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Energy Consumption and Congestion Avoidance Mechanism using Cross Layer Design Approach

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Abstract: In this research work we discuss the quality of service for minimizing energy consumption and congestion control in WSN. In this paper we developed MAC and network layer operated a cross-layer protocol, introduces QoS and wake and sleep states. For traffic controlling or traffic shaping QoS delivering the data as providing guaranteed packet delay or network throughput. Based on channel signal strength information MAC layer adaptively selects a transmission data rate. As a congestion routing metric for optimal route discovery the MAC layer utilization sent to DSR.We use the source codes of DSR protocol and 802.11 MAC layer. The simulation results show that in MAC layer rate adaptation improves the network performance in terms of end-to-end delay, throughput and delivery ratio. From overall network load balance MAC layer in routing discovery improves the performance of the network.

Keywords: QoS, congestion control, active queue management, ICMP source quench, fairness.

I. Introduction

It has been observed that power saving will always remain a problem to be solved. To solve this problem, there have been increasing interests in design for wireless networks that relates on interactions between protocol stack of various layers. This is a promising solution approach of wireless sensor network called cross layer design. For network dynamics to avoid congestion in the IP framework, the flows without end-to-end bandwidth guarantees have to adapt efficiently to network dynamics. Using unicast and multicast (UDP) communications Network resources are shared. Using congestion control unicast flows, adaptation is enforced by TCP. For network congestion, one approach is for all UDP flows to use a congestion control mechanism and become responsive, another is to build into the network the capacity to handle unresponsive flows effectively (e.g. by dropping packets). Both unicast and multicast best-effort flows are addresses by a congestion avoidance mechanism, offering to all i.e. responsive or not responsive flows involved in a congested router. Rate adaptation process is based on the channel quality estimation. A cross-layer design [6] explore the significant performance enhancement at MAC layer and interference estimation of this layer for optimal routing selection at network layer.

II. CONGESTION CONTROLLING

Once congestion has occurred it is important challenge that addressing congestion is how to keep routers from entering the congestion state rather than having to recover, which allows the network to prevent congestion is called a congestion avoidance scheme. TCP congestion control has been enhanced with Explicit Congestion Notification to avoid congestion. For router active queue management ECN builds on the Random Early Detection (RED) mechanism. RED detects incipient congestion by computing the average queue length of the router buffer using a low-pass filter with exponential weighted moving average. To detect the congestion at router two thresholds are used to measure average queue: min_{th} and $max_{th.}$. The mechanism works as (i) The average queue size < min_{th}, no action is done.(ii) The average queue size is between min_{th} and max_{th}, the incoming packets are ECN marked with a certain probability. And (iii) when the average queue size > max_{th}, ECN marked by all the arriving packets. To inform the source of the congestion state is introduced by TCP acknowledgments to control overhead. In the case of multicast communications, the control overhead could be much higher, depending on the number of receivers.

In this paper utilization of the two ECN bits in the IP header to mark like ECN the packets experiencing congestion and uses ICMP source quench messages as a feedback mechanism to inform the sender of the network congestion state. The main objectives are as follows: (i) responsive for all flows, (ii) additional control overhead to be minimized, (iii) in the case of multicast to avoid scattering the congestion information towards receivers and aggregating it afterwards for the sender, (iv) to be efficient in terms of delay by allowing the congested router to directly inform the sender about its status, and (v) by addressing only the scarce resources between the sender and the worst bottleneck to provide fairness among the flows experiencing congestion. An ICMP source quench message is sent from the router to the packet’s source host to inform of congestion state, when the active queue management detects congestion on a router.

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Energy consumption can be reduced by making the nodes to sleep in a regular interval of time so that there is a need of handshaking to check whether the node is in sleep state or not. There is no need to do handshaking with sink node because it will not sleep.

Handshaking will be done in the following way:

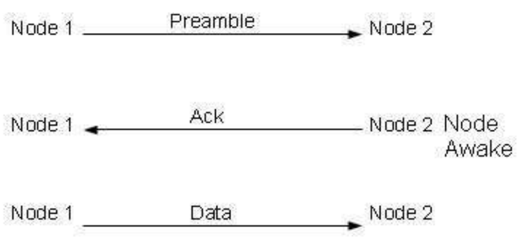

Fig.1: Handshaking signals

If node[2] is in sleep state then node[1] will continuously send the preamble until it gets acknowledgment. If a node contains information then it will not go to sleep state until it sends whole information to next node even though its sleeping period occurred just by checking whether there is any data packet in the memory or not. If a node receives more than one packet then the packet is saved in the form of linked list along with the previous packet and while sending the packets, the node will send in the form of First In First Out process. Every time when a node went to sleep or idle, time will be calculated and added to the previous sleep or idle time. For every transmission of preamble, acknowledgment and data packets, node will calculate the energy individually. The signal strength required to send to a particular node will be calculated based on the distance to the node. For example if 'node a' is sender and 'node b' is receiver then 'node a' will calculate the power required to transmit the packet to that particular node as follows.

Let P_tx be the power delivered to transmit the packet to D distance, where D is the distance between node a and node b. The power received by the destination using Frii's transmission equation is

$P\_rx = P\_tx * (\lambda/(4 * \pi * D))2$, where λ is wavelength.
The power required to transmit to destination node with distance D is
$Ptx = P\_threshold * ((4 * \pi * D)/\lambda)2$,

where Ptx is the power required to transmit and P_threshold is the minimum required receiving power. So, by reducing the signal strength the energy can be saved. The time node sleeps, idle and transmitting will be calculated in milliseconds. The energy required to transmit preamble will be

Ptx * Tpt, where Tpt is time taken to send preamble.
The energy required to transmit acknowledgment will be
Ptx * Tat, where Tat is time taken to send acknowledgment.
The energy required to transmit data will be Ptx * Tdt,
where Tdt is time taken to send data.

The energy required to send the preamble, acknowledgment and data packets for a node will not be same because node can send packets to different neighbors with different distances so the energy required to transmit packet will vary. Let us assume that the total energy spent by a node to send Preamble, total energy spent by a node to send Acknowledgment, total energy spent by a node to send data be 'P','A' and 'Da' and the total time node sleeps and total time node is Idle be 'S' and 'I'. Then the total energy spent by a node with sleeping schedule is

$Es = P+A+Da+(S*Ps)+(I*Pi)$,

where Ps is the power taken to sleep and Pi is the power taken to idle or listening. Then the total energy spent by a node without sleeping schedule is

$Ei = Da+((S+I)*Pi)$,
where it was shown in results that $Ei > Es$.

Using this handshaking is not only an advantage but also a disadvantage for this protocol because the node must wait for longer time in order to send data but this is the only way for the sender to know that the receiver is awake in asynchronous protocols. Another problem is that many transmitters are sending preamble to one receiver, so it is very important for the receiver to handle this kind of situations. After transmitting the data packet the node will remain awake for some time and then go to sleep, just in case if any other transmitter may send preamble.

III. CONGESTION AVOIDANCE MECHANISM.

As described above, our mechanism relies on active queue management on the routers to detect incipient congestion and uses ICMP source quench messages to indicate the congestion state backwards to the senders whose packets are involved in congestion, as shown in Figure 2.

(i) Router mechanisms.

The router active queue management algorithm detects incipient congestion. In this case, the packet to be sent is checked in order to identify two different conditions: 1, the packet is ECN marked, and 2, the packet is the last packet of a burst of packets belonging to the same flow and stored in the router's queue. When the packet is not marked (condition 1 does not hold), the ECN bit is set in the IP header. If condition 2 applies and if the packets of the burst do not hold any ECN mark, an ICMP source quench message is returned to the source of the burst.

The ECN bit set in the IP header of a packet is used by the successive congested routers as an indication that the burst has already passed through at least one congested router. Hence, an ICMP source quench was already transmitted to the sender for this burst and an additional ICMP source quench transmission is avoided.

When the router's queue becomes full, the queue enters the congestion state and the arriving packets are dropped. The queued packets to be sent are checked as in the incipient congestion case

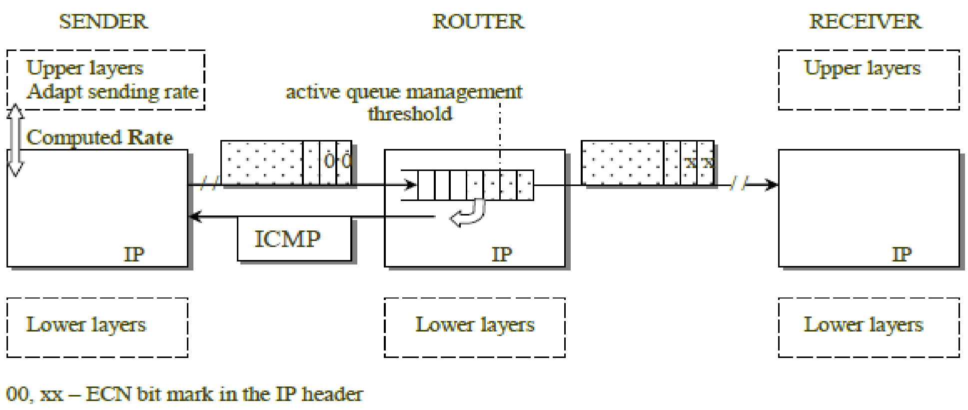

Fig 2: An end-to-end scenario for congestion avoidance

(ii) Sender mechanisms.

The sender reaction to network congestion is the most sensitive part of a congestion avoidance scheme, influencing the loss rate at the bottleneck link, the efficient utilization of resources and the fairness among the flows involved. Negotiations between sender and receiver by means of end-to-end flow control mechanisms allow establishing data transfer rate boundaries agreed by receiver. These boundaries are hereinafter called limits. In the case of TCP, the flow control is ensured by a window mechanism that uses a field in the acknowledgments to advertise the buffer space of the receiver to the sender. In the case of UDP, flow control mechanisms, if any, are handled at a higher layer. We focus below on the algorithm used to adjust the data transfer rate offered by the sender to ICMP source quench. Let assume, each node can transmit to or receive from at most one adjacent node at a time and cannot transmit or receive simultaneously. Each location dependant node has a limited transmission range and contention among links.

Time is slotted in intervals of equal unit length and the i-th slot refers to the time interval [i, i + 1), where i = 0, 1, . . .; i.e., transmission attempts of each node occur at discrete time instances i. Assume a MAC protocol based on random access with probabilistic transmissions. Each node n transmits data with probability qn at the beginning of a slot. To determine the transmit data, it selects one of its outgoing links $l \in Lout(n)$ with probability pl/qn, where pl is the link persistence probability;

$$\text{Sum}(pl)=q_n \quad <=1 \quad \text{where } l \in L_{out}(n)$$

The utility is maximum is $\max(\text{sum}(U_s(x_s))$ the link throughputs given p and q, since the term $pl^*\prod(1-q_k)$where $k \in N^I(l)$is the probability that a packet is transmitted over link l and successfully received by its receiver.

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IV. RESULT OBSERVATIONS

The proposed congestion control scheme is implemented on a multihop network. The network is created with randomly distributed nodes. Assume network having following properties:

Table 1

Distribution	Random
No.of nodes	50
Region	280 × 300 units
Communication Range	80 units
Mobility	static
MAC	802.11
Packet Size	61 bits
Weight	0.1

Using variable no. of nodes several multihop networks are tested for various cases of network load.

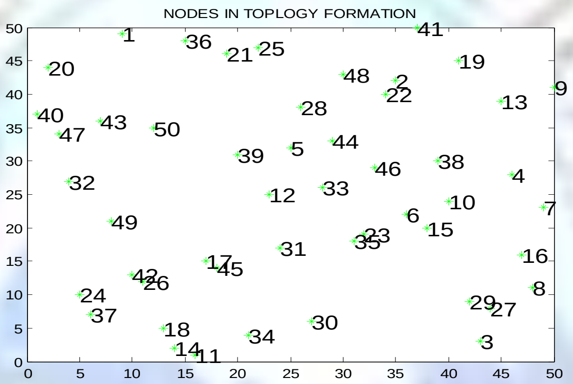

Fig 3: Simulated network with the stated specifications

Case 1: With No Add-on nodes, Source node: 8 Destination node:12 then route taken for communication from source to destination is 8 → 4→ 6 → 17→ 12.

(i) Fig 3 shows a dynamic multihop network with 50 nodes and 8 congested nodes distributed randomly. (ii) Fig 4 shows the performance of congestion avoidance routing with proposed protocol for the above randomly distributed network we have chosen 7 as source node and 15 as destination node. Congesting nodes are indicated by round circles .The black dotted line shows the optimum link that has been selected to reach the destination.

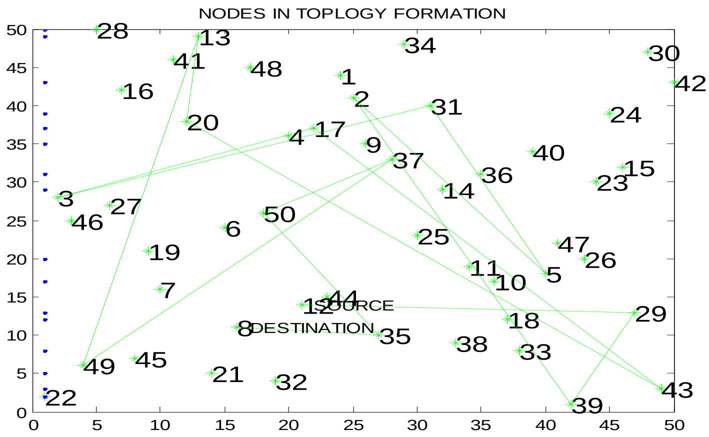

Fig 4: performance for the randomly distributed network with multihop for communication.

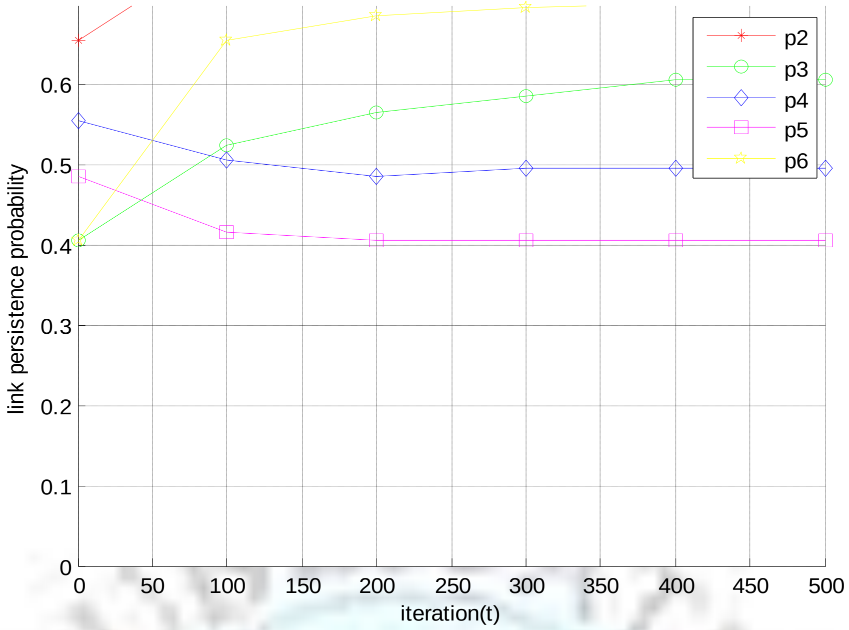

Fig 5. Average link persistence wrt. iteration.

The average blocked links increases if percentage of congested nodes increases but with the use of cross layer design average links blocked decreases.

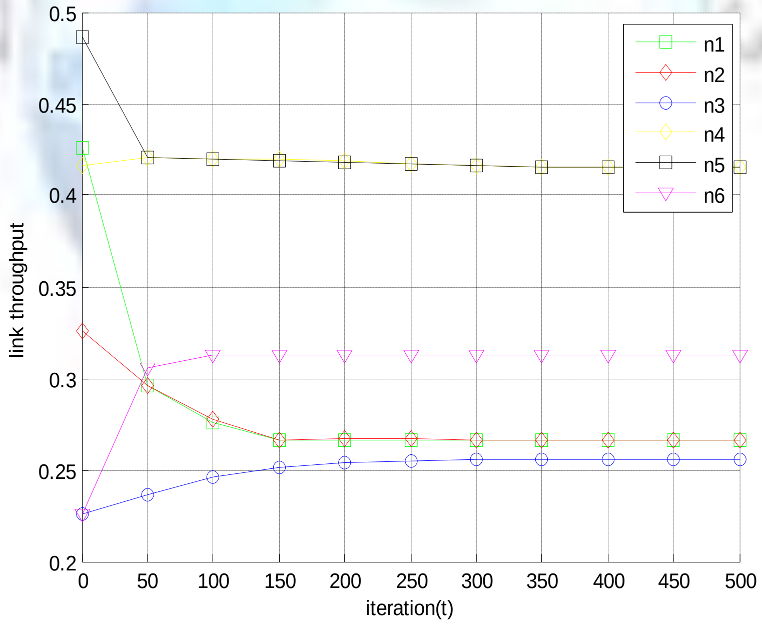

Fig.6. Total Hops under communication w.r.t. Percentage of congestive node plot.

The number of blocked link from the source to destination increases as percentage of congesting nodes increases hence the number of hop counts required for communication also increases. The total hop counts for communication remains constant with the use of cross layer design even if percentage of congesting nodes increases to 60%.

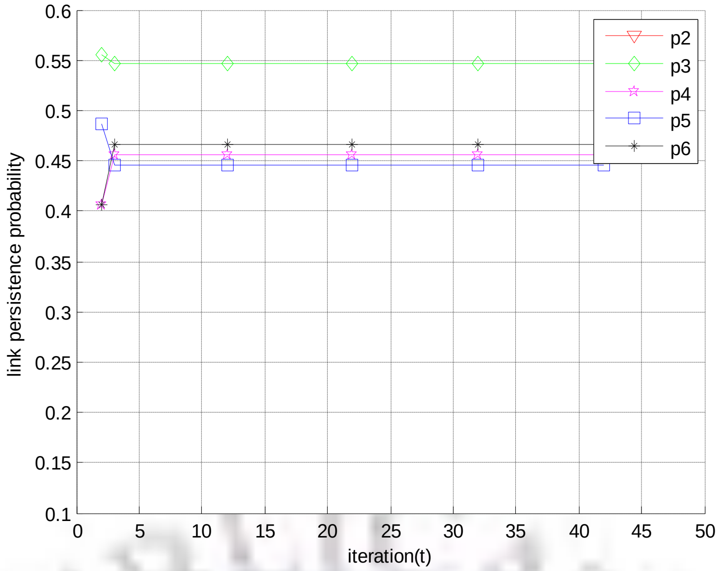

Fig 7. Link persistence probability versus iteration plot

In this simulation N=20 to represent a low density cell and N=100 to represent high density cell for numerical evaluation. In Figure 15, the two-hop routing success probabilities are shown as functions of the average number of routers inside the coverage area. Note that, as the feasible region shrinks with increasing ℓ, the chance of locating a relay within the feasible region also declines. The total energy consumed when there is no sleep state is 3.1133e+010µJ and the total energy consumed when there is sleep state with 10 milliseconds is 2.5377e+010µJ. This shows that the ~18.4% of energy was saved because of sleep state than without sleep state. Most of the traffic that are further away from sink node passes through this nodes. It is because the nodes that are 200m distance is the gateway for the further nodes.

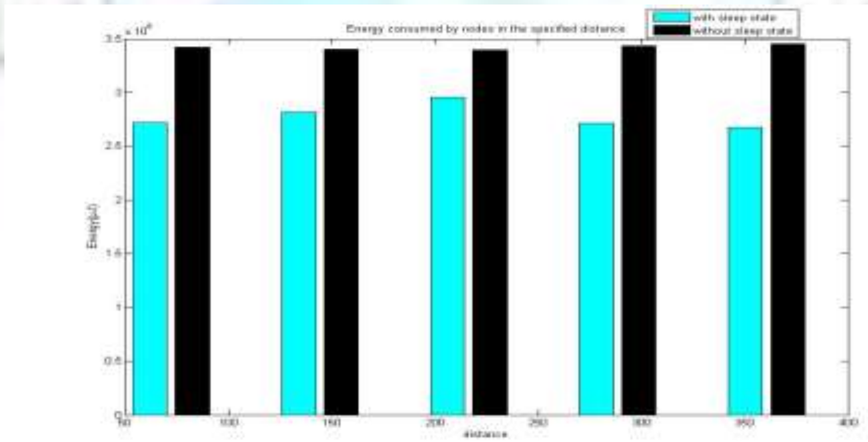

Fig. 8: Difference in Energy consumption for network with sleep state of 10ms and without sleep state based on distance from sink.

CONCLUSION

Even though the X-MAC is giving better results, idle listening is consuming almost 98-99% of the total energy. It will be better to reduce it by making at least the nodes on the edges to go to sleep early and make the network core to work as it is. We can also make the nodes that are not in use for very long time to go to sleep for very long time and the nodes that are being used regularly to go to sleep for very short period of time. We presented in this paper a congestion avoidance mechanism which addresses unicast and multicast best-effort (reliable or not reliable) flows. We introduced a new approach to fairness by means of the router round trip time concept used by our mechanism. The mechanism operation evaluated by simulations and results show that using little bandwidth control overhead, achieves fair sharing of network resources. Due to space limitations, many details of the algorithm and simulation results are not shown in this paper. Our future work is to carry out more and larger scale simulations and to refine the mechanism based on the gained experience. Another issue we plan to explore is a theoretical analysis of the fairness as defined here.

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