Beacon Optimisation Foroptimized Routing Model Using Tsch Network

Suresh Babu. B[1], Dr. N. Geethanjali[2], Dr. Mohammed Ali Hussain[3],
[1]Research scholar SCSVMV University, Kanchipuram, TamilNadu, [2]Professor, Department of Computer Science and Technology, Sri Krishna Devaraya University, Anantapur Dist. Andhra Pradesh,
[3]Professor Department of Electronics and Computer Science Engineering, KL Deemed to be University, Guntur Dist. Andhra Pradesh.

Abstract- The recently launched IETF 6TiSCH working group combines low energy consumption and highly reliable IEEE 802.15e Time Slotted Channel Hopping with IPv6 for dynamic Internet of Things (IoT). However, the IEEE 802.15.4e only describes TSCH link-layer design without a study of communication scheduling and network formation for high density and rapid mobile adhoc network which are still an open issue to the research community. In existing TSCH network, device associationtakes longer time because the device has to wait till there is at least one enhanced beacon packets advertised by synchronized device in the network on its specific channel. As a result incurs association latency and energy overhead. Especially, when frequent association and disassociation arises. To overcome research challenges, this work present amodified TSCH network and Adaptive and Efficient Routing (AER) model for MANET. The modified TSCH network reduces the overhead of mobile device within TSCH network by introducing a novel modified beaconing for achieving Adaptive and Efficient Routing (AER). Experiment are conducted to evaluate performance of AER over existing approaches shows significant reduction of energy overhead and attain good packet routing outcomes.

Keywords- IEEE 802.15.4e networks, Internet of Things, Mobility, Network formation, TSCH.

I. INTRODUCTION

The IEEE 802.15.4 standard aimed at building low-rate wireless personal area networks with node that are low-power, low data rate and short communication range radio frequency [1] such as Mobile adhoc network (MANET) and sensor network (SN). The standard supportssingle hop, multihop and cluster based communication and is composed of full-function device (FFD)/Mobile MANETdevice (MMD) and reduce-function device (RFD)/MANET devices (MD). The medium access control (MAC) support both beacon enabled and non-beacon enabled communication approach. In beacon enabled approach, to synchronize the communication among coordinator and the devices, a periodic beacon is transmitted by personal area network coordinator, while for non-beacon enabled approach the nodes contend with each other to transmit to the coordinator using un-slotted CSMA/CA without broadcasting beacon [2]. To provide interoperability among the internet cloud and MANET devices, the802.15.4 standard introduced 6LoWPAN adaptation layer [3] which is a hot area of future scope of research and lead to the environment of Internet of things (IoT). 6LoWPAN adaptation layer is placed between data-link and network layers (or can be considered as layer 2.5) in the OSI network architecture and allows the IPv6 packets to be transmitted over the 802.15.4 frames [4]. The significant usage of 6LoWPAN adaptation layer has motivated researcher to model a new way of organization to the routing environment in the $MANET$, this organization is based on which layer the decision of routing is taken and based on which two kinds of routing is defined such as route-over and mesh-under [5]. However, neither 6LowPAN nor IEEE 802.15.4 describes how mesh network will be accomplished to perform routing towards the coordinator, which is considered to be the sink.Regarding network topography, cluster and multihop based network can attain better performance and scalability when compared with other types of topography [6], low communication overhead which will aid in reducing energy overhead [7] and can be considered as energy efficient design for MANET routing [8].

The IoT application such as smart homes, smart cities and wearables requires robust (i.e., work reliably) and flexible (i.e., ease of use and satisfy applications dynamic requirements) and also should minimize energy overhead and support large scale operation. The requirement for routing design in low-power environment are dependent on applications dynamics such as building automation, urban monitoring, home automation etc. [9]. Several routing design has been presented [10] and these protocol adopts Ad hoc On-demand Distance Vector (AODV) routing protocol [11] such as the one-to-one communication of the IPv6 routing design for low power and lossy network (RPL)[12], which is standardized by IETF ROLL working group [13],mesh routing design of the ZigBee stack [14], and other design [15]. The main key parameter of wireless multihop network is routing metric. The consideration of link quality as input in routing design in IEEE 802.11 network is proved to be efficient approach [16]. However, in 802.15.4 network, most of the existing work [10], [17] has considered link quality indication (LQI) has an input for routing metrics. LQI depict the quality of link, as observed by receiving device of a frame at the instance of frame reception. However, it achieves well below par performance to meet IoT growth which resulted in preventing true internet capabilities. To address the IEEE defined a new MAC [18] namely, IEEE 802.15e based on theDSME (Deterministic and Synchronous Multi-channel Extension) for scalability requirement and deterministic latency, AMCA (Asynchronous Multi-Channel Adaptation) for infrastructure monitoring networks, TSCH

(Time-Slotted Channel Hopping) for bounded latency, high throughput requirements, and high reliability, , RFID Blink (Radio Frequency Identification) for people and item tracking, identification, and location, and LLDN (Low Latency Deterministic Network) for low latency and high reliability and.The development of low power wireless communication has resulted in creation of various IETF working group such as ROLL RPL [12], 6LoWPAN [19], and CoAP [20]. However, these model are designed considering centralized network and incurs energy overhead [21]. A new MAC is presented for distributed (MANET) clustered and multihop network by IETF 6TSCH that combines IEEE MAC and IETF networking methodologies to attain scalable and robust IoT protocol stack [22].

The TSCH presented coordinated listening mode (CSL) to minimize energy overhead by sampling the listening time. Further, it introduced fast association using Modified beacon (MD)/ Enhanced beacons (EB) which composed of data element (DE)/information element (IE) parameter. DE is composed of necessary information to designated course that MB called for. TSCH used hybrid MAC i.e., it composed of both Frequency division multiple access (FDMA) and Time division multiple access (TDMA) technique, this aid in achieving robust and reliable performance. Adopting time slotting strategy aid in in reducing radio duty cycle and minimize energy overhead, the frequency hopping aid in maximizing network reliability and minimize the effect of channel fading. Along with, it also can maximize network capacity due to frequency diversity. Since, more than one node can access and communicate using same time slot [23]. The device within TSCH network are fully synchronized and each device in the TSCH network exchange information with neighbouring device using specific time slot.

The key stage of mobile TSCH networks is network formation stage [24] which is related to configuration and synchronization. The initial synchronization is carried out by at least electing one device (sink or the coordinator). When an associating device wishes to associate a network, it should listen for MBs advertised by devices which has synchronized already. Once the associated node obtains an MB, it receives the same absolute slot ID (ASI) parameter with other synchronizers and synchronizes the entire network through its scheduled slot frame. This devices then becomes a synchronizers and continuously advertises MBs to other associating device for network extension along with network synchronization maintenance.

The MANET device keeps on changing frequency channel at each time slot according to 802.15.4e channel hopping mechanism. As a results, impacts synchronization process among associating device and synchronizers in TSCH networks. Especially, associating device and synchronizer have to instance of time to identify the same frequency for transmitting and receiving MBs. This is because when synchronizer transmitMBs on specific channel, a associating device may listen on another channel. As a result, the associating device may not obtain any MB for synchronization. Along with, the associating device also has to remain fully active to listen for MBs on its own synchronization channel for a longer time period. As a result, incurs associating overhead (i.e., incurs energy overhead and high latency) during network formation. Considering research analysis, it is observed that designing inefficient association scheme will result in degrading the performance of network. Especially, in highly dynamic network where device frequently join or leave a network [25], [26].

Though TSCH offered efficient performance in minimizing energy overhead, considering rapid mobility of MANET device for TSCH IEEE 802.15.4 MANET incurs high latency as compared to [27]. The device are firstly synchronized via listening to advertised Modified beacons (MBs) while maintaining the schedule through slotted association with adjacent devices. The standard defines the structure of MBs, however does not specify how the MBs are will be advertised. And it also does not defined how time slot allocation design by which the device will be allocated a time slot [23]. The 802.15.4 TSCH design must provide the following things to obtain a fully connected mobile TSCH mobile adhoc network

1) The mobile device must be able define to which frequency channel that MBs are being advertised. Therefore, will aid in reducing packet loss and waiting time for joining a network.

2) As the TSCH IEEE 802.15.4 does not specify how the TSCH network should be built [23], the TSCH must offer a design that describes how the MBs will be broadcasted (i.e., which devices broadcasted and when to broadcast (i.e., period of communication).

3) The TSCH has to describe an assignment methods by which the mobile device will have a dedicate links. For two neighbouring $MMDs$ region of area (ROA) (or group) that possess the same channel offset, absolute slot ID (ASI) sequence parameter will be same which result in collision of links. This needs to be considered in channel assignment method.

4) The data element (DE) should specify any changes that may arise in the slot frame configuration which is due to addition/deletion of new mobile device that join/leave the MMD.

The objective of this work is to address the issue pertaining to rapid mobile device in TSCH network. A stochastic model is developed using Markov chain model to address the impact of node association process based on which this work presented a modified TSCH network for MANET. The modified TSCH network reduces the overhead of device mobility within TSCH network by introducing a novel modified beaconing for achieving Adaptive and Efficient Routing (AER). The modified beacons use the acknowledgement packets, transmitted by MMD devices, to show the presence of $MMDs$. These modified beacons will be sent in arbitrary manner on a fixed channel. Thus, each MMD will choose an arbitrary time reference using predetermined time window in order to minimize the likelihood of packet collision with other acknowledgment packets. The proposed adaptive and efficient routing model minimize energy overhead, latency,and achieves good packet routing performance.

The rest of the paper is organized as follows. In section II the proposed Adaptive and Efficient Routing (AER) model for MANET using TSCH network is presented. In penultimate section experimental study is carried out. The conclusion and future work is described in last section.

II. ADAPTIVE AND EFFICIENT ROUTING MODEL FOR MANET USING TSCH NETWORK

Here we present an adaptive and efficient routing model for MANET using TSCH (Time Slotted Channel hopping) network. Firstly, we present a TSCH network for mobile adhoc network. Secondly, we present adaptive routing model for MANET using TSCH network and lastly we present beacon optimization for MANET using modified mobility enabled TSCH network.

a) TSCH network for MANET:

The TSCH network introduce a novel idea of channel hopping and it's also introduce a fast association method using modified beacons (MBs). The range of frequency channel will decide the MBs be advertised on different channels and thus mobile device has to gather information on which channel MB is been broadcasted. The communication between mobile devices in TSCH network is represented by so called link, which is a mixture of frequency and time, where each device has a shared or dedicated time slot and frequency channel. The channel frequency is computed using absolute slot ID (ASI) which behaves a counter for each lapsed time slot and time slot has distinctive ASI parameter.

$$K_{chnl} = F_{lst}\left[\left(ASI + chnl_{offset}\right)\%G_{chnl}\right] \qquad (1)$$

where, the K_{chnl} depicts the physical frequency channel that a mobile device will possess for association or transmission, F_{lst} is composed of list of frequency channel available, $chnl_{offset}$ is a predefined parameter that the device are constructed before initialization or association phase, and G_{chnl} parameter depicts the number of channel in the F_{lst}.

The TSCH protocol also describes data element (DE) that will be incorporated in to MB which composed of information/data for a device looking to associate the network.TheDE can describe the amount of slot frame and amount of link per slot frame along with channel offset which is preceded by five bytes ASI parameter and one byte for describing association priority parameter. Further, it is composed of $macTimeslot$ which depicts the format of each time slot and it consumes up to twenty five bytes. This parameter must be presented for performing network initialization, for each association request reply but can be omitted to guarantee not exceeding the $aMaxPhyPktSize$.Lastly, the DE depicts the hopping sequence information which can also be eliminated to prevent exceeding the $aMaxPhyPktSize$. The parameter qT_F and qU_t represent the number of slot frames and the number of time slots in each slot frame. Therefore, the MMD can broadcast MB in each mbL and mbL is obtained as follows

$$mbL = \sum_{j=1}^{qT_F}\sum_{k=1}^{qU_t} U_{jk} \qquad (4)$$

where$U$ corresponds to the timeslot duration. Therefore to minimize the waiting time for mobile device association with network, we must minimize qT_F, since minimizing qU_t can impact or affects the association. Reducing qU_t will result in reduction of number of accessible shared slots that are necessary to allow the mobile deviceand provide communication/transmission with a MMD.

b) Adaptive Routing model for MANET:

To obtain or define the whether a mobile device will join a network or not, we compute the time that a mobile device will be reside in a respective Region of Area (ROA) and prerequisite time to associate with MMD (MANET Mobile Device). In this work, we consider that in each ROA, a mobile device will constantly move at specific direction and speed.Thelikelihood of mobility in a given path is $^1/_q$ and evenly distributed. Therefore, the predictable residing time U_t elapsed in a ROA of a MMD that has a range of transmission S at restove dBM is approximated by following expression,

$$U_T = \frac{\sum_q u_q}{q} \qquad (3)$$

where, n is the quantum of likely paths or trajectories in a ROA and u is the residing time of a given path in a ROA. As time is segmented in two stages, the requesting association time (i.e., the time requisite to associate the MMD) and associated/join time (i.e., time by which mobile device can communicate with the MMD).

The mobile deviceassociation behavior in TSCH network can be modeled as a stochastic model using Markov chain that describes the probable states a mobile device can arise to associate/join a TSCH network. The likelihood $L_{mb}(t_f)$ of obtaining at least one MB within a frame slot t_f composed of qU_s will follow binomial distribution and is described as follows

$$L_{mb}(t_f) = \sum_{k=1}^{qU_s}\binom{qU_s}{k}\left(\frac{1}{G_{chnl}}\right)^{k}\left(1-\frac{1}{G_{chnl}}\right)^{G_{chnl}-K} \qquad (4)$$

where G_{chnl}, is the quantum of accessible frequency channel that the TSCH hopped over. Along with, we also consider a scenario where mobile device require an connection time greater than the residing time in a ROA, the likelihood (L_{mb}) that a mobile device obtain an MB in given slot index$u_{s_q}$is obtained as follows

$$L\left(u_{s_q}\right) = \frac{\left(1-\frac{1}{G_{chnl}}\right)^{G_{chnl}-K}}{G_{chnl}}\, u_{s_q} = 1,2,\ldots. \qquad (5)$$

An important thing to be noted here is the difference among u_{s_q} and $u_{s_{q+1}}$ is always dependent on the instance of frame slot size and MB transmission where maximum iteration is j that is with respect to number of accessible frequency channels.

The order of which time slot a mobile devices obtains an MB is not only aiding in the delay by which a mobile device can associate/join a MANET, but also increases radio duty cycle. Thus, incurs energy overhead. However, in our model the average residing time will always be greater than the prerequisite time for communication or association.

$$U_t > U_{xt} + U_M + U_C \tag{6}$$

where U_{xt} is the prerequisite time for mobile device to join with a coordinating device once it obtains an MB, U_M is the time depicting the mobile device is disconnected due to missing acknowledgement packets (which is related based on the amount of missed acknowledgment packets to broadcast the node as new member and start searching for MBS, and U_C is the time depicting the mobile device is in connected state. As a result, the coordinating device will always complete its instance of channel hopping while the device is in its ROA. In turn, the communicated MB may constantly be broadcasted on all accessible frequency channels while mobile device is in ROA. Thus, the likelihood $L_{mb}(t_f j)$ that mobile device obtain an MB on a precise frequency channel in a given frame slot j is obtained as follows

$$L_{mb}(t_f j) = \frac{1}{G_{chnl} - (j-1)} * \prod_{y=0}^{J-1} 1 - \frac{1}{G_{chnl} - y}, \ for\ j \neq 1 \tag{7}$$

The likelihood β of leaving a ROA is obtained based on the location of a mobile device with restive to MMD position and whether it moving toward or away to ROA is obtained as follows

$$\beta_{\prime} = \frac{S_{dBm} - \square_{\square\square\square\square}}{2\square_{\square\square\square}}, \quad \square\square\square\square_{\square+1} < \square\square\square\square_{\square} \tag{8}$$

$$\square_{\prime\prime} = \frac{\square_{\square\square\square} + \square_{\square\square\square\square}}{2\square_{\square\square\square}}, \quad \square\square\square\square_{\square+1} > \square\square\square\square_{\square} \tag{9}$$

where, $\square_{\square\square\square}$ is the maximum range of communication of □□□ for a given transmission power in □□□ and $\square_{\square\square\square\square}$ is the distance of mobile device from a □□□ which is obtained using $RSSI$of the obtained acknowledgement packet from the MMD.

This work further identify the likelihoodγ that a mobile device will gain free access to shared transmission link, we extract appropriate parameter that a MMD can offer, as: expected number of mobile device (F_n) moving toward a ROA at a given t_f, number of links shared (shd), number of dedicated links (M_E), and number of device attached (B_q) to the MMD.

$$\gamma = \frac{shd}{F_n + (B_q - M_E)}, \qquad for\ M_E \leq B_q \tag{10}$$

Furthermore, the likelihood μ that a mobile device obtains an acknowledgment bask is describes as follows

$$\mu = 1 - \left(\omega_{qBd1} + (1-\gamma)\right) \tag{11}$$

Additionally, the likelihood φ that a MMD admits a connection request is dependent on the available number of time slots (δ) that a MMD can furthermore accommodate without affecting mobile device energy overhead,α is the channel error rate,Req is the number of association requests, and $\overline{F_n}$is the mobile device that is alleviated out of the ROA within same t_f.

$$\varphi = \left(1 - \frac{Req}{\overline{F_n} + \omega}\right)\alpha \tag{12}$$

The transition likelihood of the probable states that a mobile device can engage during association phase can now be computed. The likelihood of a shared transmission slot being engaged is described below as follows

$$L\left(T_{f_y}, C, H\right) |y,z,H) = \left[1 - \frac{shd}{\overline{F_n} + (B_q - M_E)}\right] \cdot \left(\sum_{q=1}^{y} \frac{1}{G_{chnl} - (q-1)} \prod_{a=1}^{y} 1 - \frac{1}{G_{chnl} - a} + 1\right) \tag{13}$$

Similarly, the likelihood of shared transmission slot is not engaged and request has be transmitted successfully is obtained as follows

$$L\left(T_{f_y}, Bd, H\right) |y,z,H) = \left(1 - \left(\omega_{qBd1} + (1 - \gamma)\right)\right) \cdot \left[\sum_{q=1}^{y} \frac{1}{G_{chnl} - (q-1)} \prod_{a=0}^{q-2} 1 - \frac{1}{G_{chnl} - a} + 1\right] + L\left(T_{f_y}, C, H\right) |y,z,H) \tag{14}$$

Considering above things the likelihood of transmission failure inside shared transmission slot is obtained as follows

$$L\left(T_{f_y}, qBd1, H\right) |y,z,H) = \left(\sum_{q=1}^{y} \frac{1}{G_{chnl} - (q-1)} \prod_{a=0}^{q-2} 1 - \frac{1}{G_{chnl} - a}\right) + L\left(T_{f_y}, C, H\right) |y,z,H) \tag{15}$$

Therefore, the likelihood of failure to associate after cumulative back-off shared transmission slots is obtained as follows

$$L\left(T_{f_y}, z, S\right) |y, z, H) = \Bigg(1 - \left(1 - \frac{Req}{\bar{F}_n + \omega}\right)\alpha\Bigg) . \left[\sum_{m}^{k} L\left(T_{f_y}, qBd_1, H\right) . \omega_{qBdm} + L\left(T_{f_y}, Bd, H\right)\right] \tag{16}$$

Lastly, the likelihood that a mobile device will associate a network is described as follows

$$L\left(T_{f_y}, z, K\right) = \varphi\left(L\left(T_{f_y}, Bd, H\right) + \sum_{m=1}^{k} L\left(T_{f_y}, qBd1, H\right) . \omega_{qBdm}\right) \tag{17}$$

Here the mobile device will not come back to C state once mobile device get into the qBd state, since the MMD has enough shared links. As a result, from state qBd_j, the device will either directed to states H or to states k.

c) Beacon optimization for MANET using modified mobility enabled TSCH network:

The proposed modified mobility enabled TSCH depends on beaconing that is used in standard 802.15.4 beacon enabled approach. This work we introduce a novel beacons by which mobile device can establish whether they left a ROA and to identify the existence of MMD in a new location they transpired to. Thus, the modified mobility enabled TSCH depends on the acknowledgement packets that a MMD responses to a device in order to confirm a successful communication or transmission. As a result, the acknowledgement packets are acting as passive beacons which broadcasts the existence of a MMD. Rather than making mandatory for MMD device to response for each transmission individually and use the acknowledgement packet in the sake of acting as beacons, the acknowledgement packets of the TSCH is to be altered. EACH MMD has to reply, at end of each slot frame, only to validate a successful transmission for all the associates. This is similar to low-latency deterministic networks [18], along with each acknowledgement will depict:

1. The timeengaged for a MMDto listen for any mobile device. Here the radio is kept ON for obtaining connection requests.
2. The mobile devices that whose communications were received correctly.
3. Whetherany changes has arisenwithin group/networkor not (due to association/disassociation of a mobile device).

All the acknowledgement packets will be communicated on a fixed frequency channel while neglecting this channel from theF_{lst}that the MANET TCSH network hopping over. As a result, the mobile devices that pursue to associate a network have to search only one channel which will aid in minimizing energy and time. Furthermore, the MMD has to response only one acknowledgment for all the associates which will aid inminimizing time by(vs)which is obtained as follows

$$vt = \sum_{n=1}^{B_q - 1} TrnsAkt_n \tag{18}$$

Each slot frame receives an added free time h_u that aid in utilizing more resources. Thus affecting in increasing the number of node association that can be handled using Eq. (11). Where h_u is formulated as follows

$$h_u = \sum_{n=1}^{B_q} (TrsRecOffset + TrsTrnsAktDel + TrnsAkt)_n \tag{19}$$

For a mobile devices to describe it has been eliminated or removed from the MANET (inacceptable acknowledgment) at instance$y$, the device may turn ON its radio and starts scanning passively for acknowledgement packets on frequency channel G_{Akt}. Once the mobile device finds an acknowledgement packets, it will estimates the M_u time that is presented in last field of acknowledgment frame with respect to the time by which a MMD will turn ON its radio to listen for any connection request from a mobile device. In our work, the waiting time (x) of a mobile device requesting to associate a MMD with only two consecutive slot frames and start transmitting data within third slot frame. PostM_u, the mobile device sends its connection request and wait for certain instance u_l (time desired for a node to reply to a request) and then obtains the connection request that classifies the synchronization parameters needed for a mobile device to associate a MANET. This packets is composed of ASI, assigned $u_t$by which a device can send its data within a slot frame schedule, recent timing slots (this is considered to make the mobile device know when to increase the ASI and keep its schedule synchronized with network and lastly the acknowledgment time which describes the time instance by which the MMD will send its acknowledgment packets to the devices. The M_u is computed as follows

$$M_u = \left(T_f - U_{akt}\right) + U_{MN} \tag{20}$$

where U_{akt} is random time within $X_{Akt}$to transmit acknowledgement packets,X_{Akt}depicts whether their transmission is successfully received,U_{MN} is the random time within X_{MN} to turn radio ON and listen for any association request, and X_{MN} is the time taken for MMD listening for association request. . Dependency on arbitration with predefined time aid in minimizing likelihood of collision and the mobile device can also turn its radio ON within M_u to describe if there is any other MMD beaconing within higher radio signal strength indicator to guarantee more residing time. Our AER model will minimize energy overhead and achieve good packet routing performance and utilize resource efficiently with high throughput which experimentally shown in next section.

III. SIMULATION RESULT AND ANALYSIS

The system environment used for experiment analyses is intel Pentium I-5 class 64 bit quad core processor, 12 GB RAM, 4GB dedicated CUDA enabled NVIDIA graphic card, windows 10 enterprises edition operating system. The 6TiSCH simulator is written in using python programing language by the associates of 6TiSCH WG [28] and it is open source. It composed of existing model[30] and proposed AER model is incorporated into 6TiSCH simulator. The simulation parameter used for experiment analysis is tabulated in TABLE I. The parameter considered are according to industrial environment condition where traffic are bursty in nature [29]. The experiment are conducted to evaluate performance of proposed AER over exiting model in terms of energy overhead and packet routing performance.

TABLE I. SIMULATION PARAMETER CONSIDERED

Network Parameter	**Value**
Network/Simulation area	100m×100m
Number of nodes	20
Number of iteration	100
Maximum number of packet retransmission	8
Maximum queue length	8
Total number of slots allocated	4
Minimum utilization threshold	0.8
Maximum utilization threshold	0.9
Traffic rate	5
Reception probability	0.9
Transmission data rate acknowledgement	92.6
Reception data rate acknowledgement	96.3

a) Energy overhead performance evaluation of AER over existing approach:

This section describes performance evaluation of *AER* over existing approach in terms of energy efficiency considering varied packets andtransmission rate. Energy overhead or consumption incurred considering varied packets by both AER and existing model is shown in Fig. 1. The packet is varied from 1200 to 7200 packets. The outcome shows AER reduces energy consumption by 4.471%, 0.272%, 15.52%, 22.83%, 27.99%, and, 32.776% over existing approaches considering 1200, 2400, 3600,4800, 6000, and 7200 packets respectively. An average energy overhead minimization of 17.3% is achieved by AER over existing approach considering varied packets. The outcome shows significant performance achieved by AER over existing approach in terms of energy overhead minimization considering varied packets. Similarly, Energy overhead or consumption incurred considering varied transmission rate by both AER and existing model is shown in Fig. 2. The transmission rate is varied from 1 to 20. The outcome shows AER reduces energy consumption by 26.62%, -4.55%, 18.026%, 27.99%, and 36.34% over existing approaches considering 1, 5, 10, 15, and 20 respectively. An average energy overhead minimization of 20.88% is achieved by AER over existing approach considering varied transmission rate. The outcome shows significant performance achieved by AER over existing approach in terms of energy overhead minimization considering varied transmission rate. The energy saving of AER over exiting approach is shown in Fig. 3, an energy saving of -4.68%, 18.71%, 41.03%, 54.16%, and 62.63% is achieved by AER over existing approach considering 1200, 2400, 3600, 4800, 6000, and 7200 packets respectively. An average energy saving of 34.37% is achieved by AER over existing approach considering varied packets. The outcome shows significant performance achieved by AER over existing approach in terms of energy saving considering varied packets.

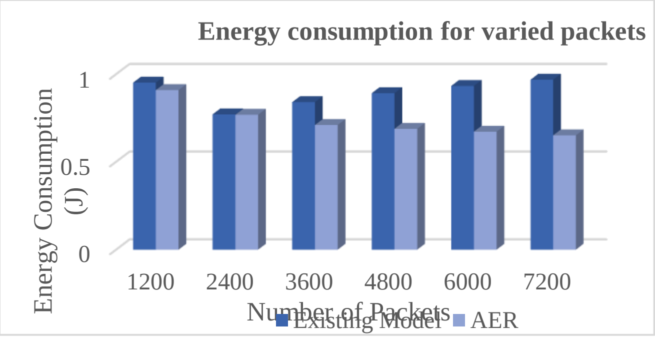

Fig.1: Energy consumption performance evaluation considering varied packets

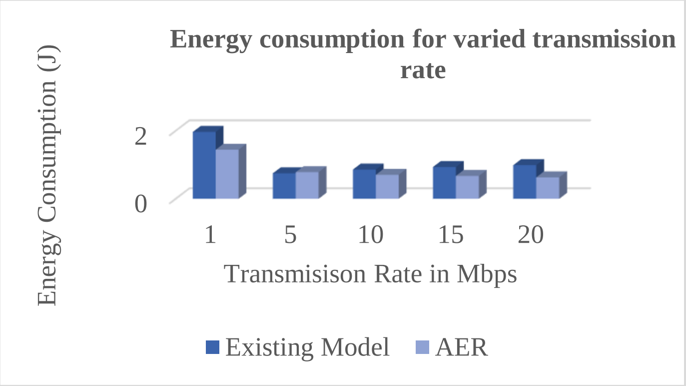

Fig.2: Energy consumption performance evaluation considering varied transmission rate

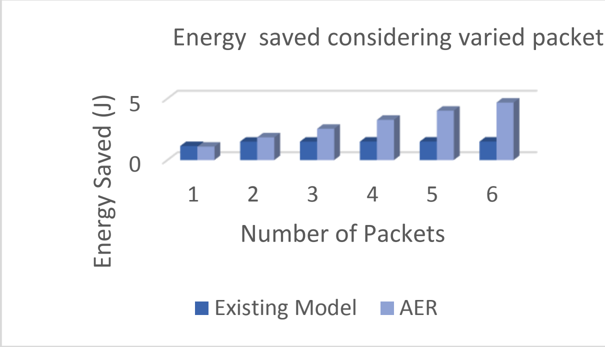

Fig.3: Energy consumption performance evaluation considering varied transmission rate

b) Packet routing performance evaluation of AER over existing approach:

This section describes performance evaluation of *AER* over existing approach in terms of packet routing performance such as drop rate, successful packet transmission, idle and pending packet transmission and throughput considering varied packets and transmission rate.

Fig. 4 determines the idle packets present for AER and existing technique considering total number of transmission packets. Here, the AER model consists of large number of idle packets compare to existing model. An average improvement of 69.13% is achieved by proposed AER model over exiting model in terms of idle packet usage.

Similarly, Fig.5determines the pending packets present for AER model over existing technique considering total number of transmission packets. Here, number of pending packets which need to be transmitted are more while using existing technique than proposed AER model. An average improvement of 45.31% is achieved by proposed AER model over exiting model in terms of pending packet usage.

Fig. 6 determines the number of packets dropped out of total number of packets transmitted using AER and existing technique. Using the existing technique the number of dropped packets are very high in comparison with total transmitted packets and number of dropped packets increases as number of transmitted packets is increased. However, the number of dropped packets using the AER technique are minimum. The proposed AER model reduces packet drop by 82.87% over existing model.

Here, Fig. 7 determines the throughput of the network for AER and existing model for different transmission rates in Mbps. It is clearly seen from figure that throughput of our AER model is much higher than the existing technique of packet transmission considering different transmission rates. It is clearly visible from the figure 2 that the conventional static algorithm perform satisfactory till the transmission rate of 5 Mbps. However, it underperforms for higher transmission rate and throughput remains almost similar for all the further transmission rates whereas the proposed scheduling algorithm perform satisfactory for all the transmission rates till 20 Mbps. An average improvement of 42.95% is achieved by proposed AER model over exiting model in terms of throughput.

Here, Fig. 8determines the packet success ratio comparison between AER and existing for different transmission rates in Mbps. From the Fig. 8 it is clearly visible that existing technique can perform satisfactory for lower transmission rate. However, for higher transmission rate, this technique is highly insufficient. On the other hand, the AER model performs far better for all the transmission rates. The environmental conditions are altered in second set of outcomes since the parameters considered for the simulation remains under static congestion and dynamic channeling. Fig. 9 demonstrates the number of successful packet transmission using the AER and existing model considering total number of packets transmitted. From Fig.9 it is clearly visible that successfully transmitted packets are more from total transmitted packets using proposed AER model than the existing technique.An average improvement of 42.86% is achieved by proposed AER model over exiting model in terms of successful packet transmission considering both under varied packets and varied transmission rate.

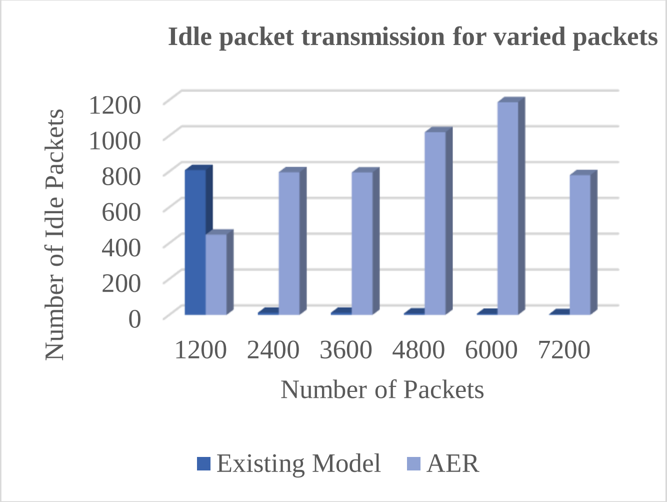

Fig.4: Idle packet transmission performance considering varied packets

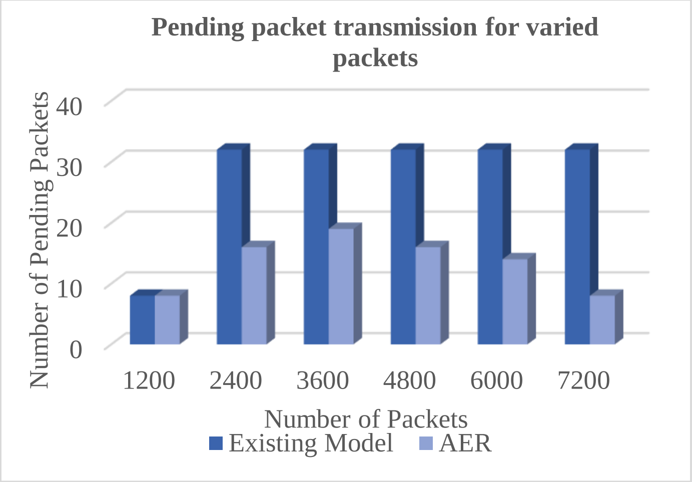

Fig.5: Idle packet transmission performance considering varied packets

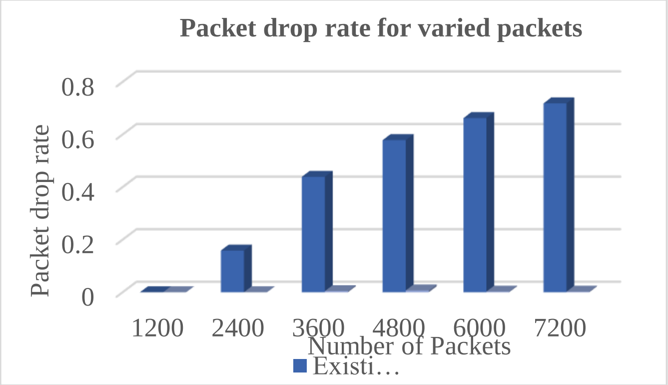

Fig.6: Packet drop rate performance considering varied packets

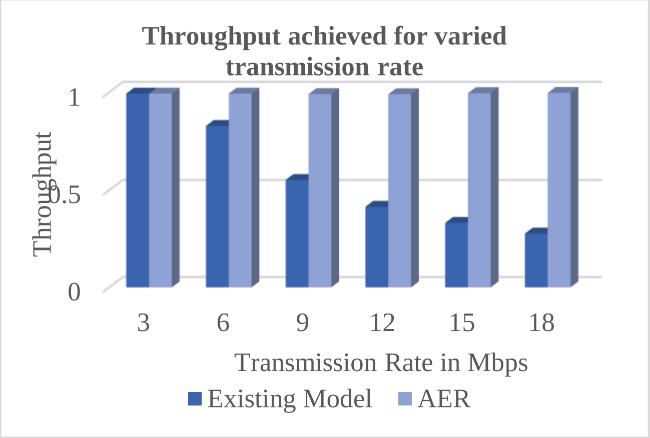

Fig.7: Throughput performance considering varied transmission rate

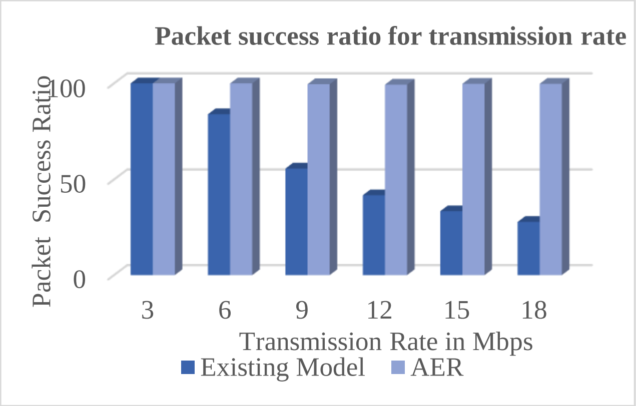

Fig.8: Packet transmission success ratio performance considering varied transmission rate

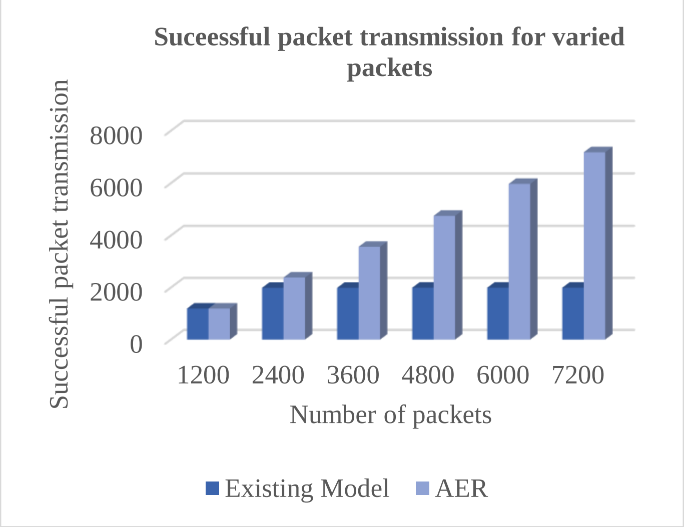

Fig.9: Successful packet transmission performance considering varied packets

c) Result comparison and Discussion:

This section evaluates the outcome achieved by various existing model and comparison with proposed AER model is carried out.In [31] carried out extensive survey on existing algorithm developed to address the performance issues TSCH network to provision future real-time dynamic applications needs. The model [30] presented a scheduling model considering decentralized network and achieved a throughput improvement of 45.5%. However, energy overhead and other packet routing performance evolution is not carried out. In [24], [29] carried out experiment analysis energy overhead performance. An energy overhead reduction of 27.08%% and 25.6%is achieved respectively. Similarly, [32] achieved 22.38% reduction of energy overhead and [33] reduced packet drop rate by 25% over exiting approaches. The AER model is compared with [30] since it is adopts decentralized network. AER model attain good tradeoff between energy overhead minimization and routing performance requirement. It is clearly seen from result outcome achieved, AER attain significant performance improvement over state-of art technique [24], [29], [30], [31], [32], and [33] in terms of energy overhead, packet drop rate reduction, throughput performance, successful packet transmission and resource utilization.

IV. CONCLUSION

In this paper we presented an adaptive and efficient routing model for MANET using TSCH (Time Slotted Channel hopping) network. Firstly, we present a TSCH network for mobile adhoc network. Then, an adaptive routing model for MANET using TSCH network is presented and finally beacon optimization for MANET using modified mobility enabled TSCH network is presented. The modified TSCH network reduces the overhead of mobile device within TSCH network by introducing a novel modified beaconing for achieving Adaptive and Efficient Routing (AER). Experiment are conducted to evaluate performance of AER over existing approaches in terms of energy overhead, energy savings, idle packet, pending packets, packet drop rate, packet throughput, and packet successful ratio considering varied packets and transmission rate. An average energy overhead reduction of 17.3% and 20.885% is achieved considering varied packets and transmission rate respectively by AER over existing approach. An energy saving of 34.37% is achieved considering varied packets by AER over existing approach. An average idle and pending packet transmission reduction of 69.135% and 49.31% is achieved considering varied packets respectively by AER over existing approach. An average drop rate reduction of 82.87% reduction is achieved considering varied packets by AER over exiting approach. An average throughput improvement of 42.95% is achieved considering varied transmission rate by AER over exiting model. An average packet successful ratio improvement of 42.86% is achieved considering varied transmission rate by AER over exiting model. The result outcome attained shows the proposed AER is scalable and robust considering rapid mobile environment and brings a good tradeoff between energy overhead reduction and routing performance requirement of future mobile adhoc network. The future work would consider further consider evaluating considering different network parameter and further improving the scheduling algorithm.

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