised more than one sink and large number of sensor nodes [1]. A sensor node collects data and transmits the information either in compressed or aggregated form to neighboring nodes. Thus each node acquires a view of monitored space which can be accessed by devices connected externally through some gateway nodes in WSN.

A network consists of mobile devices that communicate via radio transceiver along a multi hop path. Ad-hoc network is used where wired setup is not feasible [2]. Two or more devices exchange information by using radio signal and are called nodes. The development of WSN was initiated for military purpose but nowadays WSNs have become pervasive.

In literature lot of routing protocols [3] have been proposed to extend the lifetime of network. One such routing protocol is energy aware routing protocol. This protocol selects routing based on higher energy nodes routing path. Source sends the information to destination by sending the data to higher energy neighbor nodes. However these types of routing protocols reserve a particular node for communication purpose. If a node is receiving packets from multiple sources due to its higher energy and insufficient buffer space, the packets get drop. Thus these routing protocols creating a load balancing issue, which interns causes the packets drop. This type of situation in network is known as bottleneck [4]. From above discussion we needs a routing protocol which address the three issues

- Energy efficiency
- Load balancing
- Mobility

While selecting the neighbor node of sender it needs to check the two factors namely energy and load. Thus in this paper, we develop a routing protocol which selects a routing path by considering the energy and load of the neighbor nodes. In order to achieve our goal, we first calculate the reactive status of node regarding buffer and then we calculate proactive status of node regarding energy. Thus our proposed routing protocol is hybrid routing protocol as it is a combination of reactive and proactive status of energy and buffer of an intermediate nodes.

In order to overcome the problem of bottleneck intermediate node, the appropriate solution is to change the sink node position based on the status of sink node intermediate node with respect to energy and load. Thus we design a routing protocol to extend the energy efficiency and network lifetime by mobile sink named as Composite and Hybrid Routing Protocol for WSN with Mobility consideration (CHRPM), which performs better in terms of lifetime, energy consumption and mobility.

Remaining paper is organized as follows. Next section discuss about the LEACH routing protocol designed for WSN and random mobile sink routing protocols along with mentioning literature of other related protocols. Section III discuss about proposed routing protocol i.e., CHRPM. The paper ends with Simulation Results followed by Conclusion.

II. RELATED WORK

LEACH is Energy efficient hierarchical clustering protocol. It is design for minimizing power utilization. It is designed for prolonging life of the network. It randomly selects the cluster head from a set of clusters. Routing information is forwarded from cluster heads. Cluster heads are responsible for reducing energy utilized by the nodes present in the cluster. With the help of local coordination that restricts the amount of data forwarded to sink. It also makes the routing strong and scalable. Leach uses fusion technique. This technique aggregates the data and communicates only useful information to all nodes. Cluster heads responsibilities are changes among nodes inside the cluster to avoid energy depletion. LEACH works in two phases.

Phase 1: First phase deals with forming clusters, selecting cluster head and preparation of transmission schedule.

Phase 2: Second phase deals with data fusion, data compression and transmission of data to the sink.

LEACH is distributed protocol which requires no prerequisite knowledge of the network. It uses single hop routing from source node to cluster head, and from cluster head to the sink. Cluster head needs to spent more energy, in case of the source is far away from sink. It happens because of dynamic clustering.

LEACH routing protocol [5] is based on time division multiple access based routing protocol. The principle point of this routing protocol is to enhance the network lifetime by reducing the energy consumption. The protocol comprises of two stages i.e., set up phase and steady phase. Protocol operation consists of several stages with two rounds in each stage, and it is hierarchical structure. This protocol is self-organized and adaptive.

LEACH protocol is cluster based routing protocol for WSN. The aim is to randomly select the sensor nodes as cluster head and uses them to router to sink node. Cluster head selection is changed based on remaining energy consumption of node in particular time period. The threshold value for selecting the cluster head is based on the following formula, i.e., $T(n)$.

$$T(n) = \begin{cases} \frac{p}{1-p\times[r \bmod(1/p)]}, n\in G \\ 0, others \end{cases} \quad (1)$$

Where,

$p = desired\ percentage\ to\ be\ a\ CH$

$r = current\ round$

$G =$ set of nodes that have not been cluster-heads in the last $\frac{1}{p}\ rounds$

Random mobile sink routing protocols

The random waypoint model is a model for the mobile users and about their locations. Mobility model is used for simulation purpose for new protocol being evaluated. Random waypoint model is famous mobility model to evaluate networks and protocols. It is simple and easily available. In this model mobile nodes move randomly. Here destination, speed and direction are selected randomly.

The work by Chatzigiannakis [6] explores the possibility of using the coordinated motion of a small part of users in the network to achieve efficient communication between two other mobile nodes. Basically, a part of the network nodes act as forwarding agents carrying packets for other nodes. The packet is exchanged when the source node and the agent are neighbors and it is then delivered to the intended destination when the agent passes by it. This basic idea has been introduced to WSNs by Shah in his work on *data mules* [7]. Mobile nodes in the sensor field, called mules, are used as forwarding agents. The idea here is to save energy by having single-hop communication (from a sensor to the mule that is passing by) instead of the more expensive multi-hop routing (from the sensor to the sink): It is the mule that will eventually take the sensed data to the sink. This approach has been further investigated by Kimet, which proposes a dissemination protocols in which a tree-like communication structure is built and maintained and mobile sinks access the tree from specified sensor nodes in the tree.

Energy consumption optimization is needed for synchronization of life of network. Load balancing is crucial for life of WSN and node having heavy load will consume energy quickly. Energy efficient consumption scheme and high lifetime of network by load balancing by applying the technique of sub network is proposed in reference [8]. This scheme proposes load balancing of individual node is to maximize system life. It manages sub network.

In [9], the authors proposed a hybrid routing algorithm for wireless sensor networks. They proposed mobility aware multi objective hybrid routing algorithm for WSN. This algorithm selects the best route and forwards the data packet from source to sink using multiple metrics such as average consumption of energy, control overhead reaction time, LQI and hop count. This algorithm proposed a novel two-tier cluster based algorithm in order to make MWSN more efficient in terms of amount of consumption of energy, packet delivery ratio and jitter. It evaluates regularly for different route and picks the best in two phases.

i. Setup phase: Routing tables are setup at each sensor node.

ii. Data Communication phase: Data sent from source to sink. This is when paths are chosen with respect to weighted average of many metrics.

The authors of [10] proposed a hybrid routing protocol for WSN with mobile sink. It is a combination of reactive and proactive approaches and hence called hybrid. It enhances the existing protocol efficiently by taking care of multiple sinks random movements. There are multiple mobile sinks in networks that change their positions randomly. It enable node to start a demand discovery for nearest sink in the zone. It also predicts future location by estimating speed and previous position of moving sink. It helps in reducing traffic, reducing load of network and hence result in less congestion.

The protocol, termed SEAD (Scalable Energy-Efficient Asynchronous Dissemination) demonstrates the effectiveness of deploying mobile sinks for energy saving with respect to the static case via simulation. SEAD is shown to be more effective for energy conservation than directed diffusion [11], TTDD [12] and ADMR [13].

In all these works, the mobility of the sink is unpredictable, for instance, sinks move according to the random way point model. A first attempt on how to determine specific sink movements for energy minimization is presented in [14]. The authors present an ILP (Integer Linear Programming) model to determine the locations of multiple sinks in the case multi-hop routing to the sink is allowed. The model aims at minimizing the energy consumption per node and the total energy consumption during a given time. The authors argue that minimizing the energy consumption yields to improved network longevity. In order to obtain stronger energy saving results, the authors consider the presence of multiple sinks in the network. The ILP model is used to determine feasible locations.

In this paper, we are concerned with the joint problems of determining the movements of the sink and the times the sink rests at certain network nodes so that network lifetime is maximized. Moreover, proposed method uses the cluster based approach to implement the CHRPM, where sink changes its position based on the node status with respect to load and energy.

III. PROPOSED MODEL

Proposed protocol is an extension of the existing energy efficient routing protocol LEACH designed for WSN.

A network consists of many clusters of sensors in hierarchical routing. Every cluster has a cluster head. Cluster head is responsible for overall activities of sensors in the particular cluster. Hierarchical routing protocols provide scalability, less energy, less load and more robustness.

TEEN is also a hierarchical clustering protocol. It combines sensors into clusters with each group headed by a cluster head. The sensors inside a cluster exchange their sensed data to their cluster head. After getting the data from sensors, the cluster head sends aggregated data to a head in the higher level until the data reaches to sink. Thus the architecture of network in this protocol is based on hierarchical grouping. Here, sensor nodes form clusters and the process continues till sink gone to the second level. This protocol is useful for application where users manage efficiency of energy, accuracy of data and response time effectively.

Hybrid Energy Effective Distributed Clustering protocols extends the basic idea of LEACH by using residual energy for cluster selection to maintain power balancing [15]. HEED operates in multi hop network by using transmission power in the inter-clustering communication. HEED is proposed with four goals.

i. Extending network lifetime by dividing energy consumption.
ii. Terminate the process of clustering within a constant number of iterations.
iii. Reducing control overhead.
iv. By producing distributed cluster heads.

APTEEN is hybrid clustering based routing protocol which allows the sensor to forward sensed data over a particular amount of time, as well as react to any sudden changes in sensed attributes. This will be reported to their cluster heads [16]. TEEN and APTEEN architectures area same. They use the concept of hierarchical clustering for efficient energy communication between source sender and sink. APTEEN guarantees a large number of sensors alive by lowering energy consumption. Here cluster heads calculates data aggregation to save energy.

After the clusters are formatted, the cluster-head node creates a TDMA [17] schedule noticing each node when it can transmit data to the cluster-head [6]. The cluster-head also aggregates the data before transmitting these data to the sink.

We consider the random way point mobility model for sink mobility to communicate with intermediate node. Thus mobile node stay at particular place for some interval of time for communication then change its location by random way point mobility model. After this interval of time node change the position to other intermediate node based on node status. Initially sink select the node randomly for its first time and move nearer towards it and communicate through it. Then sink node selects the new intermediate node for communication and moves towards it by random way point mobility model.

Most of the existing routing protocols deal with sensor nodes that do not move and are un-replaceable, where the sensed data have to be delivered to the sinks that are static as well. A trend of the research on data dissemination in WSNs has recently started where the mobility of some of the nodes is exploited to facilitate the delivery of the sensed data to the sinks. The primary objective of these works is to deliver messages in disconnected ad hoc networks and to improve network throughput.

Energy and Load awareness

The aim of proposed routing protocol selects the neighbor node of mobile sink node based on its buffer and energy status so that intermediate node must not drop the packets and also should not exhaust. Here we consider the two considerable parameters in a single process to calculate the routing path between communication entities. Cluster head must compute the status regarding energy and buffer or load. In this work we computed it proactively as, maximum number of packets it can process (receive, proceed and transmit) within its available energy. Every node in a network needs to calculate its load status. In this work we computed it reactively as, the queue present in a node is less than or greater than predefined threshold value. Two factors are used to remove node to become bottleneck intermediate node there by reducing packet loss.

Proactive status of node regarding energy

Reducing the packet drop by an intermediate node due to its constraint energy is overcome by the multi objective optimization process. That is capacity optimized maximum packets can be processed by an intermediate node in its current battery of energy. Let us consider that an intermediate node equipped with a battery capacity (E) joules, and it can be processed maximum of $'n'$ number of packets in its current battery of energy.

Multi objective optimization

1. Energy of node
2. Energy is required to process the packet

Energy consumed by an intermediate node for processing one packet let $'P_1'$ is computed by, equation 1.

$$E(P_1) = E_r(P_1) + E_p(P_1) + E_t(P_1) \ldots\ldots\ldots(1)$$

Where,

$E_r(P_1) = energy\ require\ to\ recive\ the\ packet\ 'P_1'$

$E_p(P_1) = energy\ require\ to\ process\ the\ packet\ 'P_1'$

$E_t(P_1) = energy\ require\ to\ transmit\ the\ packet\ 'P_1'$

Now remaining energy of node after processing $'P_1'$ packet is given by equation 2.

$$E(residual) = E - E(P_1) \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

In order to compute the capacity optimized maximum packets can be processed by an intermediate node in its current battery of energy is achieved by two dimensional array with entries, as given below.

$$K\,[P_i\,, E(residual)\,] \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where $i = 1,2, \ldots .\ number\ of\ packets$

$E(residual) = energy\ required\ to\ process\ the\ packet$

Computation of capacity of optimized maximum packets can be processed by an intermediate node in its current battery of energy is given by equation 4

$$K\,[P_i\,, E(residual)\,] = \max(K\,[P_i - 1\,, E(residual)]\,, K_i + K\,[P_i - 1\,, E(residual)]) \ldots\ldots\ldots(4)$$

$$\forall\ 1 \le P_i \le n$$
$$and$$
$$0 \le E(residual) \le E$$

Here $K\,[P_i\,, E(residual)\,]$, provides the capacity of optimized maximum packets can be processed by an intermediate node in its current battery of energy.

Reactive status of node regarding Load

Reducing the packet drop by an intermediate node due to its buffer overflow is overcome by the queuing mechanism. An intermediate node reactively calculates its buffer status by number of packets arrived in current interval of time as well as number of packets departure from node. If packet arriving rate is greater than its departure rate then packets will get drop from an intermediate node. If the arrival rate is less than departure rate then queue is created at node buffer based on difference between arrival and departure rate. Node compute arrival and departure rate using exponential moving average method.

Packet arrivals or departures at time zero or no packet arrival or departure in previous time interval as event zero. Weighted constant values are decided based on time constant of receiving circuit. Number packets queued at an intermediate node is computed by queuing theory by equation 5.

$$\text{queue size} = \text{Average Packet Departure}/(\text{Average Packet Departure rate} - \text{Average Packet Arrival rate}) * \text{bytes} \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

If queue size is greater than the buffer packet holding capacity then packet drop from node. Thus while selecting an intermediate node, source node must consider the two factors such as buffer and energy so as to reduce the packet loss in network there by enhance the network performance and efficiency.

Mobile sink node maintains the distance table of the cluster head location nodes in its memory table. Initially network creates a cluster based network model with the help of existing LEACH protocol. Then mobile sink node moves randomly using random way point mobility model to collect the location of cluster head. Then cluster head computes the average distance between cluster heads by following equation 5.

$$D_{avg} = \frac{\sum_{i=0}^{m-1} \sqrt{(X_i - X_c)^2 + (Y_i - Y_c)^2}}{m-1} \quad i \neq c$$

Where, $(X_i, Y_i) = Location\ of\ the\ cluster\ head$
$(X_c, Y_c) = Location\ of\ the\ current\ CH$
$m = Total\ number\ of\ cluster\ heads$

After particular time interval the memory table of mobile sink node is updated or it also updated whenever new cluster head is selected. Mobile sink selection about intermediate node/cluster head is made by two factor energy and load, which is calculated above in the section, and moves towards it for communication. The control packets are used to inform the cluster head that the mobile sink is visited to it. Every cluster head in LEACH protocol acts for particular amount of time. If new cluster head is elected for the cluster then mobile sink compare its residual status with remaining cluster heads residual status, if it find the another node has better status than current cluster head status. Then cluster head moves towards new cluster head and this process is go on.

The proposed algorithm is explained as follows

1. Divide the network into clusters and select the cluster head based on LEACH routing protocol
2. Cluster heads compute their current status of load and energy.
3. Mobile sink calculates the cluster head distance and their current status information and the same is maintain in vector table by moving nearer to them.
4. Decide the life time of cluster head according to the vector table and decide it as the time period “T”. This is the time for which sink node will collect the information from the current cluster head, and create the communication session between it and cluster head
5. Now cluster head collect the sensing information from cluster members and transmit it to sink node
6. After this communication session, cluster head reselection process will begin and now it is based on their load and energy status. If cluster head is selected then the sink node computes the distance as well as status and updates the vector table and compare the status value with other cluster head values. If it found greater than sink then set the communication session time interval and start the communication. Otherwise sink node moves to that cluster head which is having higher status regarding energy and buffer and start communication with it.
7. This process continues.

IV. SIMULATION RESULTS

We used the NS2.34 [18] simulator to evaluate the performance of our model and compare it with existing algorithms with respect to throughput, delay and routing overhead. In our simulation we consider the variable number of nodes with random way point mobility model with 20 m/s pause time. Every node equipped with battery of 10j energy initially and fixed radio transmission range of 250m and IEEE 802.11 MAC card with data rates of 2 Mbps. The receiving power is 300mW and transmission power is 600mW. Finally, source nodes generate CBR traffic with a packet size of 512 bytes. Simulation duration is 1000s, we took the average of 3 scenario performances. In order to measure the performance, we considered the following performance metrics.

- Throughput: It is a network performance metric to calculate how much data packets transmitted from source to destination in a particular amount of time.
- Delay : Delay is calculated as the average time take to reach the packet from source to destination
- Overhead: It is the ratio of amount of control packets are transmitted for routing (including routing path finding, maintaining the route) to actual data transmission in the network.

Simulation parameters are shown in table1.

Table1. Simulation parameters

Network Parameters	Values
Simulation Time	1000 s
Number of Nodes	10-100
Link Layer (LL)Type	Logical Link (LL)
MAC	802.11
Radio Communication	Two-Ray Ground
Queue Type	priority Drop-Tail
Routing	Proposed
Traffic	CBR
Area of Network	1500m x1 500m
Mobility Type	Random Way point

Packet Delivery Fraction (PDF) is a ratio of packets forwarded by sender and number of packets received at the destination node. As per the simulated results, there is higher PDF in proposed protocol as shown in figure 1. Results studied that in proposed protocol, PDF averaging at 95 in comparison with Protocol where no bottleneck consideration was taken, is averaging nearly 100 and existing-1 is averaging 4 and existing-2 is averaging 57 in terms of packet delivery fraction.

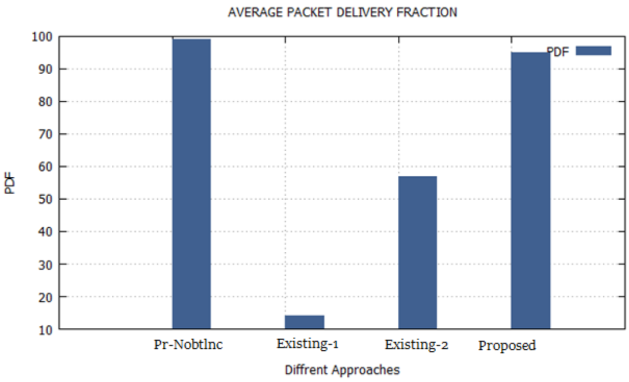

Figure 1: Performance comparison of average PDF in different approaches.

Throughput is the rate of at which messages are delivered successfully during the communication. As per the simulated results, there is highest throughput in proposed protocol as shown in figure 2. Results studied that the proposed protocol has average throughput nearly 100 in comparison with Protocol where no bottleneck consideration was taken, is averaging 88 and existing-1 is averaging 72 and existing-2 is averaging 55 in terms of throughput.

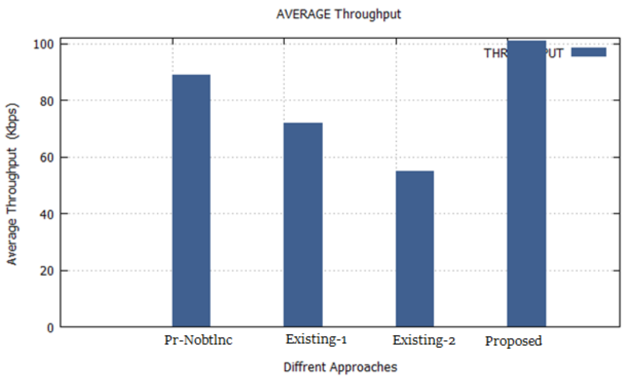

Figure 2: Performance comparison of throughput in different approaches.

It is observed from the following figure 3 that the proposed protocol saves energy in comparison with the existing protocols. As the number of nodes increases in the network the remaining energy is also decreasing but comparatively better results shown in terms of saving energy by the proposed work.

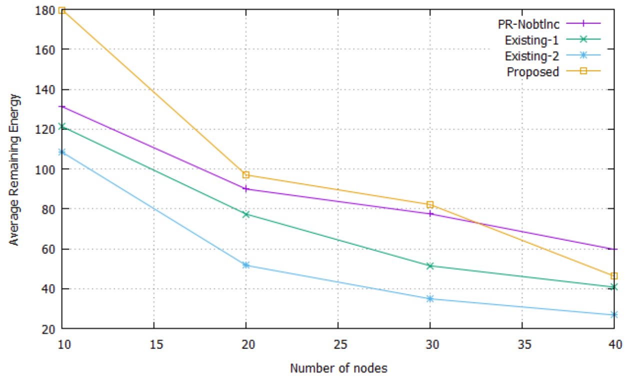

Figure 3: Performance Comparison of average Remaining Energy with varying number of nodes.

In the figure 4, throughput is compared with average remaining energy for proposed model and existing protocol for observations. Collectively in both characteristics the proposed model has shown better results.

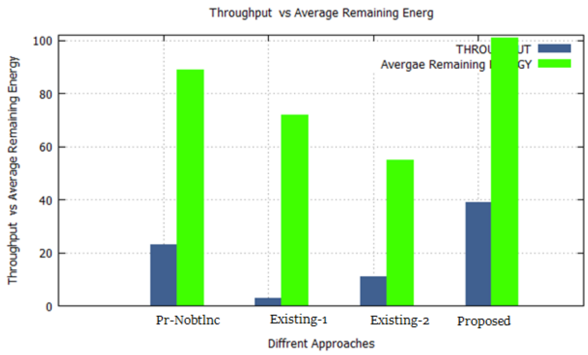

Figure 4: Performance comparison of throughput vs. Remaining Energy in different models.

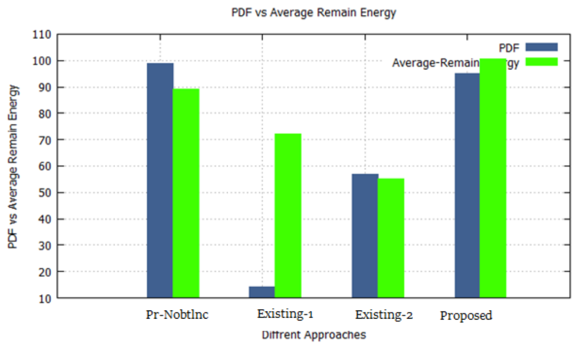

Figure 5: Performance comparison of PDF vs. Average Remaining Energy in different models.

In Figure 5, the performance comparison of network lifetime is shown. The results clearly depicts the proposed model maximizes the network life time ratio in comparison with existing schemes because we contribute to select best congestion less node.

V. CONCLUSION

In this work, a hybrid routing protocol for wireless sensor network with mobility consideration is designed. It improves the network performance and reduces the packet loss by removing the congested and constrained nodes from routing path. Moreover, it improves the network lifetime by making sink node mobile based on its neighbor node load status. The nodes deployed in WSN are static and fixed to particular location and we cannot change the position of sensing nodes. One possible solution is to make the sink node to mobile and its location can be changed according to neighbor node properties with respect to energy and load. This protocol selects the path between communication entities. The routing path is selected based on the reactive status of node regarding load and energy. Proposed hybrid routing protocol performance validated through simulation and compared with energy aware routing protocols in terms packet delivery and throughput. Thus the aim is to change the position of sink to achieve the energy efficiency and extend the network lifetime. Experimental values show that providing mobility to sink node results in achieving the network lifetime and energy efficiency by removing the problem of neighbor node of sink to become bottleneck node.

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