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ECDC: Energy Efficient Cross Layered Congestion Detection and Control Routing Protocol

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Abstract: Here in this paper A MAC layer level congestion detection mechanism has been proposed. The proposed model aims to deliver an energy efficient mechanism to quantify the degree of congestion at victim node with maximal accuracy. This congestion detection mechanism is integrated with a Two-Step Cross Layer Congestion Control Routing Protocol. The proposed model involves controlling of congestion in two steps with effective energy efficient congestion detection and optimal utilization of resources. Packet loss in network routing is primarily due to link failure and congestion. Most of the existing congestion control solutions do not possess the ability to distinguish between packet loss due to link failure and packet loss due to congestion. As a result these solutions aim towards action against packet drop due to link failure which is an unnecessary effort and may result in loss of resources. The other limit in most of the existing solutions is the utilization of energy and resources to detect congestion state, degree of congestion and alert the source node about congestion in routing path. Here in this paper we propose cross layered model of congestion detection an control mechanism that includes energy efficient congestion detection, Zone level Congestion Evaluation Algorithm [ZCEA] and Zone level Egress Regularization Algorithm [ZERA], which is a hierarchical cross layer based congestion detection and control model in short we refer this protocol as ECDC(Energy Efficient Congestion Detection and Control). This paper is supported by the experimental and simulation results show that better resource utilization, energy efficiency in congestion detection and congestion control is possible by the proposed protocol.

Keywords:Ad-hoc networks, cross-layer design, optimization, random access, wireless networks.

I. INTRODUCTION

The regular TCP congestion control mostly adapted for internet is not an appropriate for MANETs because MANETs are known to affect protocols and protocol stacks of control mechanisms .also the MANETs are environmentally incompatible with standard TCP [17]. The packet delivery delays and losses in MANETs are primarily due to their node mobility combined with intrinsically unpredicted medium which is a direct consequence of the shared wireless multi hop channel cannot be construes as congestion losses [17]. The primary characteristics of a wireless multi hop channel is that within interference range of one node only a single data is transmitted .In MANETs' networks in an entire area are congested due to shared medium where as internet congestion is single router[17].A note worthy point is that in a MANET the nodes are not congested[17]. The main reason for the conflicting of a regular TCP and a MANET is the fact that packet losses in MANET may not always be due to network congestion and the transmission times (including the round trip times) vary highly making the package losses quite difficult to observe .

It is difficult to find the source of congestion in a multi hop network because a single user has the capability to produce a congestion resulting in comparatively lower bandwidth of mobile ad-hoc networks .The wireless networks are more susceptible to congestion problems when compared with the traditional wire line networks. Therefore a balanced congestion control system is to be employed compulsorily for the stability and superior performance [17] of a wireless network. The non homogeneous nature of the application protocols in the multihop wireless networks, a single and unified solution for the congestion related problems cannot be obtained .Instead a suitable congestion control depending upon the properties and functions of the related network[17] can be designed .As a result ,these proposal majorly form a subset of solutions for the identified problems rather than a complete ,instantly used protocol . They pose as a parent for application-tailored protocol stacks. Exceptionally , few of the protocol properties serve wide range of applications[17]. The recent years have witnessed a much more focus on the congestion control methods concentrating on the modeling, analysis, algorithm development of closed loop control schemes (e.g. TCP) making them favorable for adaption to the mobile hoc networks .under the provision of constraints of routing path and bandwidth algorithms possessing the ability to unify and stabilize operations have been evolved .Another major constraint to be considered in a wireless hoc network is due to the MAC[Media access Control) layer [17].Majority of wireless MACs possess a time constraint permitting a single user to access a physical channel at a given time. The sections in the paper are organized to provide the following details regarding. The section2 explores the most cited works in the area of literature .section3 gives a detail discussion of the proposed protocol and section 4 relies on the simulations and their results to be consummated by conclusion and references.

II. RELATED WORK

QoS centric congestion control solution can be found in [1]. Metrics based solution for congestion aware routing was proposed in[4]. Et al., [2] introduced metrics to evaluate data-rate, MAC overhead and buffer delay, which helps to identify and deal the congestion contention area in network. Hongqiang Zhai, et al., [3] proposed a solution by arguing that congestion and severe medium contention is interrelated. Yung Yi et al., [4] proposed a hop level congestion control model. Tom Goff, Nael et al., [5] discussed a set of algorithms that initiates alternative path usage when the quality of a path in use becomes suspect. Xuyang et al., [6] present a cross-layer hop-by-hop congestion control scheme designed to improve TCP performance in multihop wireless networks.

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Dzmitry et al [7] presents the impact congestion on transport layer that decreases the performance. Duc et al.[8] proposed that current designs for routing are not adaptable to congestion.

The existing models aim at identifying congestion losses in routing path .The packet loss generates a link failure. Making efforts to control the packet losses that cause link failure are in effective. Another expensive approach is regularizing the egress at all nodes participating in routing. In majority of cases of control the congestion at hop level [4][15]. Henceforth egress regularization at each node of the network involves utilization of expensive resources.. Here in this paper we argue that it is a essential to identify the reason for packet loss. Hence we can avoid the congestion control process via egress regularization under the circumstances of link failure. And also we continue the argument that hop level congestion control alone is not sufficient when the hop levels are unable to regularize themselves. The egress load to control the congestion by utilizing the same resources can be done as in source level egress regularization models. In this context in our previous work we proposed a Two-Step Cross Layer Congestion Control Routing Protocol [18]

Here we propose a new energy efficient cross layer based congestion control routing protocol that contains Congestion detection and congestion control models.

III. ENERGY EFFICIENT CROSS LAYERD CONGESTION CONTROL ROUTING PROTOCOL FOR AD HOC NETWORKS

I. Energy efficient Congestion detection mechanism

The aim of the proposed congestion detection mechanism is to capture degree of congestion at relay hop level node with maximal accuracy. In proposed model, the detection mechanism is decoupled from other activities of the MAC layer such as link reliability analysis and buffer size analysis. The detection model extended to detect the congestion at traffic level, which is based on the degree of congestion measurement at relay hop level node.

II. Measuring degree of congestion at Relay hop level node:

Unlike traditional networks, nodes in the ad hoc network exhibit a high degree of heterogeneity in terms of both hardware and software configurations. The heterogeneity of the relay hop nodes can reflect as assorted radio range, maximum retransmission counts, and buffer capacity. Hence the degree of channel loading, packet drop rate, and degree of buffer utilization at relay hop level node is minimum combination to find the degree of congestion. The usage of these three functional values supports to decouple the congestion measuring process from other MAC layer activities.The degree of channel loading, packet drop rate and degree of buffer utilization together provide a scope to predict the congestion due to inappropriate ratio between collision and retransmission count. When retransmissions compared to collision rate are significantly low then egress delay of relay hop node will increase proportionally, which leads to congestion and reflected as congestion due to buffer overflow.

A. *Measuring degree of congestion at path level traffic*

The degree of congestion at each relay hop together helps to identify the degree of congestion at path level traffic from source to destination node. Each relay hop level node receives the degree of congestion from its ingress initiator. Since the destination node, which is last node of the routing path is not egress the congestion status. Hence the destination node initiates to measure the degree of congestion at path level traffic. The periodic updates of congestion status at each relay hop level node to it's successor in routing path is significantly energy consuming activity. Hence to conserve the energy, the congestion update strategy considers two conditional activities, which follows:

1. Degree of congestion $d_c(h_i)$ at relay hop level node h_i will be sent to its successor h_{i+1} iff the '$d_c(h_i)$' is greater than the node level congestion threshold $d_c(\tau)$. Hence the energy conserves due to conditional transmissions.
2. If degree of congestion at path level traffic $d_c(rp)$ that received by node h_i from its ingress initiator h_{i-1} is smaller than $d_c(h_i)$ then it updates the $d_c(rp)$ else it remains same, hence energy conserves due to avoidance of $d_c(rp)$ update.

III. Two step cross layer Congestion Control Model

The packet dropping often occurs in Manets. The reasons for this packet dropping are as below

- Transmission Link failure.
- Inferred Transmission due to overwhelmed Ingress that leads Ingress receiving strength to low. This also can claim as packet dropping due to congestion at routing.

The congestion control can be evaluated in two stages by assigning of the zonal head with the network partitioned into zones as follows

- The Status of congestion at intra zone level
- The status of congestion at inter zone level

This helps in minimization of source level egress regulation cost and balances the power consumption.

Table1: Notations used in proposed model

Zone	A geographical area, which is the part of selected mobile ad hoc network
ZCEA	Zone level congestion evaluation algorithm
ZERA	Zone level Egress Regularization Algorithm
ERA	Egress Regularization Algorithm
DPG	Distance Power Gradient
EIL	Ingress inferred Loss
LFL	Link Failure Loss
IRS	Ingress receiving strength
IRS_p	Present Ingress receiving strength

IRS_e	Expected Ingress Receiving Strength
RP	Routing Path
dt_n	Delay time at node n
N	Number of nodes in entire network
Zn_i	Number of nodes in a zone i
zh_i	Zone head of the i^{th} zone
zh'_i	Reserved Zone head of the i^{th} zone
Z_c	Current zone in the hierarchy
Z_p	Preceding zone to the current zone Z_c in hierarchy
Z_f	Fallowing zone to the current zone Z_c in hierarchy
Z_i	i^{th} Zone in the routing path
n_z	Zone of the node n
ζ_Z	Zone level Transmission Load Threshold
ζ_n	Node level Transmission Load Threshold
ζ_T	Predefined threshold that represents interval between two transmissions at one hop level
ζ_t	Actual interval between last two transmissions
ζ_{et}	Elapsed time since last transmission at one hop level
IRS_{ζ_T}	Average Ingress receiving strength threshold observed for predefined interval ζ_T
∂'	Average slopping threshold of the receiving strength
IRS_{ce}	Expected Ingress receiving strength threshold at current interval
IRS_r	Ingress receiving strength ratio
IRS_{cr}	Current ingress receiving strength ratio
BT_n	Buffering time at node n
$zdil_i$	Zone level degree of ingress load, here i is a zone id.
$ndil_k$	Node level degree of ingress load, here k is the node id of zone i

i. Network and Node activities under proposed protocol:

The network is to be split into Zones

For each zone i where $i = 1..|Z|$; ($|Z|$ is total number of zones)

Select zone-head for each zone i

Find transmission load threshold ζ_n for each zone i

By using ζ_n of each zone Transmission load threshold for entire network can be measured .

ii. Splitting the network in to zones:

We opt to the approach described by Mohammad M. Qabajeh et al[8]. With the knowledge of the existing nodes the region is divided into equal partitions. Hexagon is mostly chased for the zonal shape because it covers a maximum surface and also provides the advantage of communicating with more neighbors as they have near circular shape of the transmitter. The availability of small, inexpensive low power GPS receiver makes it possible to apply position-based in MANETs. The transmission range of node is denoted as R and the side of hexagon as L.As the nodes should be able to communicate with each other the R and L are related as L=R/2.

Each zone has a Zone Identity (zid), Zone Header (zh) and Zone Leader Backup (zh'). The zh node maintains information about all the nodes in a zone with their positions and IDs. Also, maintains information about the zh of the neighboring zones as shown in the figure 1. The CLB node keeps a copy of the data stored at the zh so that it is not lost when the zh node is off or moving the zone. By knowing the coordinates of a node position, nodes can perform our self-mapping algorithm of their physical locations onto the current zone and calculate its zid easily. Figure 1.shows the general overview of the network architecture.

iii. Selecting Zone-Heads

A zone-Head selection occurs under the influence of the Following metrics:

1. Node positions: A node with a position *p* that is close to the centre is more likely to act as a zone head.
2. Optimum energy available: a node with higher energy e more probably acts as a zone head.
3. Computational ability: the node with high computational ability c is more possible to act as a zone Head.
4. Low mobility: the mobility *m of* a node is inversely proportional to its selection as a zone head.

Each node of the zone broadcasts its (p,e,c,m). The node that identified itself as most optimal in (p,e,c,m) metrics, announces itself as zone head zh. The next optimal node in sequence claims itself as reserve zone head zh'.

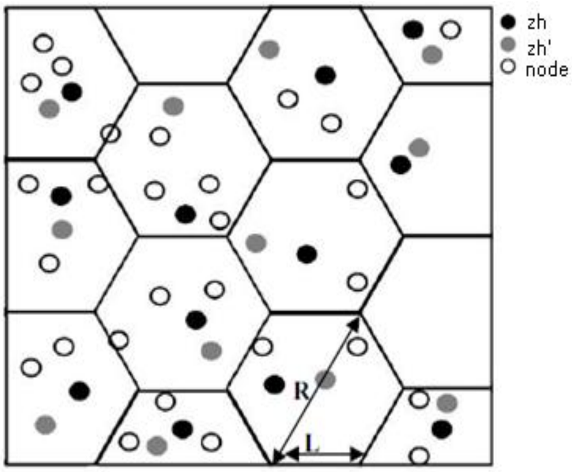

Figure 1[8]: General overview of the Zone partitions in network.

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iv. Information sharing at intra zone level [between Node and zone head]

Each node n that is a subset to zone Z verifies the Ingress load and shares degree of ingress load dil_n with zone head. Once $ndil_k$ received from each node k of the zone i, the zone head zh calculates the degree of ingress load at zone level $zdil_i$.

$$zdil_{z_i} = \frac{\sum_{k=1}^{zn_i} ndil_k}{zn_i}$$

v. Zone level Congestion Evaluation Algorithm (ZCEA)

Zone level congestion evaluation algorithm abbreviated as ZCEA is presented in this section. ZCEA is an optimal algorithm that helps in locating the packet dropping under congestion. This evaluation occurs under Mac layer and then alerts network layer.

Fig2: ZCEA for determining congestion caused packet dropping

At an event of ingress receiving by node i :

Updating Ingress receiving strength:

$if\ (\zeta_t < \zeta_T)\ do$

$$\delta' := \frac{1}{2}\left(\frac{IRS_{cr} - IRS_{\zeta_T}}{\zeta_t}\right) + \frac{1}{2}(\delta')$$

$$IRS_{\zeta_T} := IRS_{cr}\left(\frac{\zeta_t}{\zeta_T}\right) + IRS_{\zeta_T}\left(\frac{\zeta_T - \zeta_t}{\zeta_T}\right)$$

$endif$

$if\ ((\zeta_t) \neg< (\zeta_T))\ do$

$$\delta' := \frac{IRS_{cr} - IRS_{\zeta_T}}{\zeta_t}$$

$IRS_{\zeta_T} := IRS_{cr}$

$endif$

Detecting packet drop at Mac layer level

$IRS_{ce} = IRS_{\zeta_T} + \delta' \zeta_{et}$

$if\ (IRS_{ce} < IRS_r)\ do$

$macAlert: link-failure$

$else$

$MacAlert: congestion$

$endif$

vi. Zone Level Egress regularization Algorithm (ZERA)

This event occurs if Mac-layer alert indicates the congestion circumstance. Once the routing protocol [13] gets an alert from the Mac layer regarding the congestion at a node i, it alerts the neighbor node which is the source node s for contention node i. Hence s evaluates it's dil_s by comparing with $zdil$ of Z_c (zone of the node s). If dil_s is more in quantity than $zdil_{z_c}$ the difference between dil_s and $zdil_{s_z}$ should be either greater or equal to the egress threshold ε then node s regularizes the egress load by manipulating its buffering time BT_s such that $ndil_s \geq zdil_{s_z} + \varepsilon_{s_z}$.

Here ε can be calculated with following equation

$$\varepsilon_j = \frac{\sum_{k=1}^{zn_j} zdil_j - dil_k}{zn_j}$$

In case that the node s not able to regularize its egress so that contention node i terminates congestion then it alerts the zh_{s_z} (zone-head of the Z_c, $s \in Z_c$). Succeeding that event zh_{z_c} alerts all the nodes in the network making the all nodes in the upstream of source node to egress load using the above stated methodology. Then all nodes update their $ndil$ and send to zone-head zh_{z_c}, then zone-head zh_{z_c} calculates $zdil$ and confirms integrity of the $zdil$ by comparison with dil. $zdil_{Z_c} \geq dil + \bar{\varepsilon}$ concludes that congestion at contention node maintained by egress regularization at current zone level. If $zdil_{z_c} < dil + \bar{\varepsilon}$ then CEA will be started at Z_p, which is adjacent upstream zone to Z_c in hereditary . In this process zone head of the Z_c firstly alerts the zone head of the counterpart Z_p then zh_{z_p} alerts all nodes that belongs to Z_p, of the route path. The above process of egress regularization at zone level can be referred as ZERA (Zone level Egress Regularization Algorithm). Hence the nodes belong to Z_p regularize their egress load by utilizing ZERA and alert zone-head about their updated degree of ingress load $ndil$. Then zh_{z_p} measures $zdil_{z_p}$ and verifies the result of $zdil_{Z_p} \geq dil + \bar{\varepsilon}$ .True indicates the elimination or minimization of congestion at the zone due to the egress regularization at zone Z_p, if false then zone head of the Z_p performs the action of alerting all other zone heads using a broadcasting[12] mechanism about the congestion at adjacent zone in downstream of the heridetary. Hence all zones in the upstream side of the Z_p apply ZERA and the zones in downstream side of the Z_p update their $zdil$. Then all zones broadcast $zdil$ to source zone. Hence the source zone revaluates the dil .Basing on the dil, source node regularizes its egress load.

Fig 3: Zone Level Egress Regularization Algorithm

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Notations used in Algorithm:
i: Node that had been effected by congestion
s: source node of the i.
Z_c : current zone where $i, s \in Z_c$
Z_p : Immediate zone to Z_c in upstream side of the hierarchy.
$\{n_{u1}, n_{u2}, ..., n_{uk}\}_{Z_c}$: All upstream nodes to s .
$\{n_{d1}, n_{d2}, ..., n_{dk}\}_{Z_c}$: All downstream nodes to s .
$\{Z_S, Z_{u1}, Z_{u2}, ..., Z_{uk}\}$: Set of upstream zones to Z_p in routing path, here Z_S is a zone that contains source node of the routing path
$\{Z_{d1}, Z_{d2}, ..., Z_{dm}, ..., Z_T\}$: Set of downstream zones to Z_p in routing path, here Z_T is a zone that contains target node of the routing path
ε : Zone level egress threshold
$\overline{\varepsilon}$: Network level Egress threshold
Algorithm:
Mac layer alerts about the congestion at node of zone Z_c to routing protocol, hence the following steps performed in sequence

$$\varepsilon_{Z_C} = \frac{\sum_{k=1}^{zn_{Z_C}} zdil_{Z_C} - dil_k}{zn_{Z_C}}$$

Perform following at node s
If $ndil_s > zdil_{Z_c}$ and $ndil_s - zdil_{Z_c} \geq \varepsilon_{Z_c}$ begin

$$BT_s = BT_s + bt$$

Note: Value of buffer threshold bt should be decided such that $dil_S \geq zdil_{Z_C} + \varepsilon_{Z_C}$
Return.
Endif
s sends alert to zh_{Z_c} about contention node i .
zh_{Z_c} alerts all nodes that belongs to zone Z_c
$\{n_{u1}, n_{u2}, ..., n_{uk}\}_{Z_c}$ updates their $ndil$ by applying ZERA recursively and alerts zh_{Z_c}
$\{n_{d1}, n_{d2}, ..., n_{dk}\}_{Z_c}$ measures their $ndil$ and alerts zh_{Z_c}
zh_{Z_c} Measures $zdil$ as fallows

$$zdil_{Z_C} = \frac{\sum_{k=1}^{zn_{Z_C}} ndil_k}{zn_{Z_C}}$$

If $zdil_{Z_c} > dil$ and $(zdil_{Z_c} - dil) \geq \overline{\varepsilon}$ begin
Alert: congestion at contention node handled at current zone Z_c level.
Return.
Endif
zh_{Z_c} Alerts zh_{Z_p}
zh_{Zp} Alerts all nodes that belongs to zone Z_p
For each node $n \in Z_p$ begin
If $ndil_n > zdil_{Z_p}$ and $ndil_n - zdil_{Z_p} \geq \varepsilon_{Z_p}$ begin

$$BT_n = BT_n + bt$$

Note: Value of buffer threshold bt should be decided such that $dil_n \geq zdil_{Z_C} + \varepsilon_{Z_C}$
Endif
Find dil_n *and send* dil_n *to* zh_{Z_p}
End-of-for each
zh_{Z_p} measures $zdil_{Z_p}$
if $zdil_{Z_p} > dil$ and $(zdil_{Z_p} - dil) \geq \overline{\varepsilon}$ begin
Alert: Egress regularization at Z_p leads to overcome congestion situation at contention zone.
Return;
Endif
zh_{Z_p} Alerts all zone heads in network regarding congestion contention zone.
For each zone z in $\{Z_S, Z_{u1}, Z_{u2}, ..., Z_{uk}\}$ begin
zh_z Alerts all nodes that belongs to zone z
For each node $n \in z$ begin
If $ndil_n > zdil_z$ and
$ndil_n - zdil_z \geq \varepsilon_z$ begin

$$BT_n = BT_n + bt$$

Note: Value of buffer threshold bt should be assumed such that
$dil_n \geq zdil_z + \varepsilon_z$
Endif
Find dil_n *and send* dil_n *to* zh_z
End-of-foreach
zh_z measures $zdil_z$ and broadcasts towards source zone.
End-of-foreach
For each zone z in $\{Z_{d1}, Z_{d2}, ..., Z_{dm}, ..., Z_T\}$ begin
For each node n belongs to zone z begin
Measure $ndil_n$ and sends to zh_z
End-of-foreach
zh_z measures $zdil_z$ as

$$zdil_z = \frac{\sum_{k=1}^{zn_z} ndil_k}{zn_z}$$

zh_z Sends $zdil_z$ to source zone via broadcasting [12]
End-of-foreach
Z_S Measures dil as

$$dil = \frac{\sum_{i=1}^{|Z|} zdil_i}{|Z|}$$

Hence source node S of zone Z_S, which is source node of the routing path regularize it's egress load to routing path.

1. SIMULATIONS AND RESULTS DISCUSSION

In this section we discuss the results acquired from simulation conducted using 'Madhoc simulator' [16] in this section. We evaluated performance using madhoc with the following considerations:

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No of Hops:	225
Approximate Hop distance	300 meters
Approximate total network	1000X1000 meters
Approximate Zone Rdious	100X100 meters
Physical channel bandwidth	2mbps
Mac Layer:	802.11 DCF with option of handshaking prier to data transferring
Physical layer representation	802:11B
Performance Index	Egress regularization cost and end-to-end throughput
Max simulation time	150 sec

Table 2: parameters used in madhoc [16] for performance analysis

The simulations are conducted on three routes differing by the no of hops and length.

1. Short length path: A route with 15 hops
2. Medium length : A route with 40 hops
3. Max Length: A route with 81 hops

The same load is given to all the paths with a regular interval of 10 sec. Load given in kilo bytes are shown in fig 4. The fig 5 concludes the advantage of ECDC over congestion control protocol[15] in congestion control cost. A. The congestion detection cost comparison between ECDC and congestion control protocol[15] is explored in fig 6 that elevates the energy efficiency achieved under ECDC.

The process of measurement of congestion control and congestion detection cost is as follows:

Based on the resource availability, bandwidth and energy, for individual transaction a threshold value between 0 and 1 assigned. In the mechanism of congestion detection and control the total cost is calculated by summing the cost threshold of every involved event. In fig 5 the comparison between congestion costs observed for ECDC and congestion and contention control model [15] are shown.

$$\cos t_{ch} = \sum_{e=1}^{E} ct_e$$

Here $\cos t_{ch}$ is the price of a congestion controlling activity ch, E is total number of events included. ct_e is the threshold cost of an event e. The example events are:

1.” alert to source node from Mac layer”

2. “Alert from node to zone head”, “broadcasting by zone head to other zone heads”

3. “Ingress estimation and egress regularization”.

4. Alert about $d_c(h_i)$

5. Update $d_c(rp)$

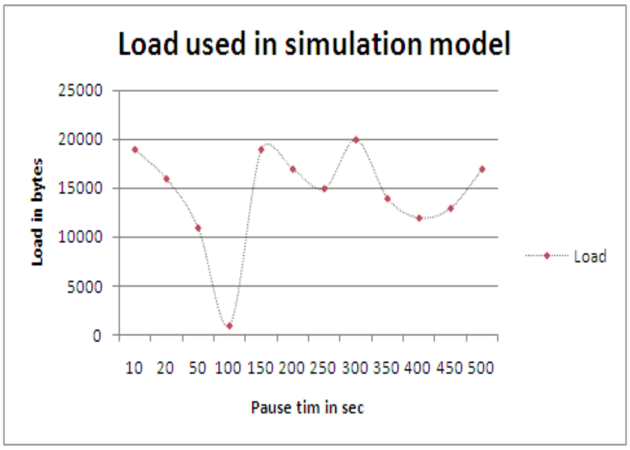

Fig 4: Load in bytes send by source node of the routing path [in regular interval of 10 sec]

IV. CONCLUSION

This paper discussed about proposed “Energy Efficient Cross layered Congestion Detection and Control Routing Protocol” in short referred as ECDC(Energy Efficient Congestion Detection and Control). ECDC derived a cross layered congestion detection mechanism with energy efficiency as primary criteria that included as congestion detection mechanism to our earlier work “Two step cross layer congestion routing”[18] .

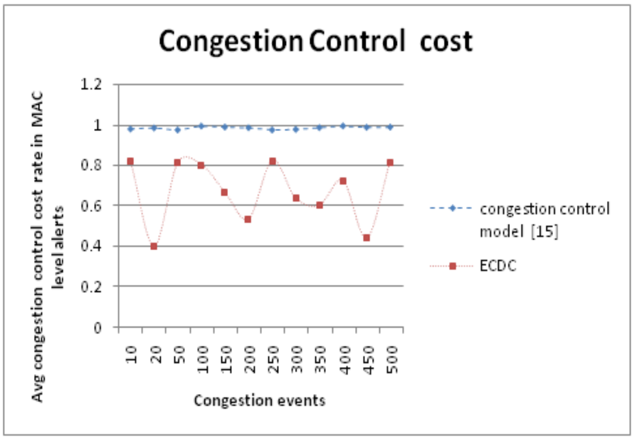

Fig 5: Congestion Control cost comparison chart

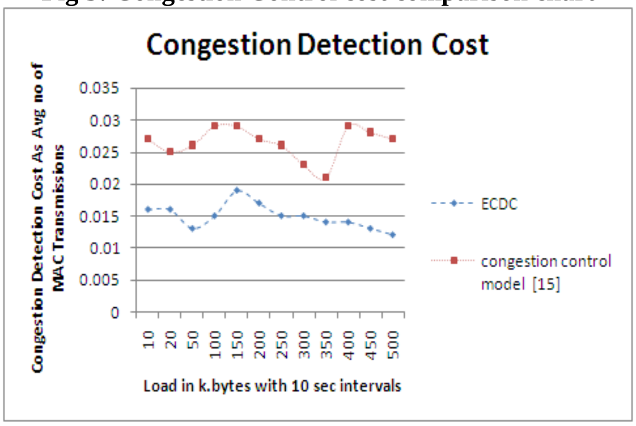

Fig 6: A line chart comparison of Congestion detection cost

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