RATE BASED TRANSPORT PROTOCOL USING DELAY INFORMATION for REDUCING ENERGY CONSUMPTION of NODES in MANET

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Abstract

The MANET requires rate based transport protocol for node-to-node data transfer to be effective. The well-known transport protocol processes the packets in sender, receiver and intermediate nodes and thus the energy consumption by the intermediate nodes are imperative. In this paper, a mechanism is proposed, which makes ATP as en-to-end protocol. The transmission and queuing delay is calculated and weight is assigned suitably to understand the effect of the delay in the network. The effect of recent delay is considered and more weight is assigned to the delay value and the same is stamped in the header of the packet. The header is processed in the most of the layers of sender and receiver nodes only. The intermediate node process the header only in minimized layers and thus the energy of the nodes are saved. The percentage of power consumption time is considered as evaluation parameter and NS2 simulator is considered as tool. The performance of the proposed approach is encouraging compared a recently proposed similar approach.

Keywords: MANET, Transport Protocol, Energy Saving

1. Introduction

Various transport layer protocols have been designed for large number of real time applications. For the conventional wired network, the TCP is found to be suitable and for mobile ad hoc network, ATP protocol is found to be suitable. TCP operates only in source and destination. The TCP utilizes various network events to improve its performance [1] and [2]. Some of the well-known approaches such as TCP-Feedback (TCP-F) [3] and TCP-Explicit Link Failure Notification (TCP-ELFN) [4] schemes identifies the packet loss due to route failures. Similarly, Link Random Early Detection (LRED) [5] and TCP-Dynamic Adaptive Acknowledgment (TCP-DAA) address the link-layer contention problem in static ad hoc networks. Ad Hoc-TCP (ADTCP) considers multiple network events such as including buffer overflows, channel errors and disconnection/route changes [6]. The information from transport protocol along with the network information is also used by routing protocol for improving their functions. The authors of [7] have proposed a pre-emptive routing scheme to initiate path discovery procedure upon a path is likely to break. In addition to TCP, network and data link layer protocols can be included for improving the data transmission so that their functionality in all the intermediate nodes in the data path will process the information in each layer. Thus, it is very difficult to handle the error present in the intermediate nodes until the error is propagated to the end nodes. In contrast to the wired network, the mobile ad hoc network is closed with nodes from an organization for a specific application. The nodes communicate themselves may not be requiring the compatibility of TCP. It may be possible to embed ATP into TCP and found that this approach increases the load on the intermediate nodes. While TCP is designed as an end-to-end node, ATP is designed as node-to-node. Here, it is possible to adjust the transfer rate anywhere in the network by considering the feedback from the intermediate nodes. The node-to-node approach is the research development and credit based node-to-node congestion control approach has been proposed in paper [8] and [9]. The node-to-node protocols have also been used in packet switched networks [10]. These two approaches periodically transmit the status queue and packet serving rate of each node to its immediate neighbours and the neighbours controls the downstream data rate to avoid the loss. However, each of these approaches, the flows in the intermediate nodes is stored and processed, which consumes more processer power in the intermediate node. It is well-known that each node in the mobile ad hoc network is driven by the battery and considered as an important resource. To handle this issue, ATP has been proposed, which is a semi node-to-node protocol. The operation of ATP is similar to end-to-end and however, the packets are carried upward to the transport layer only to update the delay *(D)* stamping and the flow control is handled only at the end nodes. Since, the ATP is the combination of node-to-node and end-to-end protocol, the demerits both of these approaches are large overhead in the intermediate node, poor performance, etc. It is observed that there are large numbers of system calls and copy overhead in the intermediate nodes in the data path and consumes lot of resources [11] and [12]. It may be argued that we need not consider the processor speed as one of the scarce resources since there is good growth in the development of high speed processors. However, the high speed processor dissipates more heat and being considered as one of the major issues and can be alleviated if power hungry processors are used [13]. In general, ad hoc networks are limited resource network and processing power, memory and power consumption scarce in nature. Memory access for copying data requires CPU processing time consume large power [12]. Thus, it is imperative that a protocol is required, which minimizes the load in the intermediate nodes by not processing up to the transport layer. Also, the processing nature of *D* has to be improved such that data transfer is seamless. In this paper, we propose a mechanism to make ATP as end-to-end protocol. The delay is calculated based on a suitable weighting mechanism. The recent delay value is updated with higher weight so that real scenario of the network is updated for deciding the sending and receiving rate. The rest of the paper is organized as follows. We review the literature in the next Section. In Section 3, the proposed approach is presented. The experimental results are presented in Section 4 and we conclude the paper in the last section of the paper.

2. Literature Review

Managing a mobile ad hoc network is considered as an important factor with the aim of improving the lifetime of each node. A node with downed battery may introduce network partitioning and thus conserving battery energy is important. Thus it is imperative that energy efficient protocol is required for ad hoc network for data transfer with delay manipulation capability. Various research groups have concentrated on this issue and classified the power requirement broadly into two groups such as processing and transceiver power. While the processing power is confined to the execution network algorithms, the transceiver power is for communication purposes. The transceiver power is used by the network and data link layer. There are large numbers of power aware algorithms in the network layer [14], [15], [16], [17], [18], [19]. In cost aware routing, the routing decisions are made based on the lifetime of the nodes between the source and destination [20], [21], [22], [23], [24], [25]. In data link layer, there is a large number of research works for reducing the energy consumption in nodes [26], [27], [28], [29], [30]. All the above mentioned works have concentrated on minimizing the energy in the data link and physical layers. The transceiver energy loss also has been explored for improving the life of a node in an ad hoc network [31] and [32]. However, none of the above approaches have systematically approached the issue of power consumption by the processor while software instructions are executed on it. A cross layer approach has also been proposed for improving performance of the transport layer protocol by considering various network parameters such as disconnections, channel errors, buffer overflow and link-layer contention, which may cause packet loss. Based on any of the events, the network can use the power aware transport protocol and take actions [33]. In this approach, while a node detects an abnormal network event, it first explicitly sends an immediate notification message about the nature of network event to the source. Even after this explicit message, if the abnormal event still exists, the node again sets the notification bits in the forwarding packets. In this way, the explicit warning message is eliminated. However, the congestion control mechanism proposed by this approach large numbers of network parameters to adapt, each network condition is sent as notification message and every intermediate node spends more energy and thus the lifetime of the node is minimized. The Energy-aware QoS model has been proposed for application sessions, which uses multiple protocols in various layers. The model provides QoS guarantee by dynamically selecting and adapting application protocols [34]. Since the performance of this approach is evaluated using a pocket PC for accessing Web server, the energy used by the packet PC may not as accurate as the energy used by a node of an application based ad hoc network. The authors of [35], have evaluated the performance of TCP in 802.11e MANET while dealing with high priority VoIP traffic. Also, the authors have proposed a TCP-friendly scheme to improve IEEE 802.11e EDCA mechanism. Based on the simulation results, the authors have argued that this scheme has improved the performance of TCP significantly and also facilitates the voice traffic transmission. However, since this approach uses, goodput, the number of retransmissions per second and the segment delay for performance evaluation, the energy and power parameters has not been considered. The authors of [36] have proposed mechanisms based on signal strength to alleviate packet losses due to mobility. In case, if there is a link failure due to signal strength because of the movement of the neighbour node in the out of the range, a temporary higher transmission power is used to keep the link alive. Again, the approach proactively senses whether the link is going to fail or not and accordingly a route re-discovery is initiated. The MAC and routing layers are changed for predicting the link failures because of mobility. However, using a temporary high power node to link alive consumes more energy and proactive mechanism for identifying link failure continuously work and thus requires more energy. A TCP-friendly transport protocol for ad hoc networks has been proposed to perform multi-metric joint identification for a packet and connection behaviour based on end-to-end measurements [37]. One of the drawbacks of this approach is that entire design issue is oriented towards the multimedia traffic. In fact, multimedia traffic requires priority based processing and transmission and consumes large amounts of energy. A fuzzy based transport protocol has been proposed for rate based traffic [38]. A feedback scheme is used to adjust the data flow by receiving a feedback packet. The transmission rate is adjusted using the received packet instead of the acknowledgments or lost packets. A model has been presented for achieving interoperability between reliable transport protocols based on TCP and ATP [39]. This model proposes a thin layer between the network and transport layers in the TCP/IP stack. This layer is invoked at the receiver side and preserves the semantics of the sender's transport protocol.

Based on the above discussions, it is noticed that a suitable rate based transport protocol for ad hoc network is required, which can effectively use the delay stamping. Also, the delay stamping should be processed in lesser number of layers in the intermediate nodes present in the data transmission path and a suitable weighting scheme should be proposed to assign weights to the delay suitably. To handle these issues, in this paper, we concentrate on the processor power issue while protocols are executed on the nodes. A rate based protocol is developed for reducing the power consumption and improve the life of a node. A suitable weight assignment approach also proposed for understanding the nature of the network.

3. Proposed Work

In this section, we present the proposed transport control protocol architecture specification, which is designed for end-end transport of packets in mobile ad hoc networks. This protocol is derived from ATP and the protocol architecture specification consists of three parts such as sender, receiver and intermediate node. In general, the TCP protocol is an end-to-end protocol and its segments are processed only at the sender and receiver. The intermediate nodes in the data path do not strip the TCP segments from IP datagrams, which is what followed in the TCP/IP network. In contrast, in ATP, the TCP segment is processed and the estimated delay value *(D)* is appended by each node in the data path and thus the ATP is semi node-to-node protocol. All the intermediate nodes are designed to operate in four layers and subsequently the load on these layer increases considerably. In addition, in an ad hoc network, each node is also acting as a router, which also consumes energy. Thus, ATP protocol should be modified effectively, so that the power consumption of the intermediate nodes is reduced to a great extent and the life of the nodes is extended.

3.1 Architecture Specification of Sender Node

In general, the sender node receives the packet from an intermediate node. The nature of the request may be a connection open request or path failure notification. A probe request is sent to the network to estimate the available bandwidth of the network. While initiating the connection, the probe packet is sent along with sync and feedback for the probe packet. All the intermediate nodes consolidate the delay *(D)* and is being sent to the sender node. Based on the value of *D*, for a single RTT, the bandwidth availability is calculated and the sender is informed. This procedure is depicted in Fig. 1

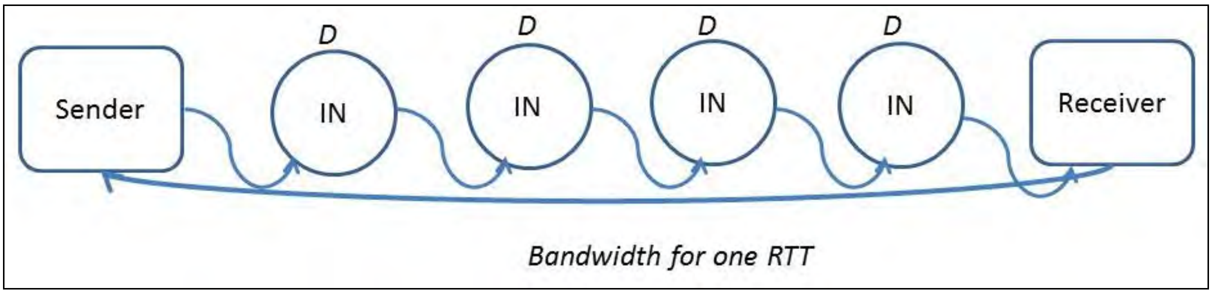

Figure 1. The scenario of obtaining the bandwidth of the network through intermediate nodes.

Though, there is no physical connection between the nodes in an ad hoc network, in the above figure, we have shown the connection for better understanding. The connection shown between the nodes are established in wireless medium. In Figure 1, the *D* denotes the estimated delay in each node. Finally, the receiver node communicates the sender the average value of *D* and is calculated as follows

$$Avg(D) = \left(\frac{\left(\sum_{i=0}^{n} D_i \right)}{n} \right) \tag{1}$$

In Eq. 1, n is the number of Intermediate Nodes (IN), D_i is the estimated delay stamp in i^{th} intermediate node. In addition, the *D* is calculated based on the transmission and queuing delay and the Eq. 1 can be rewritten as follows.

$$Avg(D) = \left(\frac{\left(\sum_{i=0}^{n} TD_i + QD_i \right)}{n} \right) \quad (2)$$

It is noticed in Eq. 2 that the delay stamp estimated at each intermediate node is based on the transmission delay (*TD)* and queuing delay (*QD)*. During packet transfer, the entire intermediate nodes stamp the value of *D* over the data packets and the receiver send the value calculated using Eq. 2 and the transmission rate is adjusted. While the feedback packet is received for a probe packet, the rate of transmission is *1/D*. On the other hand, the data transmission rate is set to *1/Avg (D)* for the ACK of the transport layer. In addition, the transmission rate is adjusted based on the Sending Rate *(SR)* and Receiving Rate *(RR)* of the sender and receiver respectively. While SR<RR, the value of SR is set to SR+1, otherwise, SR is set as RR. It is noticed that the rate adjustment is fully depends on the feedback packet and there are chances that these packet is lost. The proposed approach handles this situation by adapting multiplicative decrease approach such that the SR is decreased and increased based on the loss or arrival of feedback packet.

The Finite State Machine (FSM) for the sender node is presented below for better understanding of the working principle of the proposed TCP protocol. In Fig. 2, the FSM for the sender node is depicted and FSM captures the event/action relationship for each type of the signals received by the sender node. While the signal is an open request for connection from the application or route failure the corresponding action is to send the probe packet. For the feedback for the probe packet based signals, the sending as well as receive rate is calculated and a new epoch time is started to send the packet. Finally, in case if the signal type is a transport layer acknowledgement, the retransmission process is initiated by fetching the values of *Avg (D)*. Based on the stamp value, the sending and receiving rate is calculated. A new epoch timer is started to send the packet.

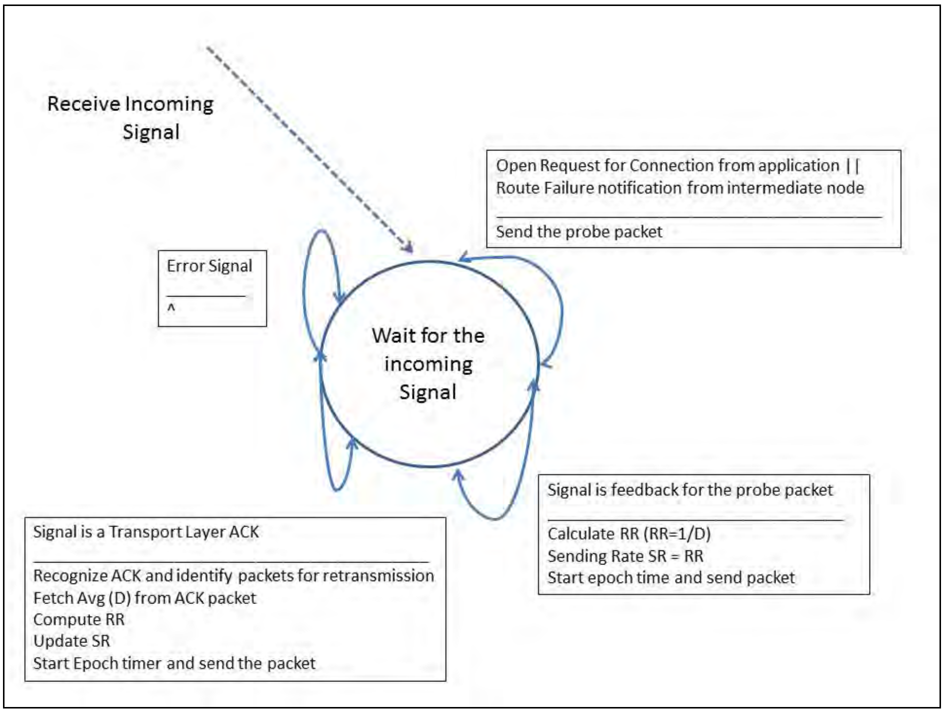

Figure 2. The FSM for sender node

as well as sends it to the sender node. The third event/action combination considers the received signal as a valid data packet. The value of *D* from the data packet is fetched and the weighted average of *D* is estimated using Eq. 2.

3.2. Architecture Specification of the intermediate node

The data link layer of the proposed protocol calculates *QD* and *TD*. While the *TD* is the function of contention among the packets within the nodes in the same contention vicinity, *QD* depends on the contention of packets belongs to different flows at the same node. The delay calculated using these two values are in such a way that new value and the old value of *D* is combined and weighted and can be written as follows

$$WAvg(D) = c1 * (WAvg(D)) + c2 * (Avg(D)) \quad (3)$$

The Eq. 3 is the weighted average of *D* is a weighted average of the actual average of *D*. This weighted average assigns more weight to the recent samplings compared to the earlier or old samplings. This is natural, as the more recent samples better reflect the current delay in the network. In Eq. 3, the value of *c1* and *c2* is very important, since both of them play a vital role in calculating the delay value and they can be inferred logically as follows. The Eq. 3 can be rewritten as

$$WAvg(D) = (WAvg(TD + QD)) + (Avg(TD + QD)) \quad (4)$$

For convenience, *c1* and *c2* are assigned as 1. It is well known that *TD* is function of link bandwidth *(BW)* and packet length *(PL)* and the value depends on *PL/BW*. Similarly, *QD* depends on *PL/BW* and Average Packet Arrival Rate *(APAR)*. This could be denoted as *PL*APAR/BW* and Eq. 4 becomes

$$WAvg(D) = 1 + (Avg(PL / BW + PL * APAR / BW)) \quad (5)$$

For convenience, the initial weighted average is assigned as 1.

$$WAvg(D) = ((1 + APAR) * PL / BW) \quad (6)$$

If the APAR is unity, then Eq. 6 becomes

$$Wavg(D) = 2 * PL / BW ,$$

since 2 is constant and the equation can be written with respect to *PL* and *BW* as below

$$Wavg(D) = (PL / BW) \quad (7)$$

From Eq. 7, it is observed that the weighted average is influenced by the ratio of *PL* and *BW* and the characteristics of the ratio can be analysed for fixing the multiplication factor is depicted in Fig. 3. It is observed from the above Fig.3 that the average delay is more while the ratio of *PL* and *BW* is high. Conveniently, we can say that the delay is proportional to the ratio of *PL* and *BW*. The output space can be spatially segmented into four groups and the value of *c1* and *c2* can be assigned accordingly, which is shown in Fig. 4

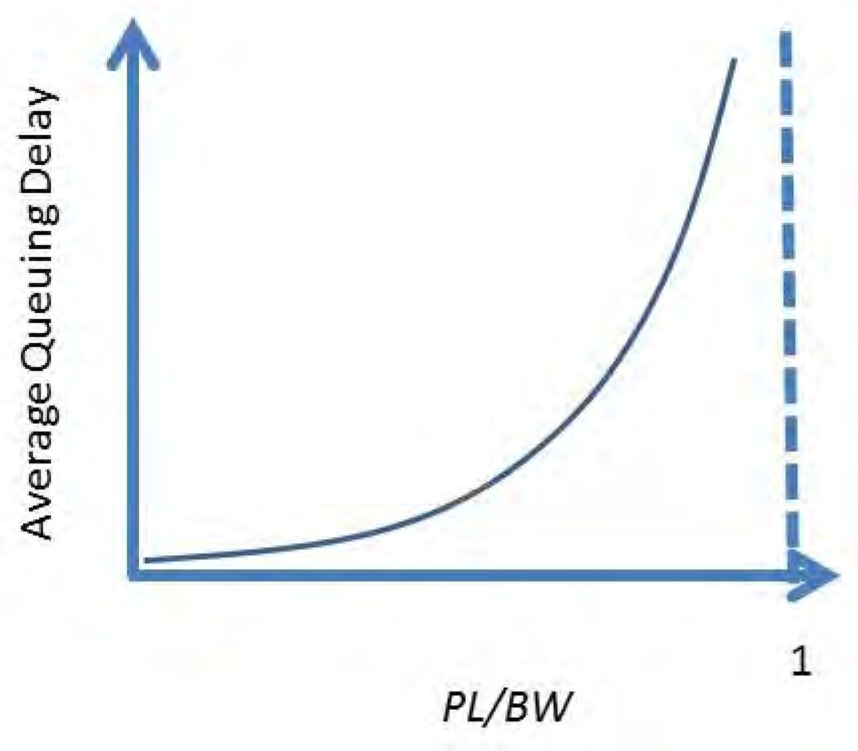

Figure 3. Dependency of delay on data traffic

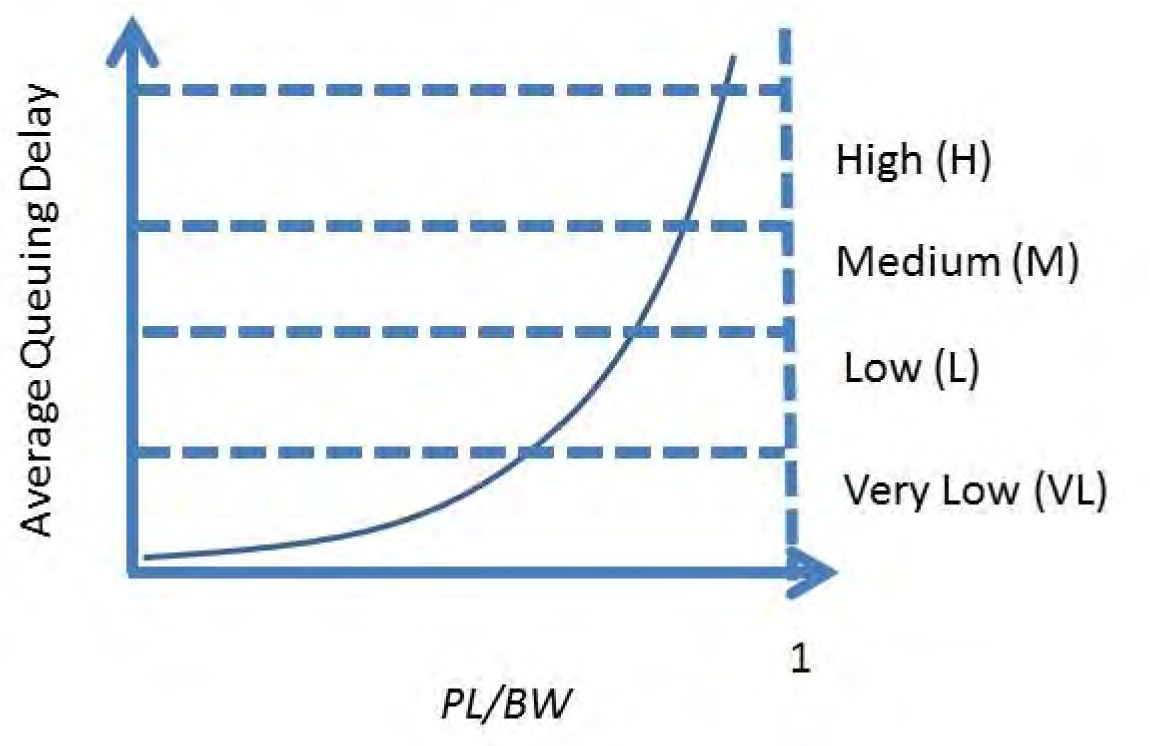

Figure 4. Spatially segmented dependency of delay on data traffic

It is essential that the value of *c1* is higher compared to and *c2* and the reason is imperative that recent samples are assigned more weights. From the above Fig, while the ratio of *PL/BW* and average queuing delay lies within the VL range, c1 is assigned 0.75 and *c2* is assigned 0.25. The value of *c1* and *c2* are 0.5 and 0.5 respectively for L range. Similarly, *c1* and *c2* are assigned 0.3 and 0.7 in M range. Finally, 0.25 and 0.75 is assigned to the H range. The assigned pair of values always considers the delay in the network and the average value of the delay is weighted. In the proposed approach, the calculated delay is appended in MAC frame and it is propagated to the receiver node through all other intermediate nodes. All the intermediate nodes check the values of delay in the MAC frame and is updated with *max(D)* as well as transmitted. The structure of the modified IEEE 801.11 MAC layer is presented below in Fig. 5

Figure 5. The modified MAC frame of the proposed approach

In Fig. 2, FC (2 bytes) is Frame Control, SC (2bytes) is Sequence Control, D/ID (2 bytes) duration or ID FCS (4 bytes) is Frame Check Sequence for CRC and frame body is a variable length field. Similar to conventional MAC frame Address1, Address 2 and Address 3 are allotted 6 bytes each. The Address 1 holds the address of the next node, Address 2 has the address of the previous node and Address contains the address of the final destination (Behrouz 2003). The newly added delay filed is provided 6 bytes. While considering various fields in IEEE 802.11, it is observed that ad hoc network requires only two address files. The reason is that the packet flow in ad hoc network is not distributed. Thus, two address fields are very much sufficient to hold the source and destination address. In this proposed approach, the fourth address field of the IEEE 802.11 MAC frame is used for storing the delay (D). However, there will not be a compatibility of the modified frame with the original IEEE 802.11 frame. But this can be easily handled since, the ad hoc network possesses dedicated protocol stack, which can be easily manipulated. The FSM for the intermediate node is presented in Fig. 6. The FSM has two event/action combinations, where one combination is related to the data link layer and the other is related to the network layer. While the data link layer signal processes the data packet or probe packet, the link failure notification is handled by the network layer signal processing. If the incoming signal is link failure notification, the path failure notification is sent to the sender along with the *D*. For the data packet or probe packet signal, the *D* is calculated based on *TD* and *QD*. The *Avg (D)* is estimated, epoch timer is initialized, the value of *D* is stamped, and the data or probe packet is sent.

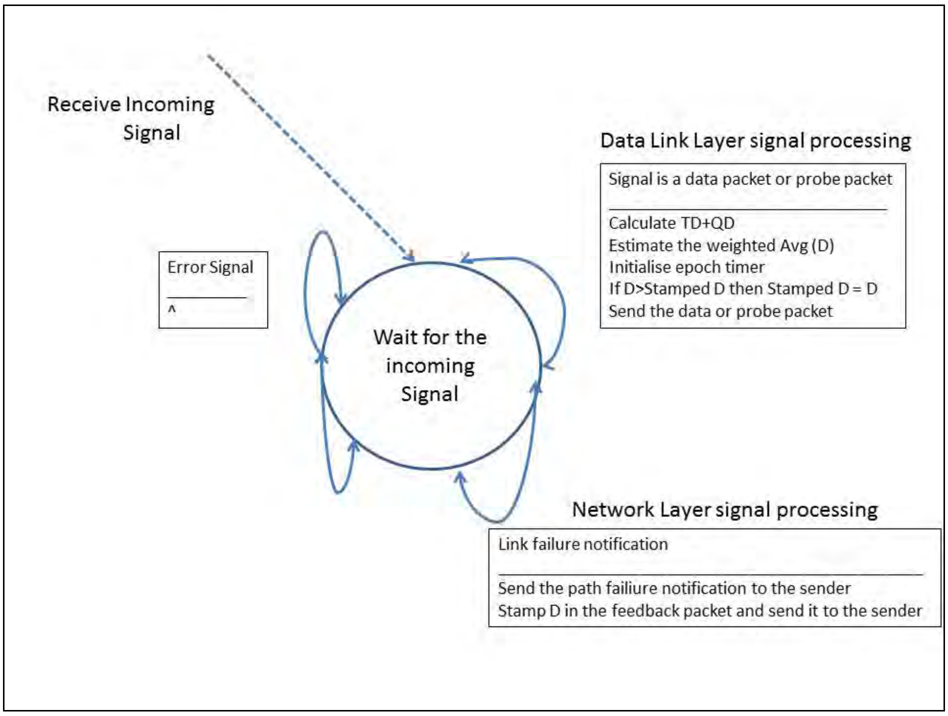

Figure 5. The FSM for intermediate node

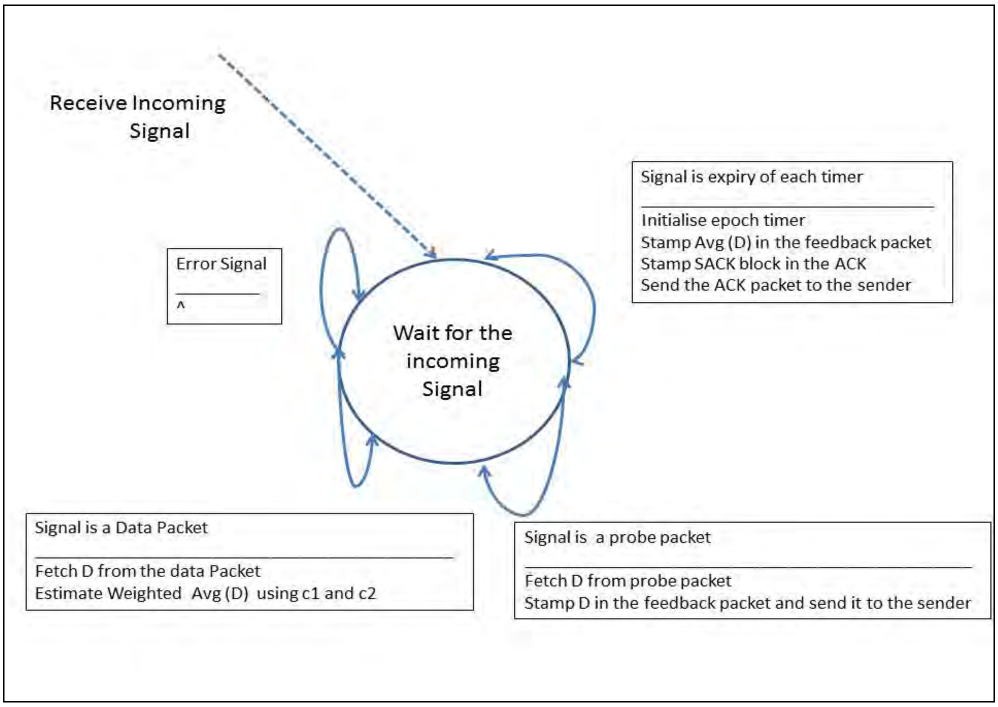

Figure 6. The FSM for receiver node

The FSM for receiver node is depicted in Fig. 6, which has four event/action combinations. In the first event/action combination, the incoming signal is verified as signal expiry of each timer. The corresponding actions are to initialize the epoch timer, stamping *Avg (D)* in the ACK packet, stamp the SACK in the ACK and sending the ACK packet to the sender. In another event/action combination, the signal is verified either as probe packet and the value of *D* is fetched from the probe packet and the *D* is stamped in the feedback packet

4. Experimental Results

We have considered the percentage of power consumption time as evaluation parameter and used NS2 simulator as the tool. We have adapted the random way point mobility with an area of 500 x 500m grid is considered for node placement. The source and destination are selected randomly. In the experiment, the number of nodes is 30, 50 and100 with different data speed such as 1ms, 10ms, 20ms. The behaviour of intermediate node in terms of load is examined by flow values 1, 10 and 30. The TELNET protocol is used as an application. In Fig. 7, we show the power consumption in intermediate nodes with respect to time. It is observed from Fig. 7, that the intermediate nodes in the using the proposed approach consume lesser power compared the competitive approach. Initially, both the proposed and competitive approach consumes more or less same power and latter, i.e. while the simulation time increases, the power consumption is reduced drastically. This is due to the fact that for the higher simulation time, the *D* value is propagated and transmission rate is controlled. We can also note that for a longer simulation time, the power consumption is stable and this situation is due to the fact that the value of *D* is copied in an effective way such that the power consumption is reduced. Also, the network situation is observed using *D* and weighted *D*, which is calculated rationally for controlling *SR* and *RR.* In addition to the above evaluation parameter, we have also considered a number of flows and measured the power consumption. Here, while the number of flows through the intermediate is low, the load on them also will be low. Similarly, when the number of flows using the intermediate node is sufficiently high, it increases the load on the node and the power consumption is also increased. In this experiment, we have considered load for each layer is 1 unit and have compared the performance with ATP. The ATP consumes 40 units for 10 flows (10x4). And the proposed approach consumes 30 units (10x3). Thus it is imperative that the power consumption by the proposed approach is comparative and encouraging compared to the well-known ATP[35].

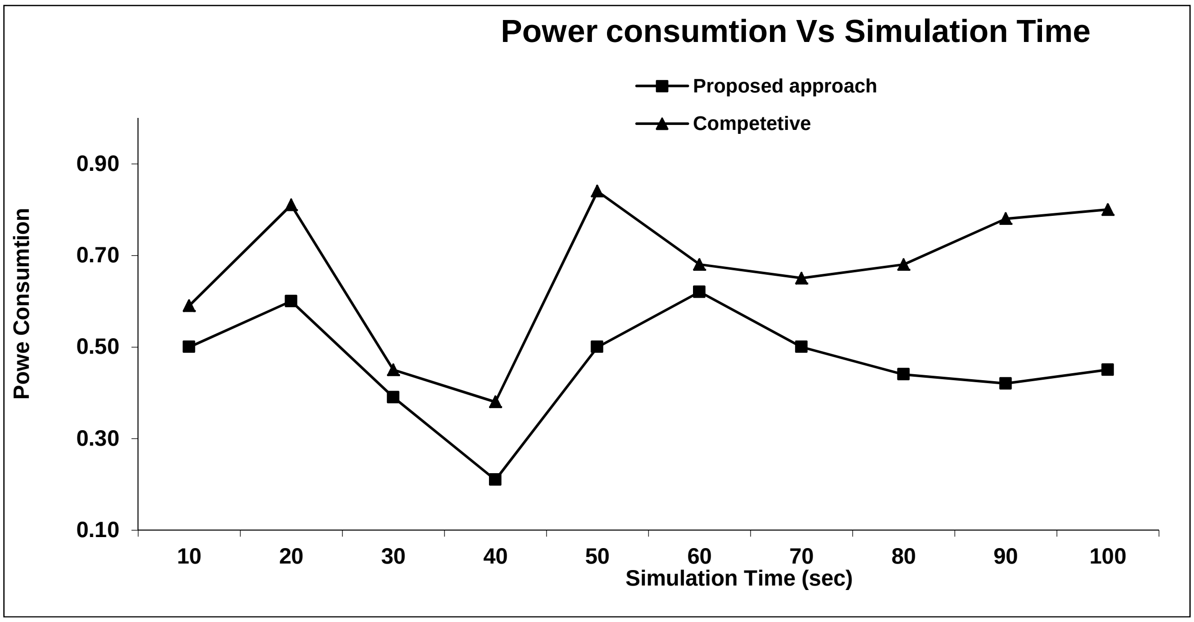

Figure 7. Power Consumed by intermediate nodes

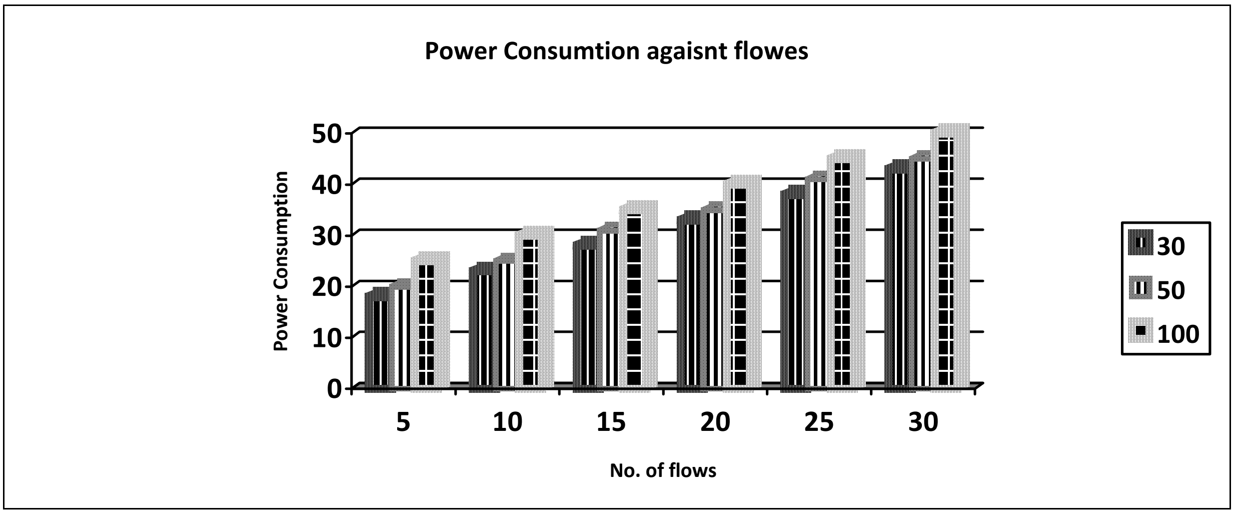

Figure 8. Power Consumed by intermediate nodes against number of flows

Conclusion

We have proposed a suitable transport protocol for MANET for improving life time of a node. The transmission rate is adjusted based on sending rate and receiving rate of sender and receiver nodes. Sending rate is increased or decreased based on the packet loss or arrival of feedback packet, which has the delay information. Number of flows is also considered as one of the parameter as load depends on number of flows and accordingly the power consumption is increased or decreased. The intermediate node consumes less power as compared to competitive approach. The performance of the proposed approach is better compared to some of the similar approaches.

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