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An Adaptive Energy Efficient Packet Forwarding Method for Wireless Sensor Networks

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Abstract: ***In Wireless Sensor Network (WSN), Sensor nodes have limited processing capabilities, therefore simplified protocol architecture should be designed to make communications simple and efficient. Due to this limited power supply, every solution elaborated for these networks should be aimed at minimizing the energy consumption. In previous approach, the original data packets are split into a number of sub-packets equal to the number of disjoint paths from source to destination. This approach is applied sequentially in that network which takes more computational time. The proposed approach splits the original messages into several packets such that each node in the network will forward only small sub-packets. The splitting procedure is achieved by applying the Chinese Remainder Theorem (CRT) algorithm. This approach is applied in entire network which takes low computational time. The objective is to improve the energy in wireless sensor network.***

Keywords: Chinese Remainder Theorem, Energy Efficiency, Packet Splitting, Packet Forwarding, Wireless Sensor Networks.

1. Introduction

Wireless Sensor Networks (WSNs) have been widely considered as one of the most important technologies for 21st century. Building sensors is made possible by the recent advances in Micro-Electro Mechanical Systems (MEMS) Technology. A WSN is a wireless network consisting of spatially distributed autonomous devices that use sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSNs measure environmental conditions like temperature, sound, pollution levels, humidity, wind speed and direction, pressure, etc.,

A wireless sensor network consists of a large number of sensor nodes distributed over a geographic area. A WSN is a collection of low- cost, low- power disposable devices. The main task of a sensor node in a sensor field is to detect events, perform quick local data processing and then transmit the data. Power consumption can be divided into three domains: Sensing, Communication and Data processing.

Each such sensor network node has several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting.

The main characteristics of a WSN include:

- Power consumption constraints for nodes using batteries or energy harvesting
- Ability to cope with node failures
- Mobility of nodes
- Communication failures
- Heterogeneity of nodes

- Scalability to large scale of deployment
- Ability to with stand harsh environmental conditions
- Easy to use

Each node is usually powered by an energy-limited battery, therefore the energy budget is a critical design constraint in WSNs and energy saving is the key issue in order to increase the network lifetime. With the aim of reducing energy consumption, a new approach is introduced which splits the original message into several packets such that each node in the network will forward only small sub packets. The splitting procedure is achieved by using Chinese Remainder Theorem (CRT) algorithm. The splitting procedure is especially helpful for those forwarding nodes that are more solicited than others due to their position inside the network.

2. Related Works

Energy saving, reliability, and complexity are major key issues in WSNs. The concept of sensor networks which has been made viable by the convergence of MEMS, wireless communications and digital electronics [1]. With regards to energy saving, two main approaches can be found in the literature: duty cycling and in-network aggregation [2] and [9]. The first approach is to put the radio transceiver on sleep mode (also known as power-saving mode) whenever communication is not needed. Although this is the most effective way to reduce energy consumption, and energy saving is obtained at the expense of an increased node complexity and network latency. The second approach is intended to merge routing and data aggregation techniques and is primarily aimed at reducing the number of transmissions. Low Energy Adaptive Clustering Hierarchy (LEACH) presented by Heinzelman et al. forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control [4].

An interesting example of using a multipath approach together with erasure codes to increase the reliability of a WSN is proposed in [8]. However, in that work, the authors suggested the use of disjoint paths. When compared to our proposed forwarding technique, using disjoint paths has two main drawbacks. First, a route discovery mechanism is needed. Second, as the numbers of disjoint paths are limited, the numbers of splits (and therefore the achievable energy reduction factor) are limited as well. The authors considered general forward error correction (FEC) techniques without investigating their specific complexities and/or their impact on energy consumption [8].

SMAC [3] is a MAC protocol specifically designed for wireless sensor networks. It forces sensor nodes operate at low duty cycle by putting them into periodic sleep instead of idle listening. Sensor nodes also sleep during overhearing to save power. Although, SMAC saves more power than 802.11, it does not adapt to network traffic very well since it uses a fixed duty cycle for all the sensor nodes. A duty cycle tuned for high traffic loads results in energy wastage when the traffic is low, while duty cycle tuned for traffic loads results in low throughput under high traffic loads.

In another similar work [6], the authors have proposed a protocol called Rein Form (Reliable Information Forwarding using multiple paths in sensor networks). The main idea investigated in this paper is the introduction of redundancy in data to increase the probability of data delivery. The redundancy adopted is in the form of multiple copies of the same packet that travel to the destination along multiple paths. Multiple paths could remarkably consume more energy than the single shortest path because several copies of the same packet have to be sent [10]. An attempt is made to guarantee reliability, while minimizing the energy consumption and at the same time, considering a packet-splitting procedure [7].

In this paper, by using the CRT-based approach, both reliability and energy saving can be achieved with a moderate increase in the overall complexity and with very low overhead as compared to the commonly used forwarding technique is proposed.

3. Basic Idea

Let us consider a sensor network where sensor nodes periodically send messages to a sink node through a multihop transmission. The basic idea of the paper is to split the messages sent by the source nodes so that a reduced number of bits are transmitted by each forwarder node.

In order to understand the main idea, let us consider the example in Figure 1. Nodes A and B have to forward a packet to the sink S and can do it through nodes P, Q, and R, which are all in the coverage range of A and B.

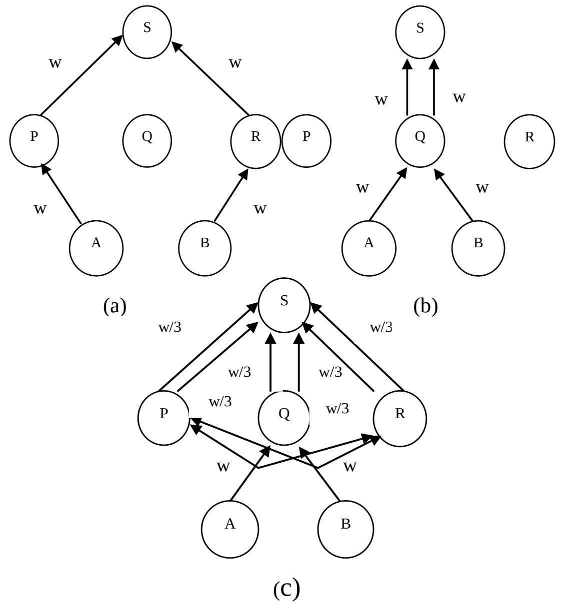

Figure 1: Forwarding examples
(a) Normal forwarding with different next-hops
(b) Normal forwarding with the same next-hop
(c) Forwarding after splitting.

If a normal forwarding scheme is adopted, two cases can be distinguished. Case i) A and B select different next-hop nodes in Figure 1(a).This happens with probability $\frac{2}{3}$ .Case ii) A and B select the same next-hop node in Figure 1(b).This happens with probability $\frac{1}{3}$

If there are "ω"bits for each packet, the maximum number of bits transmitted by a node belonging to the set {P, Q, R} is bits in the case a) and "2ω" bits in the case ii).1 Let us now assume that each node in the set {P, Q, R} knows that A and B have three possible next-hops and that a different forwarding scheme is adopted, as shown in Figure 1(c). In particular, when P, Q, and R receive a packet, they split it and send to the sink only a part (for instance, ω/3 bits each). In this case, P, Q, and R have to transmit at most 2/3 ω bits each. If two forwarding methods are compared the last one reduces the maximum number of bits transmitted by a node belonging to the set {P, Q, R}. More precisely, the reduction factor is$1-\frac{2}{3}=\frac{1}{3}$ when the splitting procedure is compared with the procedure shown in case i), and $\left(2-\frac{2}{3}\right).\frac{1}{2}=\frac{2}{3}$ when the splitting procedure is compared to the procedure shown in case ii). An average reduction factor of 4/9 is obtained.

This example shows that although the total amount of transmitted bits does not change (2ω bits are transmitted anyway, either with or without splitting), by splitting a packet, it is possible to reduce the maximum number of transmitted bits per node and therefore each node consumes mean energy for the transmission. Accordingly the lifetime of a sensor network increases as the energy consumption is distributed more among the nodes.

Finally, it can be observed that if a perfect balancing is possible, which occurs when the number of next-hop nodes is a factor of the number of transmitted messages (i.e., the number of messages is exactly divisible by the number of next-hops), the energy consumed by nodes will be the same either with or without splitting. However, if this is not the case, using a splitting technique makes the number of forwarded bits significantly reduced. For instance, let us consider Figure. 1(c) when N = 17 messages of ω = 120 b are sent. In this case, without splitting, at least one of the nodes P, Q, R will forward six messages (i.e., 120*6=720b), while using a splitting technique, each message can be split into three components of 40 b each, so that 40*17=680 b are forwarded. Therefore, when using splitting, the maximum number of transmitted bits per node is reduced by about 6%. The above difference increases if a node can forward seven messages out of 17 (in this case, have a reduction of 19%). Moreover, the reduction increases if the ratio "message length over number of components" decreases (i.e., if the number of available next-hop nodes are increases).

It is worth remarking that the splitting procedure has to be performed in a simple manner, and consequently with low energy consumption, so that the sink can recombine the original packet maintaining at the same time the overhead needed to split the packet as small as possible. Furthermore, reliability should be considered as well. In fact, when classical splitting techniques are adopted (e.g., simple packet division into chunks), the probability that the original packet cannot be reconstructed increases.

3.1 Measuring the energy efficiency

In general, if the energy consumption is proportional to the number of bits transmitted then, assume ω the number of bits in the original message m. The previous energy reduction factor can be obtained for high node densities, i.e. when there are a sufficient number of disjoint paths it is highly probable that all the CRT components are forwarded by different nodes.

4. Forwarding Technique Based on Chinese Remainder Theorem

Chinese Remainder Theorem (CRT) is used to solve problems in computing coding. In computing it can compete with shorter numbers instead of large numbers and this will make the computing-process faster and easier. In coding it can be used for error-searching and error-regulating. The algorithm allows reconstructing a large integer from its remainders modulo, a set of moduli. When all the moduli are co-prime, CRT has a simple single formula, which is well-known not robust, i.e., small errors from any remainders may cause a large reconstruction error.

4.1 Theorem

Chinese Remainder Theorem (CRT) characterized by a simpler modular division between integers. Basically, in its simpler form of the CRT can be formulated as follows:
Let the numbers $m_1, m_2, \ldots, m_N$ be positive integers which are relatively prime p_i in pair, i.e. $\gcd(m_i, m_j) = 1$ when i≠ j. Then the simultaneous Congruence's $m = m_i \pmod{p_i}$ and it can be obtained by *m*= $(\sum_{i=1}^{N} c_i . m_i$) *(mod M)*.The coefficients c_i are given by $c_i = Q_i p_i$, where $Q_i = \frac{M}{p_i}$, and q_i is its modular inverse, i.e., q_i solves $q_i Q_i = 1 \pmod{p_i}$.
Let us consider one example,

x = 1 (mod 3)
x = 4 (mod 5)
x = 1 (mod 7)

It is simple to prove that, N = 105; a_1= 70, a_2= 21, a_3= 15, and n = 64

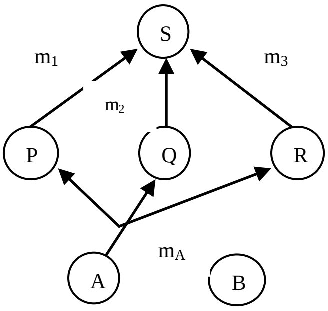

Figure 2: Example of forwarding after splitting numbers

According to the CRT, the number can be alternatively identified with the set of numbers provided that is known. However, it is worth noting that in the above example, therefore if, instead of *m*, m_i.. Figure 2 shows the example of forwarding after splitting numbers, with $m = m_i \pmod{p_i}$, are forwarded, the maximum energy consumed by each node for the transmission can be substantially reduced.

For instance, consider Figure. 2. If P, Q, and R receive a message m_A from A, each of them, applying the procedure shown above can transmit a message m_i , with $i \epsilon \{1,2,3\}$, to the sink instead of m_A . Furthermore, the sink, knowing p_i , with $i \epsilon \{1,2,3\}$, and using the CRT approach, will be able to reconstruct m_A ,In general, if the energy consumption is proportional to the maximum number of bits transmitted, and assuming ω as the number of bits in the original message m, and as the $\omega_{CRT\max}$ maximum number f bits of a CRT component, i.e., $\omega_{CRT\max} = \max([\log_2(p_i)])$,can consider a theoretical maximum energy reduction factor (MERF) given by equation (1)

$$MERF = \frac{\omega - \omega_{CRT\max}}{\omega} \qquad (1)$$

For instance, in the previous example, MERF = 7-3/7 ≈ 0.57.This means that about 57% of the needed energy could be saved by considering the proposed forwarding scheme. The previous energy reduction factor can be obtained when all the CRT components, m_i , are forwarded by different nodes (i.e., for disjoint paths). In a real scenario, where the CRT components are not always forwarded through disjoint paths, the MERF is rarely obtained, and the expected energy reduction factor (ERF) has to be expressed taking into account both the actual number of bits forwarded by a traditional forwarding algorithm and our proposed CRT-based forwarding algorithm, under the same conditions.

4.2 Selection of Prime Numbers

It is important to observe that the set of prime numbers p_i >1, with i ϵ {1…N}, can be arbitrarily chosen provided that m < M. Therefore, the number of bits needed to represent m_i can be reduced by choosing the prime numbers as small as possible. As a consequence of this choice, the MERF is maximized.

Throughout the paper, it is indicated with Minimum Primes Set (MPS), the set of the smallest consecutive primes that satisfy the condition $M \geq 2^w$. For instance, if N = 4 and m is 40 b word ($\omega = 40$), the MPS will be {1019, 1021, 1031, 1033}.This is the set of smallest four consecutive primes that satisfies the condition $M \geq 2^{40}$. The MERF in this case is 0.72. However, when the primes set are chosen as above, the message can be reconstructed if and only if all the CRT components are correctly received by the sink. In general, the paper will indicate MPS-f the Minimum Primes Set with f admissible failures.

4.3 Forwarding Algorithm

The forwarding algorithm is based on two temporal phases, the Initialization phase and the Forwarding phase.

Initialization Phase: This phase organizes the network in clusters and also has the advantage of minimizing the number of hops needed to reach the sink.
The Initialization phase has been described in detail in [5], and it is realized through an exchange of initialization messages (IMs) starting from the sink that is supposed to belong to the cluster 1, i.e., $CL_{ID} = 1$, where CL_{ID} identifies the cluster number.

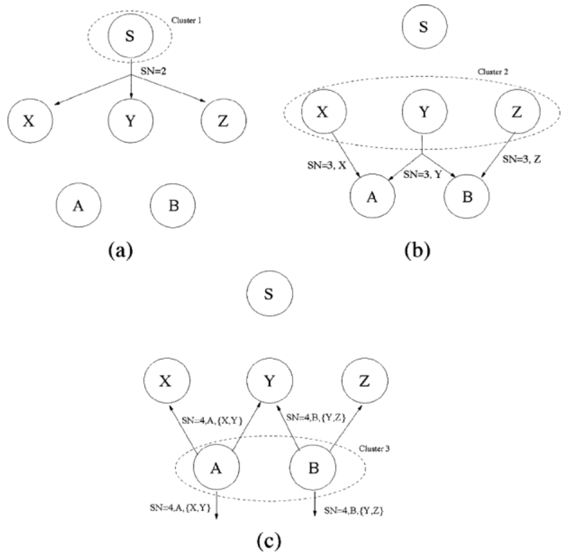

Figure 3: Initialization procedure

(a) Sink sends the first IM.
(b) Nodes X, Y, and Z belong to $CL_{ID} = 2$.
(c) Node X knows that A will use X and Y as next-hops and therefore all packets originated by A can be split in N_A parts.

Each node that receives an IM from its neighbors with a sequence number SN = h, will belong to cluster h and will retransmit the IM with an increased SN together with its own address and the list of the nodes that will be used as forwarders (that it knows on the basis of the source addresses specified in the received IMs). On the basis of the received IMs, at the end of the procedure each node in the network will know its own next-hops, which other nodes will use it as a next-hop, and into how many parts the received packets can be split Figure 3, is a simple example of initialization procedure.

Forwarding Phase: Once the network has been organized, the Forwarding phase is applied.

Basically, all nodes follow the same forwarding rule: If there is a number of neighbors at least equal to N, and the packet has not previously split, then split the packet; *else* use conventional shortest path approach. Let us consider the network shown in Figure 4, where clusters are obtained according to the initialization procedure already described in the previous section. The Figure 4 shows the messages sent by each node when the source node H sends a message *m* to the sink S

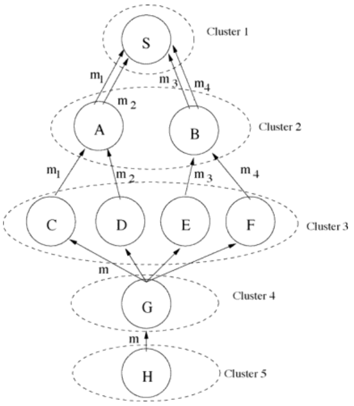

Figure 4: Forwarding example

According to the initialization procedure, node G knows that it is the only next-hop of node H, and therefore it must forward the packet without performing a splitting procedure. It is worth highlighting that it is not necessary for G to specify the list of the destination addresses {C, D, E, F} in the packet. In fact, in the initialization phase, nodes {C, D, E, F} have already received the IM message IM: [SN=5, G, {C, D, E, F}], and therefore they know that node G has four next-hops and that all of them have to split the messages received from G into $N_G = 4$ parts. Therefore, when they receive the packet, according to the packet size, ω, and N_G, they independently select the prime numbers and send the components $m = m_i (\bmod p_i)$, together with a proper mask, to one of the possible next-hops. When the sink receives a component m_i, it identifies the number of expected components on the basis of the mask, and therefore it calculates the MPS-*f* and the coefficients c_i needed to reconstruct the original message. Finally, when the sink receives at least $N_G - f$ components of the original message, it can reconstruct the message by $m = \sum_i c_i m_i (\bmod M')$. Note that because the events that happen in a sensor network may change, in number and locations, during the time period considered, consequently the packets can be generated by different nodes, and the components (m_i) received and transmitted by the nodes change accordingly. Thus, for different source nodes, any node transmits CRT components based on different prime numbers.

Concerning the complexity of the algorithm, it is worth mentioning that the message splitting is performed only one time by the nodes that are the closest to the source and have the opportunity to do it (e.g., if they are in proximity of a number of neighbors higher than the threshold specified for the initialization phase), whereas the other sensor nodes in the network will just forward the sub packets. Moreover, only the sink node will reconstruct the original message through more complex operations as described, but this can be neglected if consider that usually the sink node is computationally and energetically more equipped than the other sensor nodes. Obviously, in the case of very large packets, it is possible to split the packets recursively, but in order to keep the complexity of the proposed algorithm very low, will consider that a packet can be split only one time.

5. Performance Analysis

5.1 Performance Matrices

Wireless Sensor Network performances are evaluated by using following matrices: Packet Delivery Ratio (PDR), End-to- End Delay, Packet Lost, Throughput, and Energy Saving.

Packet Delivery Ratio: It is the ratio of the number of packets received successfully and the total number of packets transmitted.

$$\text{PDR} = \frac{\text{Number of Received Packets}}{\text{Number of Transmitted Packets}}$$

End- to- End delay: The end-to-end delay is averaged over all surviving data packets from the source to destination.

$$\text{End-to-End Delay} = \frac{\sum \text{(Arrive time- Send time)}}{\sum \text{(Number of Connections)}}$$

Packet Lost: The total number of packets dropped during the simulation

Packet Lost = Number of Packets send – Number of Packets Received

Throughput: It is defined as the total number of packets delivered over the total simulation time. It is the ratio of successfully received data packets by the base station to the total packets being sent from the source nodes. Mathematically, it can be defined as:

$$\text{Throughput} = N/1000$$

Where N is the number of bits received successfully by all destinations.

Energy Efficiency: It is defined as the total unused energy level of nodes in the network. The energy consumption is proportional to the number of bits transmitted then, assuming ω the number of bits in the original message m.

5.2 Simulated Results

NS2 is discrete event packet level simulator. NS2 is a package of tools that simulates the behavior of network. Figure 5. Expose the packet delivery ratio for both the approaches. The proposed approach achieves a high packets delivery ratio compared to the existing approach. Figure 6. Represent the end to end delay. The proposed approach reduced the delay in packet forwarding but the existing approach increase the delay in packet forwarding.

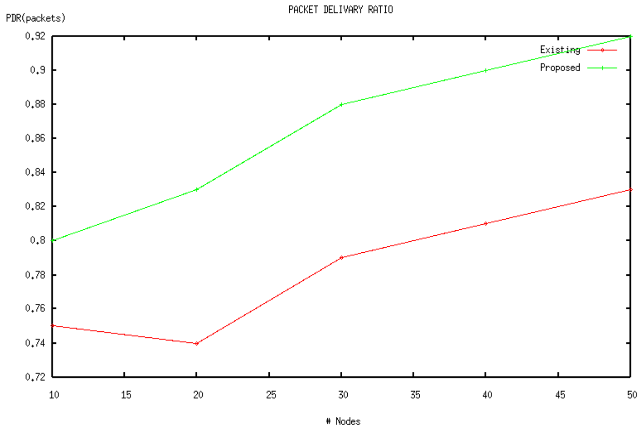

Figure 5: Node Vs Packet Delivery Ratio (PDR)

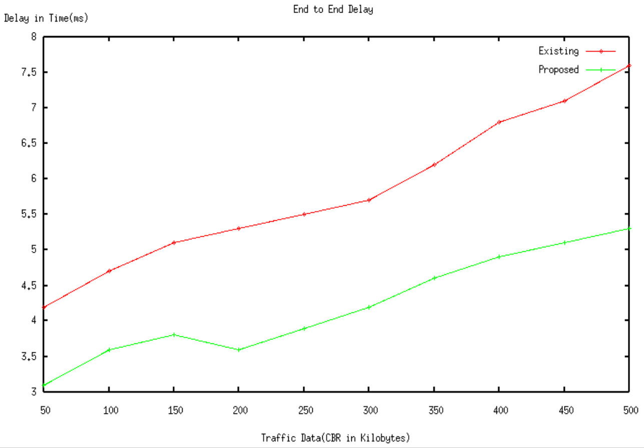

Figure 6: Traffic Data Vs End to End To End Delay

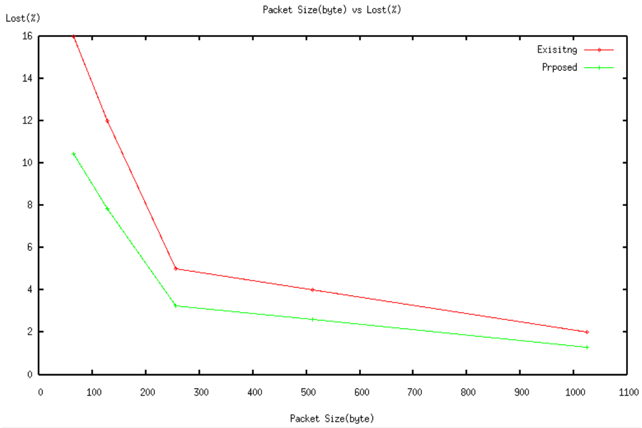

Figure 7: Packet Size Vs Loss

Figure 7. Existing approach achieves more packet loss but the proposed approach avoid this much of packet loss. Figure 8. Represent the throughput ratio. The proposed approach reaches the high level ratio compared to the existing approach.

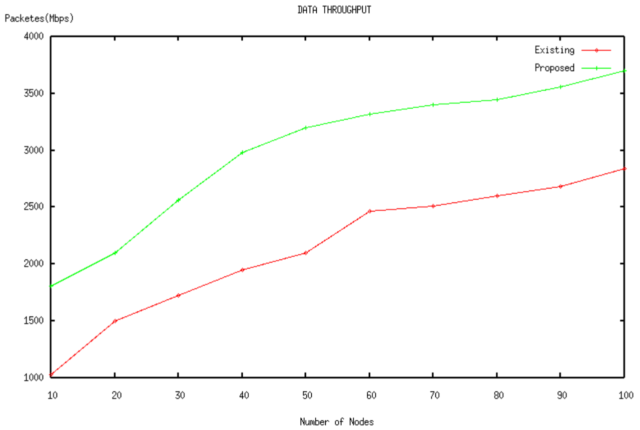

Figure 8: Number of nodes Vs Packets

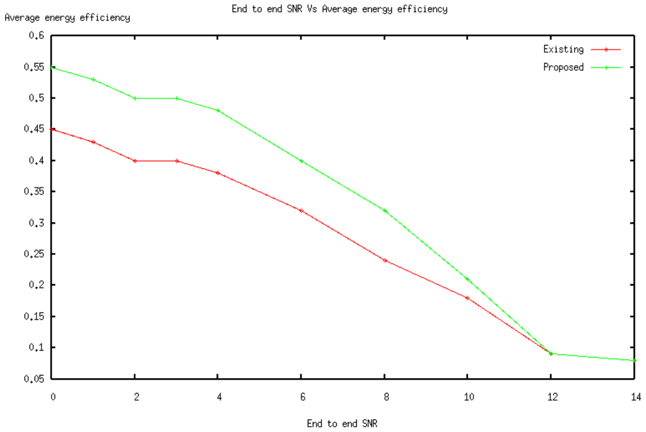

Figure 9: End- to- end SNR Vs Average Energy efficiency

Figure 9. Expose the energy efficiency and points. Consider the existing End to end SNR acts in the maximum level of 0.45. In proposed scheme energy efficiency reach the level of 0.55.

6. Conclusion

In this paper a new forwarding algorithm based on the Chinese Remainder Theorem has been introduced. This proposed technique significantly reduces the energy consumed for each node and consequently improves network life time. Computation time is also reduced by this approach. In future some security model for secure communication can be implemented.

References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E Cayirci, “A survey on sensor networks,” *IEEE Commun. Mag.*, vol. 40, no. 8, pp.102–114, Aug. 2002.

[2] G. Anastasi, M. Conti, M. Di Francesco, and A. Passarella, “How to prolong the lifetime of wireless sensor network,” in *Handbook of Mo- bile Ad Hoc and Pervasive Communications*. Valencia, CA: American Scientific Publishers, 2007, ch. 6.

[3] W. Ye, J. Heidemann and D. Estrin, “An Energy-Efficient MAC Protocol for Wireless Sensor Networks,” in *Infocom 2002*, New York, Jun. 2002, pp.1567-1576.

[4] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy efficient Communication Protocol for Wireless Micro sensor networks, *“System Sciences, 2000. Proceedings of the 33rd Annual Hawaii International Conference on*, p. 10, 2000.

[5] G. Campobello, A. Leonardi, and S. Palazzo, “A novel reliable and energy-saving forwarding technique for wireless sensor networks,” in *Proc. ACM MobiHoc*, New Orleans, LA, May 18–21, 2009, pp.269–278.

[6] B. Deb, S. Bhatnagar, and B. Nath, “ReInForM: Reliable information forwarding using multiple paths in sensor networks,” in *Proc. 28th Annu. IEEE LCN*, Bonn, Germany, Oct. 2003, pp. 406–415.

[7] P. Djukic and S. Valaee, “Minimum energy reliable ad hoc networks, “in *Proc. 22nd Bienni. Symp. Commun.*, Kingston, ON, Canada, Jun.2004, pp. 150–152.

[8] S. Dulman, T. Nieberg, J. Wu, and P. Havinga, “Trade-off between traffic overhead and reliability in multipath routing for wireless sensor networks,” in *Proc. WCNC*, New Orleans, LA, Mar. 2003, pp.1918–1922.

[9] E. Fasolo, M. Rossi, J. Widmer, and M. Zorzi, “In-network aggregation techniques for wireless sensor networks: A survey,” *IEEE Wireless Commun.*, vol. 14, no. 2, pp. 70–87, Apr. 2007. .

[10] D. Ganesan, R. Govindan, S. Shenker, and D. Estrin, “Highly resilient, energy efficient multipath routing in wireless sensor networks,” *Mobile Comput. Commun. Rev.*, vol. 5, no. 4, pp. 10–24, Oct. 2001.

[11] [Online].Available: http:// www. isi. Edu /nsnam /ns /index.html