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Enhancement of Lifetime Using Network Coding and Duty Cycle at Wireless Sensor Network

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Abstract— Network lifetime is a critical issue in Wireless Sensor Networks (WSNs). In which, a large number of sensor nodes communicate together to perform a predetermined sensing task. In such networks, the network life time depends mainly on the lifetime of the sensor nodes constituting the network. Therefore, it is essential to balance the energy consumption among all sensor nodes to ensure the network connectivity. Our aim is to increase the lifetime of wireless sensor networks by using duty cycle and network coding individually and combination of both. In network coding method we work on network coder nodes which are single hop and multi hop away from the sink.
Keywords— Wireless sensor network, duty cycle, network coding, Network lifetime, energy efficiency.

I. INTRODUCTION

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field. Sensors can be simple point elements or can be multipoint detection arrays. Each sensor node has limited battery. Typically, nodes are equipped with one or more application-specific sensors and with on-node signal processing capabilities for extraction and manipulation (pre-processing) of physical environment information. That can be deployed for monitoring forest fires, aircraft and factories. If we take example of forest fires in that case it is not good for energy efficient wireless sensor network that all node should be active because of that sensor node deplete their energy very quickly. it is not feasible or possible to recharge or replace the batteries. In wireless sensor networks all the nodes in the networks transmits data to the central point which is called as the sink. Sink only receive data from the nodes in the network. There is maximum amount of data flow nearer to the sink so nodes which are nearer to sink consume large energy. The area nearer to the sink where traffic is maximum is called as bottleneck zone.

II. RELATED WORK

There has been research on the network lifetime in WSNs. The network lifetime upper Bounds has been derived in Bharadwaj et al [6]. Wang et al [5] proposed a Bottleneck zone analysis to improve the performance of the whole network. Wang et al. [5] have derived upper bounds on network lifetime for a non-duty cycle based WSN. routing scheme for lifetime increasing has been proposed by Karkvandi et al. [8]. Energy-efficiency at intermediate nodes was examined in [7] where Markov chains were used to determine bounds on energy consumption.

In this work in order to minimize power consumed during idle listening, some nodes, which can be considered redundant, can be put to sleep. Network coding is technique in which throughput, bandwidth, energy efficiency increases and reduces delay. At the time of selection of network coder node in[1] consider network coder nodes are single hop away from the source. Here we consider network coder node is multi hop away from the source and calculate the number of packets transmitted towards the sink.

III. NETWORK LIFETIME USING DUTY CYCLE

The ratio between the time during which a sensor node is in active state and the total time of active/dormant states is called duty cycle. Unbalanced energy consumption is an inherent problem in WSNs, characterized by multihop routing and a many-to-one traffic pattern. This uneven energy dissipation can significantly reduce network lifetime. A duty cycle WSN can be loosely categorized into three main types: [1] random duty-cycled WSN , [2] co-ordinated duty cycled WSN , [3] Adaptive duty-cycle WSN . The random duty-cycled WSNs are simple to design

A system is considered with N sensor nodes scattered uniformly in area A. S1, S2, …………..SN-1 number of sensor nodes are in the network. One node is sink node. The area of the system is A with a bottleneck zone B with radius D. All the N-1 sensor nodes are switching between active and dormant states. Bottleneck zone consist of relay sensor and network coder sensor nodes. The (active) relay sensor nodes (R) transmit data which are generated outside as well as inside the bottleneck zone. The (active)

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network coder sensor nodes (N) encode the raw native data which are coming from outside the zone B before transmission. The sensor nodes outside the zone B are marked as intermediate sensor nodes (I) and Leaf sensor nodes (L). The leaf sensor nodes (L) periodically sense data and transmit them toward the Sink. The intermediate sensor nodes (I) relay the data in the direction of the Sink S. In the bottleneck zone, the relay nodes can communicate with the Sink using a multihop communication. However, the network coder nodes use a single hop to communicate with the Sink. The radius, D, should be at least equal to the maximum transmission range of a sensor node, so that the data generated outside the bottleneck zone can be relayed through the zone B. Relay sensor nodes communicate to sink using multi-hop communication[1] and network coder communicate to sink using single hop communication. Each sensor node consume energy at different state such as transmitting, receiving, sensing the data. Energy consumption by a source node per second is ,

$$Etx=Rd(\alpha 11 + \alpha 2dn) \qquad (1)$$

Where, Rd - transceiver relay data rate. α11-energy consumed per bit by the transmitter electronics. α2 - energy consumed per bit in the transmit op-amp. d-distance between source node to sink. n-path loss exponent(consider as 2 is for propagation in free space).

Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas. Moreover, the total energy consumption in time t by a source node (leaf node) without acting as a relay node is,

$$ES=t[p(rses+ Etx) + (1-p)Esleep] \qquad (2)$$

Where, Esleep - sleep state energy consumption of a sensor node per second. rs average sensing rate of each sensor node and it is same for all the nodes. es–energy consumption of a node to sense a bit probability. p - average proportion of time t of sensor nodes that in active state. (1-p)-A sensor node remains in the sleep state with probability till time t. The energy consumption per second by an intermediate node which act as a relay is given by

$$Etxr=Rd (\alpha 11 + \alpha 2dn+ \alpha 12)=Rd(\alpha 1 + \alpha 2dn) \qquad (3)$$

Where, α12-energy consumed by the sensor node to receive a bit Total energy consumption till time t by an intermediate (relay) node is,

$$ER=t [p(rses+ Etxr) + (1-p)Esleep] \qquad (4)$$

Total energy consumption in the bottleneck zone are viewed as three parts, namely, energy consumption to relay the data bits which are received from outside of the bottleneck zone (E1) and due to sensing operation of the (relay) nodes inside the bottleneck zone (E2) and to relay the data bits which are generated inside the bottleneck zone (E3). sensor nodes in the bottleneck zone may receive multiple copies of the same data bits transmitted from outside of zone B. So, the redundant bits which affect the network lifetime are transmitted inside the zone B. The total number of data bits generated outside the zone B is Np rst(A−B)/ A .

The data bits generated outside the bottleneck zone are relayed through N B/A number of nodes in the bottleneck zone. The total number of data bits which are generated outside and inside of the bottleneck zone in time t is given by Nprst. The total traffic, Nprst, is transmitted through NpB/A active relay nodes in the bottleneck zone. Therefore, the average rate of relaying packets by a sensor node in the bottleneck zone is given by Rd = rsA/B. Let Eb is the initial battery energy available at each sensor node. In a network of N nodes, the energy reserve at the start is N · Eb. The following inequality holds to estimate the upperbound of the network lifetime for a duty cycle based WSN

$$ED \leq NBEb/A \qquad (5)$$

where the term

$$Q_\chi = p\alpha_1 \frac{n}{n-1} r_s \left[D(A-B) \left\lfloor \frac{m+1}{2} \right\rfloor + \iint_B x dS \right] + Bd_m \left[pr_s(e_s - \alpha_{12}) + (1-p)E_{sleep} \right]$$

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Where, XdS= (2/3)*π*D*D and e_s taken as negligibly small(equals to zero). Here we consider 1000 nodes scattered in 200*200m2 with bottleneck zone radius 60m. α11=0.937 μjoules, α12=0.787 μjoules, α2=0.0172 μjoules, Esleep = 30 μjoules, Eb=25 Kjoules.

$$Q_\varphi = r_s\alpha_1\frac{n}{n-1}\Big[\Big\lfloor\frac{m+1}{2}\Big\rfloor D(A-B)\frac{1+k(h-1)}{kh}+\iint_B xdS\Big]+r_s(e_s-\alpha_{12})d_mB$$

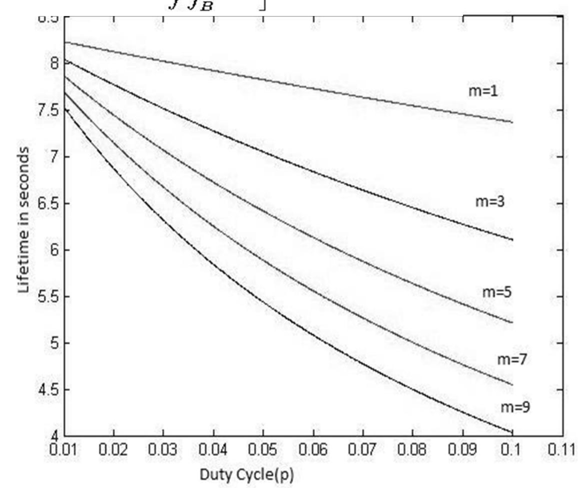

Fig.1. Network lifetime using duty cycle

IV. NETWORK LIFETIME USING NETWORK CODING

An interesting property of network operation using network coding is that, for some traffic scenarios, network coding effectively allows the nodes of the network to achieve the optimal performance while operating. Network coding technique allows the intermediate nodes to encode data packets received from its neighboring nodes in a network [6]. The network coding technique [6] improves the capacity of an information network with better utilization of bandwidth. To increase lifetime linear network coding technique is used. Linear network coding is a technique which can be used to improve a network's throughput, efficiency and scalability. Network coding technique improves reliability of the network. Bandwidth utilization scheme in bottleneck zone reduces extra load on the network. The upper bound of network lifetime has been investigated using a network coding layer near the Sink in the bottleneck zone. With network coding based relaying in the bottleneck zone, E1, E2 and E3 have been derived and renamed as E1NC, E2NC and E3NC. Energy consumption by a network coder node is assumed to be same as energy consumption by a relay node to transmit one bit data inside the bottleneck zone. The overhead of encoding process is negligible in view of single hop communication between the network coder node and the Sink. Let 1/h fraction of the total traffic which are generated outside of the bottleneck zone is relayed through the network coder nodes in the direction of Sink. So, (1−(1)/ h) fraction of the total traffic is relayed through the relay nodes in the bottleneck zone. Energy Inside the zone B, energy consumption is due to sensing inside the zone and relaying the sensed data bits. The sensing energy consumption in time t by the network coder sensor nodes are same as relay sensor nodes. The network lifetime with network coding in WSN is given by

$$Q_\delta = pr_s\alpha_1\frac{n}{n-1}\Big[\Big\lfloor\frac{m+1}{2}\Big\rfloor D(A-B)\frac{1+k(h-1)}{kh} + \iint_B xdS\Big]+Bd_m\Big[pr_s(e_s-\alpha_{12})+(1-p)E_{sleep}\Big]$$

t=dm*B*Eb/Qx (from equation 6) 8)

Here, the value of k is set as 2. after k packets, the network code layer encodes and transmits.

Here we calculate total number of packets transmitted to the sink from network coder nodes if it is single hop away from the sink. Also calculate number of transmission saved i.e. if packet is re-transmitted it will discard and saved that transmission. Each sensor node acts as a routing element for other nodes for transmitting data. First we consider receive queue is empty. Each network coder node transmit by receiving at least 2 packets. Generate the adjacent matrix to represent the topology graph of the randomly deployed wireless networks. If the Euclidean distance between two nodes is less than the transmission range, there exists a link. In this case we receive 21, 17 and 19 packets from 2, 3 and 6 node. We saved 58 transmissions.

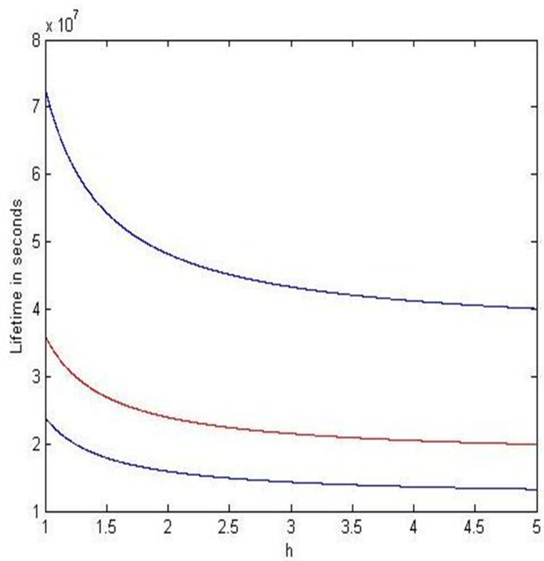

Fig.2. Network lifetime using duty cycle

V. NETWORK LIFETIME USING NETWORK CODING AND DUTY CYCLE

Lifetime bounds in duty cycle based WSN has been estimated using network coding. With duty cycle of the sensor nodes and network coding based relaying in bottleneck zone, whenever a node in the bottleneck zone receives a packet it checks the role of that node. Each node in the network coding layer maintains a received queue and sensed queue. After receiving packet node put a packet in received queue. After receiving packet node put a packet in received queue. If that packet is already processed by the node then it is discarded otherwise the node process the packet. The node checks whether it is encoder or simple relay node. If the packet is non-coded packet in that case the node uses XOR-Encoder. After successfully creating an encoding packet, the nodes transmit the coded packet to the Sink. While decoding The Sink node receives Non-coded packets from the simple relay nodes and coded packets from the network coder nodes. In [10] the intermediate nodes encode and decode packets. Unlike [10], the decoding procedure is performed only at the Sink which processes all the gathered data in WSN. The Sink maintains a pool of packets, in which it stores each, received non-coded packets. The network lifetime for network coding and duty cycle is given by

The value of k is set as 2 and the parameter h is set as 2. Lifetime by combining network coding and duty cycle is more than the duty cycle based WSN. By combining network coding and duty cycle we calculate number of packets transmitted to the sink from network coder node. Here we are considering network coder nodes are one hop away from the sink and relay nodes are at multi hop away from the sink. Also calculate number of transmission saved i.e. if packet is re-transmitted it will discard and saved that transmission. First we consider receive queue is empty. Each network coder node transmit by receiving at least 2 packets. In this case we receive 93, 83 and 68 packets from 2, 3 and 6 node. In this case saved transmissions are 51.

But the problem of above sending part is that every time in system network coder node is only one hop away from the sink. If we want system is more beneficial we want to place all the sensors (if network coder or relay node) at any position. In this network coder node may multi hop away from the sink. So, by considering network coder nodes at multi hop position we calculate number of packet transmitted to the sink and saved transmission. At starting sink is empty after 2 packets received by node it will transmit to the next node which is nearest to sink so that packet transmitted at the sink. . In this case we receive 1 9, 22 and 22 packets from 2, 3 and 6 node. In this case saved transmissions are 47.

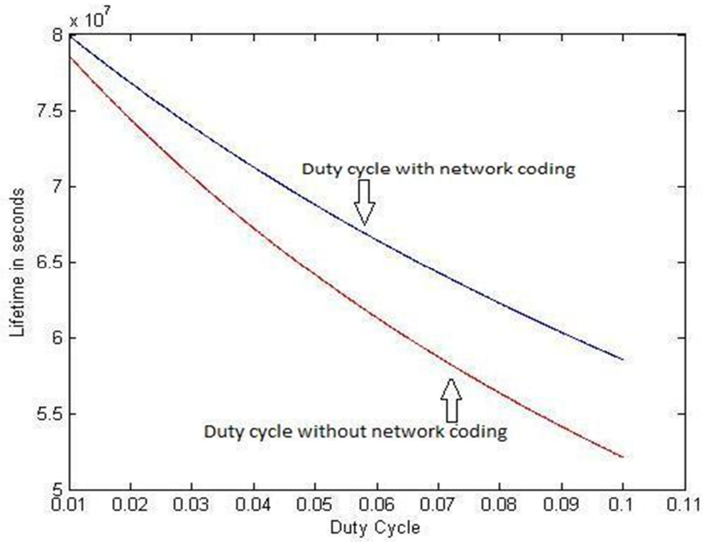

Fig.3. Network Lifetime by combining network coding and duty cycle WSN and Only duty cycle based WSN

VI. CONCLUSION

The key challenge in networks of energy constrained wireless integrated sensor nodes is maximizing network lifetime. In a wireless sensor network (WSN), the area around the Sink forms a bottleneck zone where the traffic flow is maximum. Thus, the lifetime of the WSN network is dictated by the lifetime of the bottleneck zone. By combining duty cycle and network coding it gives better results than individual network coding and duty cycle. As existing methods consist single hop communication between network coder node and sink this paper focused on the multi-hop system between network coder nodes and sink with same coding as in existing methods. In single hop network coder it transmits more number of packets. So more energy required to transmit packets. In multi hop system less number of packets are transmitted than single hop so that energy consumption is also less. In both methods retransmissions are saved and that are approximately same. It may provide efficient solution for large networks for enhance the life.

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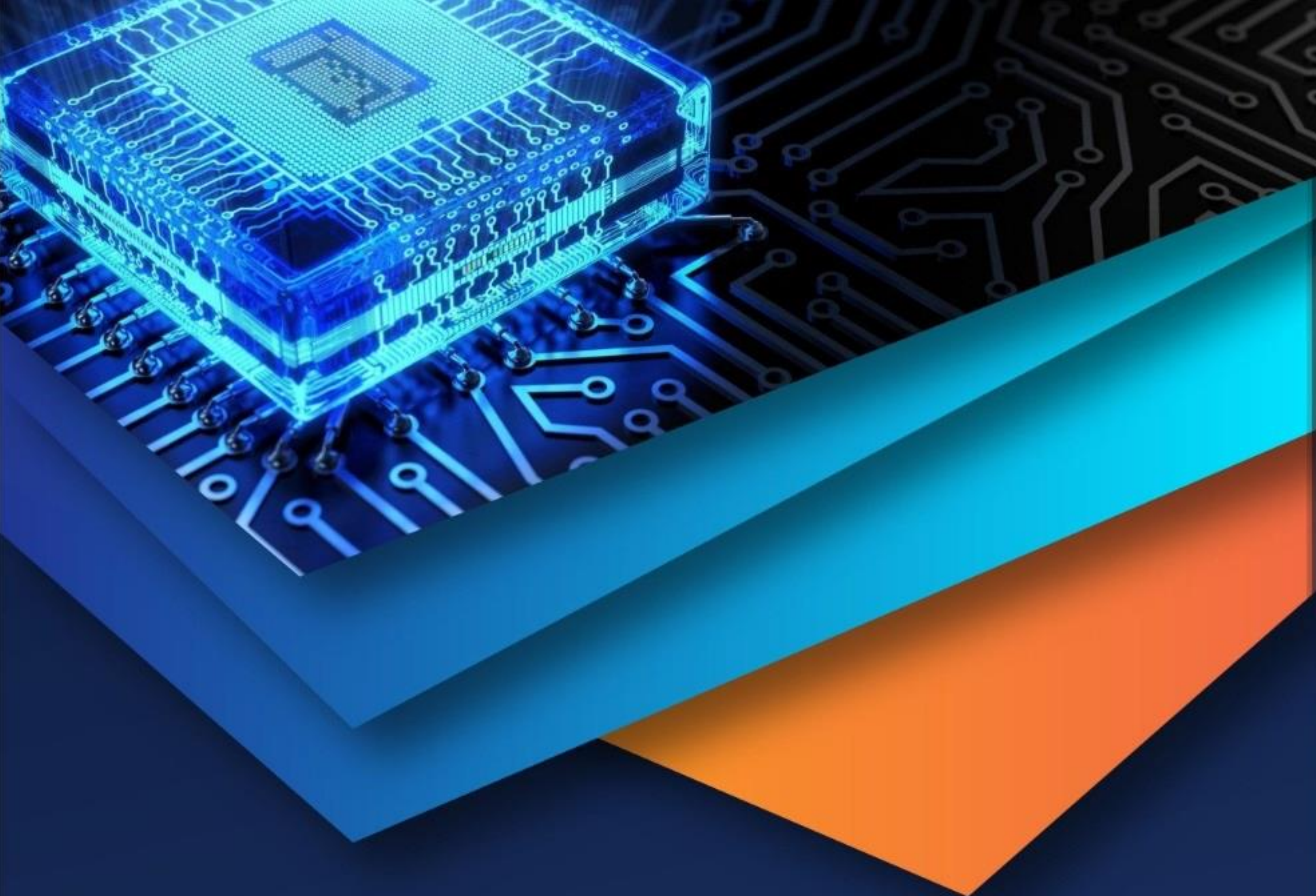

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