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# An Optimized Energy Efficient Approach for Realistic Physical Layer Data Transmission in Wireless Sensor Network

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**Abstract:** ***A typical wireless network consists of closely located static nodes with one stationary base station. The base station maintains the different node activity with more energy consumption. Existing Network coding-based cooperative ARQ scheme perform the multi-hop transmission among a set of relay nodes. However, the impact of realistic physical layer is not considered for data transmission. In addition, Polynomial time K-approximation algorithm MAP (Multi-constrained AnyPath) supports multipath path routing in wireless network. K-approximation algorithm exploits the many single paths with less costly system but data transmission is not carried out with the higher throughput level. To perfectly carry out the realistic physical layer data transmission, Energy Effective Cumulative Curvature (EECC) approach is developed in this paper. The EECC method attains the optimal data transmission result by forwarding the data packets with changeable target constraints in the queue. Proposed EECC uses the heuristic method to handle the arbitrary rate of packet arrival to the queue list and also achieve the minimal energy consumption on the large scale wireless network. The EECC method uses the discrete-time stochastic dynamic programming in wireless network to perform the multi-hop transmission with higher throughput level. The dynamic programming significantly performs the multi-hop transmission at the discrete time interval to improve the data transmission rate. Heuristic method in EECC method obtains the best energy approximation result on discrete-time stochastic function and effective data transmitted based on the queue length. Experimental evaluation of EECC method is done with the performance metrics such as throughput level, energy consumption rate, delay time, data transmission rate. Experimental analysis shows that the EECC method is able to improve the throughput level by 34% and reduces the energy consumption by 26 % when compared to the state-of-the-art works.***

**Keywords**: wireless network, base station, multi-hop transmission, realistic physical layer, queue list, discrete-time stochastic dynamic programming.

## 1. Introduction

In wireless sensor network, data transmission is very expensive in terms of energy consumption. Energy efficiency is the most important factors because it directly affects the lifetime of the network. Recently, most of the researches have been developed for energy efficient data transmission. However, energy consumption still poses the demanding issues in WSN. Network Coding-based Cooperative ARQ (NCCARQ-MAC) scheme was designed in [1] to perform the multi-hop transmission among a set of relay nodes. However, the impact of realistic physical layer is not carried out for data transmission.

Polynomial time K-approximation Algorithm MAP (Multi-constrained AnyPath) developed in [2] supports any path routing in wireless network. Though, K-approximation algorithm exploits the many single paths with less costly system but data transmission is not carried out with the higher throughput level. K-hop clustered networks as described in [3] perform the arbitrary walk mobility with non-trivial velocities. The non-trivial velocities decreases the energy consumption and recover the power delay trade off but multi hop transmissions (i.e.,) data delivery to the cluster head is not performed in wireless network.

Scheduling partition method [4] was introduced in the large scale wireless network that satisfies a set of adequate and necessary conditions to attain the optimal capability scaling. Though, the capacity scaling provides the energy failing result on the large scale wireless network. An Energy efficient data communication approach [5] was developed to improve the energy efficiency and provide reliable transmission of sensed data to the base station in WSN. A cross layer energy efficient protocol [6] was designed in Wireless Sensor Networks for minimizing the energy consumption at physical layer. However, energy efficiency is not at required level.

Data transmission scheme was presented in [7] to reduce the length of the data and to improve the energy efficiency. Another scheme [8] was introduced for data collection/transmission to the mobile sink. The Multihop Energy Efficient Clustering scheme was presented in [9] for improving the performance of multihop communications and clustering with minimum energy consumption. But, this method compromised the transmission power.

An energy efficient routing protocol [10] was designed in WSN to improve the network lifetime with minimum energy consumption and delay. However, it obtains more energy consumption in small and large WSN. A cross-layer optimization method was developed in [11] to improve the quality of user experience (QoE) and energy efficiency of the heterogeneous network. Secure and Energy Aware Routing Protocol was introduced in [12] for energy efficiency and security for wireless sensor networks. Though, the protocol has minimum data transmission efficiency.

Reliable minimum energy and cost energy routing was presented in [13] to increase the energy-efficiency, reliability, and network lifetime. But, the traffic creating nodes consumes more energy. A distributed algorithm was designed in [14] for reducing the communication energy consumption by means of minimizing the total transmission power of sensors when maintaining the connectivity of the network. Energy balanced data gathering routing algorithm [15] was developed by using the concepts of potential with the aim of minimizing the energy consumption.

Generic Energy-Balancing GBR protocol [16] was implemented to improve the energy efficiency and balancing the network even in large scale WSN. Mathematical power distribution model was proposed in [17] for optimizing energy consumption of the sensor node. Energy optimization method [18] was introduced based on the Dijkstra's algorithm. A survey on energy efficient routing protocol was presented in [19]. Decentralized Fuzzy Clustering Protocol (DCFP) [20] was designed with the aim of improving the network lifetime through efficient data delivery with minimal energy.

Based on the aforementioned techniques and methods presented, in this work we propose a novel framework called as Energy Effective Cumulative Curvature (EECC) for improving the throughput level and minimizing the energy consumption in WSN. The EECC method perfectly performs the realistic physical layer data transmission by forwarding the data packets with changeable target constraints in the queue. Proposed EEEC method handles the arbitrary rate of packet arrival at the queue list by applying the heuristic method and also attains the minimal energy consumption. Next, The EECC method uses the discrete-time stochastic dynamic programming to perform the multi-hop transmission with higher throughput level.

The paper is organized as follows. In Section 2, we describe the design of EECC framework using discrete-time stochastic dynamic programming and heuristic method. Section 3 provides an analytical analysis of the system, whereas Section 4 presents the experimental results and discusses their significance. Section 5 finishes the paper with concluding remarks.

## 2. Design of Energy Effective Cumulative Curvature (EECC) approach

The design of Energy Effective Cumulative Curvature (EECC) approach is described in this section. In EECC approach, we study optimal rate control for transmitting target constrained data packet over a time-varying channel. Specifically, we consider a wireless transmitter in which the target constraint varies stochastically over time. Therefore the packets arrivals at the queue have strict delay constraints. The main goal of EECC approach is to achieve the optimal data transmission with higher through put level and to minimize the energy utilization while performing data transmission.

The EECC approach first considers the case of 'DP' bits of data packets that must be transmitted through a target constraint 'T'. And then EECC approach uses a novel continuous-time stochastic control formulation to attain the optimal data transmission result by forwarding the data packets with changeable target constraints in the queue. Depends on a cumulative curves methodology and a decomposition approach, we then achieve the optimal data transmission while the queue has packets with changeable target constraints. Then, EECC approach uses a heuristic method to handle the arbitrary rate of packet arrival at the queue list with the objective of reducing energy consumption on the large scale wireless network. Finally, EECC approach performs the multi-hop transmission at the discrete time interval by applying the discrete-time stochastic dynamic programming in wireless network. The dynamic programming significantly performs the multi-hop transmission by means of finding the minimum cost path for transmitting the data packets which results in improved data transmission rate. The design of EECC approach is shown in Figure 1.

As shown in Figure 1, the EECC approach initially handles the arbitrary rate of the packet arrivals at the queue list by applying the heuristic method. In EECC approach, queue list is used for storing the data packets with minimum energy consumption. Queue list follows the First-In-First-Out (FIFO) data structure therefore consumption of energy for storing the data packet is reduced in EECC approach. Next, EECC approach performs the multi hop transmission by applying the Discrete-time stochastic dynamic programming. Discrete-time stochastic dynamic programming significantly finds the minimum cost path for transmitting the data packet with changeable target constraints in queue which results in improved data transmission rate with higher throughput level.

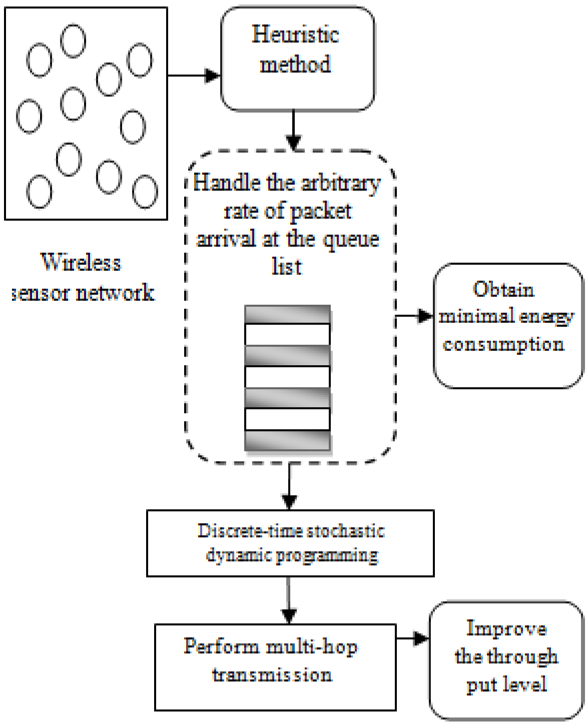


**Figure 1** Design of Energy Effective Cumulative Curvature approach

### 2.1 Heuristic method for handling the Packet arrivals at the queue list

In EECC approach, Heuristic method handles the arbitrary rate of packet arrival at the queue list by forwarding the data packets with changeable target constraints. In a queue, all the operations are take place at one end of queue or other end. Enqueue operation adds data packet to the back of the queue. Dequeue operation removes the data packet at front of the queue and returns it. After that, Heuristic method forwards the data packets with respect to the changeable target constraints in wireless network which provides optimal data transmission with minimal energy consumption. The structure of packet arrivals to the queue list is shown in Figure 2.

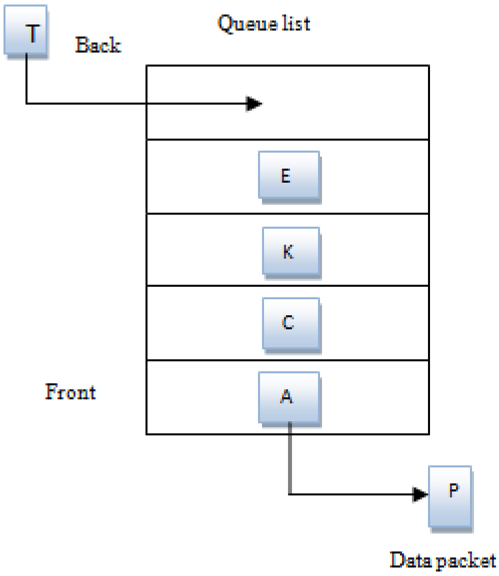


**Figure 2:** Structures of packet arrivals in the queue list

Consider queue list has '*DP*' units of data packet that must be transmitted by target *T*, with minimum energy over a time-changeable channel. We called this as the "*DPT*-problem" where the notation implies that the amount of data packet under consideration is DP and the target is *T*. The case with changeable target constraints is explained in the next sub section 2.1.1. Now, we describe the optimal control formulation for the *DPT*-problem.

Consider *DPT*-problem and let $p(t)$denote the amount of data packet left in the queue list at time *t*. The system state can be described as$(p,s,t)$, where the notation denotes that at the present time *t*, $p(t) = p$ and$s(t) = s$, where s is a channel state, p denotes the data packet. Let $tr(p,s,t)$ denote the selected transmission rate for the corresponding system state$(p,s,t)$. Because the primary process is Markov, it is enough to limit attention to transmission rules that depend only on the present system state.

By applying transmission a rule $tr(p,s,t)$, the system evolves in time as a Piecewise-Deterministic-Process (PDP) as follows. It starts with $p(0) = DP$ and $s(0) = s_0$. Until $\tau_1$, where $\tau_1$ is the first time instant after $t$ = 0 at which the channel changes, the buffer is reduced at the rate $tr(p(t), s_0, t)$. Therefore, over the interval $[0, \tau_1]$, $p(t)$satisfies the ordinary differential equation as follows,

$$\frac{dp(t)}{dt} = -tr(p(t), s_0, \qquad (1)$$

Then, starting from new state$(P(\tau_1), s_1, \tau_1)$, the above procedure repeats until $t = T$ is achieved. A transmission rule $tr(p,s,t)$ is admissible, if it satisfies the following,

a) $0 \leq tr(p,s,t) < \infty$,(non-negativity)

b) $tr(p,s,t) = 0$, if $p = 0$(no data packets left to transmit) and

c) $p(T) = 0$, as (target constraint)

Assume now an admissible transmission rule $tr(\cdot)$ and the cost-to-go function $J_{tr}(p,s,t)$ is defined as the expected energy cost starting at time $t < T$ in state $(p,s,t)$ which formulated as,

$$J_{tr}(p,s,t) = E[\int_t^T \frac{1}{s(x)} g\big(tr(p(x), s(x), x)\big)dx] \quad (2)$$

From (2), the expression within the brackets is the total energy expenditure acquired as the integral of the power cost over time and the expectation is conditioned on the starting state $p(t) = p$, $(t) = s$ .

Then minimum cost function$J(p,s,t)$is referred as the infimum of $J_{tr}(p,s,t)$ over the set of all admissible transmission rules which mathematically formulated as,

$$J(p,s,t) = inf_{tr(\cdot)} J_{tr}(p,s,t), \qquad tr(p,s,t) \text{ admissible} \quad (3)$$

As a result, the minimum cost function $J(p,s,t)$ and obtained the optimal transmission rule $tr^*(p,s,t)$ achieves the minimum cost energy for transmitting data packets in wireless network.

The optimal solution to the changeable targets problem provides a simple heuristic way to extend the results to a more general setup involving packet arrivals to the queue list. Let us assume, an arbitrary stream of packet arrivals to the queue list with each packet having a target by which it must depart. Heuristic method handles the arbitrary rate of packet arrival at the queue list by means of changeable target constraints which results in minimal energy consumption on the large scale wireless network. Regardless of the underlying stochastic process generating the packets, we then present a heuristic energy-efficient policy based on the changeable targets solution which is elaborated in forthcoming subsection.

### 2.1.1 Heuristic energy-efficient policy

Consider packet arrivals to the queue list and assume that the arrivals take place at discrete times with each packet having a target associated with it. After the packet arrivals at the queue list, the transmitter queue consists of earlier remaining packets with their targets and the new packet with its own target. Re-arranging the data in the queue list in the First-In-First-Out order, we can view the queue as consisting of some amount of data 'DP' with changeable targets 'T'. Avoiding the future arrivals and using the equation (4), we obtain the best policy to empty the transmitter buffer. Followed by this, the next packet arrival is obtained by means of updating the data amount taking into account the new packet.

For changeable targets Case, Consider the changeable targets problem with $g(tr) = tr^m$ , m > 1; $m \in R$and the Markov channel model. The optimal transmission rule $tr^*(p,s,t)$for $p_{min}(t) \leq p \leq A(t), t \in [0, T_M]$ is given as

$$tr^*(p,s,t) = max_{j:(DP \geq P, T_j \geq t)} \frac{DP_j - P}{f_i(T_j - t)} \quad (4)$$

Where $i = 1,2, \ldots, n$ and $\frac{DP_j - P}{f_i(T_j - t)}$

is referred as the rate for individual $DP_j - T_j$ constraint for channel state s. As $DP_j - P$ is the amount of data left and $(T_j - t)$is the time left until the target$T_j$, $tr^*(p,s,t)$ represents the transmission rate. The EECC approach reduced the energy consumption in the large scale wireless network by applying the optimal transmission rule.

### 2.2 Discrete-time stochastic dynamic programming for multi-hop transmission

In multi-hop transmission, the data packet is send through a number of intermediate nodes whose task is to carry information from one place to another. The EECC method uses the discrete-time stochastic dynamic programming for performing the multi-hop transmission with the higher throughput level. The dynamic programming considerably performs the multi-hop transmission at the discrete time interval which in turn improves the data transmission rate. In EECC method, Discrete-time stochastic dynamic programming is used for finding the minimum cost path from the source node to destination node while the data packet is transmitted. Dynamic programming efficiently identifies the optimal decision that minimizes total expected transmission time in EECC method. The multi-hop transmission using discrete-time stochastic dynamic programming is shown in Figure 3.

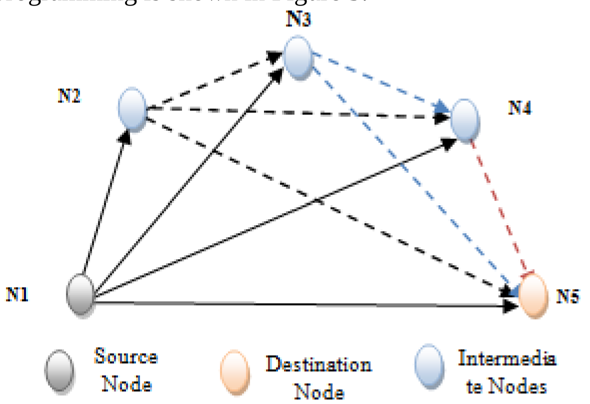


**Figure 3:** Multi-hop transmission using discrete-time stochastic dynamic programming

From the Figure 3, N1, N2, N3, N4, N5 are different sensor nodes in wireless network that are used for multi-hop packet transmission. Discrete-time stochastic dynamic programming finds the minimum cost path for effective data transmission in wireless network. The minimum cost path is determined using the following formula,

$$MC_{t\Delta}(T-2\delta,T) = min_j\,[MC_{tj}\,(T-2\delta) + MC_{j\Delta}\,(T-\delta) \quad (5)$$

From (5), the cost associated with arrival at the destination is $MC_{t\Delta}(T-2\delta,T)$ if the packet is at node j. For a packet at node t, at time$T-2\delta$, we compute $MC_{t\Delta}(T-2\delta,T)$ for all $t \in \{0,1,\ldots.N-1\}$, an action that requires N2 computations. Then finding the path form a node j at time $T-3$ is formulated as,

$$MC_{j\Delta}(T-3\delta,T) = min_t\,[MC_{jt}\,(T-3\delta) + MC_{t\Delta}\,(T-2\delta,T \quad (6)$$

The equation (6) is equivalent to N more computations. Each time, the source and destination nodes ($\sigma$and$\Delta$) of the packet are chosen at random and the minimum cost from $\sigma$ to $\Delta$ is calculated by the use of dynamic programming.
The energy cost $C_E$ is defined as the minimum power used in a data transmission which is mathematically formulated as,

$$C_E = N_0\, B\, \gamma^* \left(\frac{d_{ji}}{d_0}\right)^{\alpha} \quad (7)$$

Where $d_{ij}$ represents the distance from the node i to j, $d_0 \le d_{ij}$ is some minimum distance and $\alpha$ is the propagation exponent, B is the available bandwidth, $N_0$is the background noise spectral intensity, $\gamma^*$ is target signal to interference/noise ratio. Similarly the delay cost $D_C$ is calculated by using

$$D_C = \delta \quad (8)$$

And the equation (8) is assumed constant for each link traversal. As a result, the total cost for a transmission from node i to node j can be defined as

$$TC_{ij}\,(t) = w_d\delta + w_p N_o B\gamma^* \left(\frac{d_{ji}\,(t)}{d_0}\right)^{\alpha} \quad (9)$$

Where $w_d$ and $w_p$ are positive weighting constants assigned to delay and energy cost respectively. The algorithmic process of Discrete-time stochastic dynamic programming for multi-hop transmission is shown in below.

**// Discrete-Time Stochastic Dynamic Programming Algorithm**
**Input:** set of sensor nodes, source node ‘ $i$’, and destination node ‘$j$’
**Output:** improved throughput level with minimum energy
Begin
Step 1: while transmitting the packets in multihop transmission
Step 2 do
Step 3: Find minimum cost path using (5)
Step 4: Evaluate energy cost $C_E$ using (7)
Step 5: Compute delay cost $D_C$ using (8)
Step 6: Evaluate total cost for a data transmission from node $i$ to node $j$ using (9)
Step 7: Finally performs data transmission with minimum total cost
Step 8:End while
End

**Algorithm 1:** Discrete-times stochastic dynamic programming algorithm

Discrete-time stochastic dynamic programming algorithm effectively performs the multihop transmission by means of finding the minimum cost path which results in improved data transmission rate with higher through put level.

## 3. Experimental Setup

The proposed EECC method is implemented using NS2 simulation. The performance of EECC method is compared against with the existing Network Coding-based Cooperative ARQ (NCCARQ-MAC) scheme [1], Polynomial Time K-approximation Algorithm MAP (PTKA-MAP) [2]. The simulation parameter used for optimal data transmission is given below (table 1). The nodes in EECC method are located in uniform topology. The area to be placed is divided into grid of equal size and the node is placed randomly inside the grid.

**Table 1:** Simulation Parameters

| *Parameters* | *Values* |
|---|---|
| Network area | 1000 m * 1000 m |
| Number of nodes | 10,20,30,40,50,60,70 |
| Number of data packets i.e., number of data block | 5,10,15,20,25,30,35 |
| Size of data block (i.e., packet) | 7 – 49 bytes |
| Range of communication | 25 M |
| Speed of node | 0 – 7 m/s |
| Simulation time | 2000 s |
| Number of runs | 7 |

The network comprise of 70 nodes. The nodes are randomly placed in the wireless network that generates traffic for every 6 m/s. The sink node collects the data packets of range 5 – 35 and forwards the data to the PC with each data packet size differing from 100 KB to 512 KB. The simulation time varies from 1000 simulation seconds to 2000 simulation seconds. The proposed EECC method is evaluated using the following metrics such as throughput level, energy consumption rate, delay time, data transmission rate.

## 4. Discussion

In this section, the result analysis of EECC method is evaluated and it compared with the two existing methods namely Network Coding-based Cooperative ARQ (NCCARQ-MAC) scheme [1], Polynomial Time K-approximation Algorithm MAP (PTKA-MAP) [2] in WSN. To estimate the efficiency of EECC method, the following metrics like throughput level, energy consumption rate, delay time, data transmission rate are measured.

### 4.1 Impact of throughput level

Throughput is defined as the ratio of the data packets received at the destination from source node to the number of data packets sent. Throughput is formulated as,

$$Throughput = \frac{Data\ packet_{\ R}}{No.of\ data\ packet\ sent} *100 \qquad (10)$$

When the throughput is higher, the method is said to be more efficient and it is measured in terms of percentage (%).

**Table 2:** Tabulation for throughput level

| *Number of data packets* | *Throughput (%)* | | |
|---|---|---|---|
| | *EECC* | *NCCARQ-MAC* | *PTKA-MAP* |
| 5 | 42 | 31 | 24 |
| 10 | 46 | 33 | 26 |
| 15 | 51 | 37 | 29 |
| 20 | 55 | 40 | 31 |
| 25 | 59 | 43 | 34 |
| 30 | 63 | 47 | 37 |
| 35 | 67 | 51 | 40 |

The throughput level measurement of proposed EECC method is elaborated in table 2. We consider the framework with different number of data packets in the range of 5 to 35 is taken for experimental purpose using NS2 simulation. The performance of proposed EECC method is compared with existing two methods namely, NCCARQ-MAC [1] and PTKA-MAP [2]. From the table values, it is clear that the proposed EECC method performs well with higher throughput level.

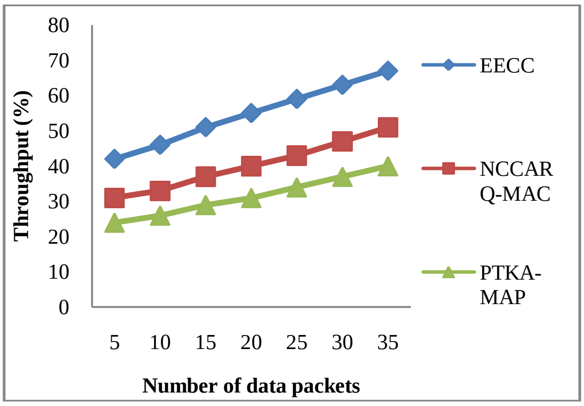


**Figure 4:** Measurement of throughput level (percentage)

As shown in Figure 4, the throughput rate is improved using the proposed EECC method. With the application of discrete-time stochastic dynamic programming, the rate of throughput is improved in the proposed EECC method. By applying discrete-time stochastic dynamic programming, EECC method effectively finds the minimum cost path for transmitting data packets which results in the improvement of throughput rate by 26 % as compared to NCCARQ-MAC [1]. In addition, EECC method significantly performs the multihop transmission thereby the throughput rate is improved by 42 % as compared to the PTKA-MAP [2].

### 4.2 Impact of delay time

The delay time is defined as the time required in obtaining the data packets with their corresponding data block size. Delay time is formulated as given below.

$$Delay\ time = \sum_{i=1}^{7} Time\ (DP_i + Size\ of\ data\ block) \qquad (11)$$

Where $DP_i$ is data packet, delay time is measured in terms of milliseconds (ms). When the delay time is lower, the method is said to be more efficient.

**Table 3:** Tabulation for Delay time

| *Size of data block (bytes)* | *Delay time (ms)* | | |
|---|---|---|---|
| | *EECC* | *NCCARQ-MAC* | *PTKA-MAP* |
| 7 | 20 | 25 | 29 |
| 14 | 24 | 31 | 37 |
| 21 | 27 | 33 | 39 |
| 28 | 31 | 36 | 42 |
| 35 | 35 | 40 | 46 |
| 42 | 38 | 43 | 48 |
| 49 | 42 | 46 | 51 |

The delay time measurement of proposed EECC method is elaborated in table 3. The performance of proposed EECC method is compared with existing two methods namely, NCCARQ-MAC [1] and PTKA-MAP [2]. From the table, it is illustrative that the delay time using the proposed EECC method is reduced when compared to existing methods.

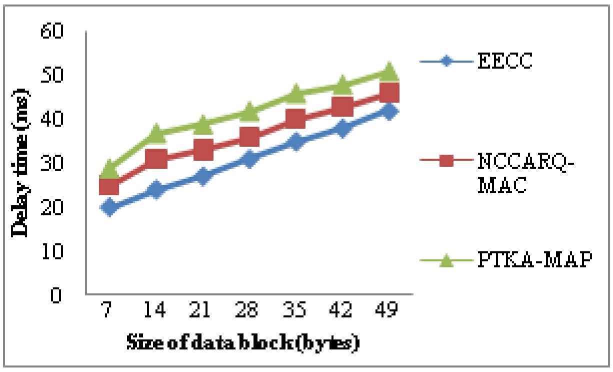


**Figure 5:** Measurement of delay time (milliseconds)

Figure 5 shows the comparative analysis of delay time with respect to different data block size. The delay time is comparatively reduced using the EECC method when compared to two other existing methods NCCARQ-MAC [1] and PTKA-MAP [2]. This improvement in delay time is because of the application of Heuristic method in EECC. Heuristic method effectively handles the arbitrary rate of packet arrival at the queue list thereby EECC method reduced the delay time by 18 % as compared to the NCCARQ-MAC [1]. In addition, dynamic programming significantly performs the multihop transmission through finding the minimum cost path which in turn reduced the delay time by 36 % as compared to the PTKA-MAP [2].

### 4.3 Impact of energy consumption rate

Energy consumption using EECC method is defined as the product of sensor nodes, power (in terms of watts) and time (in terms of seconds). The energy consumption is measured in terms of Joules (J) and it mathematically formulated as below,

$$EC = No.sensor\ nodes * Power * Time \quad (12)$$

In (12) '$EC$' is the energy consumption where the energy consumed by source nodes to reach destination node. When the energy consumption is lower, the method is said to be more efficient.

**Table 4:** Tabulation for energy consumption rate

| *No. of sensor nodes* | *Energy consumption rate (Joules)* | | |
|---|---|---|---|
| | *EECC* | *NCCARQ-MAC* | *PTKA-MAP* |
| 10 | 27.64 | 34.12 | 36.54 |
| 20 | 30.30 | 36.33 | 41.58 |
| 30 | 34.53 | 38.56 | 50.64 |
| 40 | 37.13 | 40.27 | 52.24 |
| 50 | 39.21 | 44.22 | 54.65 |
| 60 | 40.14 | 47.12 | 55.54 |
| 70 | 42.22 | 48.58 | 59.24 |

The energy consumption resultant values of three methods EECC, NCCARQ-MAC [1] and PTKA-MAP [2] are illustrates in table 4. The proposed EECC method minimizes the energy consumption rate than the other state-of-art methods.

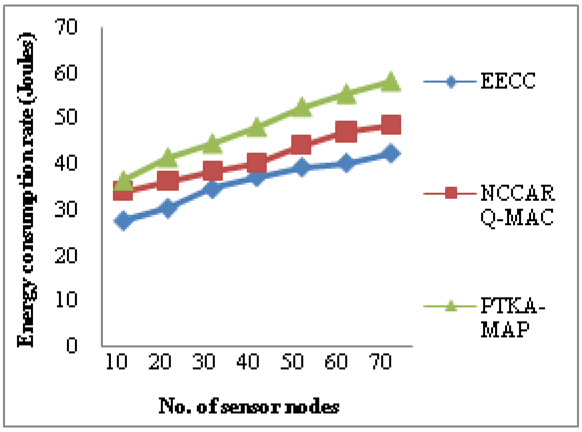


**Figure 6:** Measurement of energy consumption rate (Joules)

Figure 6 represents the energy consumption rate based on different sensor nodes. Our proposed EECC method performs well when compared to two other methods NCCARQ-MAC [1] and PTKA-MAP [2]. As illustrates in figure 6, the energy consumption rate is minimized in all the three methods but relatively it is reduced in EECC method. In EECC, the multihop transmission is performed on the sensor node then the minimum cost path is selected for efficient transmission with minimum energy consumption. In addition, Heuristic method significantly handles the arbitrary rate of packet arrival at the queue list by forwarding the data packets with changeable target constraints. Therefore EECC method reduced the energy consumption rate by 15 % as compared to the NCCARQ-MAC [1] and 36 % as compared to the PTKA-MAP [2] respectively.

### 4.4 Impact of data transmission rate

Data transmission rate is defined as the ratio of number of data packets successfully transmitted at the destination from source node to the number of data packets sent. The data transmission rate is measured in terms of percentage (%) and it mathematically formulated as below,

$$data\ transmission\ rate = \frac{Number\ \ of\ data\ packets\ successfully\ \ transmitted}{Number\ \ of\ data\ packet\ \ sent} * 100 \quad (13)$$

When the data transmission rate is higher, the method is said to be more efficient.

**Table 5:** Tabulation for data transmission rate

| *Methods* | *Data transmission rate (%)* |
|---|---|
| EECC | 84.32 |
| NCCARQ-MAC | 73.18 |
| PTKA-MAP | 65.34 |

The data transmission rate for EECC method is elaborated in table 5 and comparison made with two other methods NCCARQ-MAC [1] and PTKA-MAP [2] respectively. We consider the method with different number of sensor nodes in the range of 10 to 70 for experimental purpose using NS2.

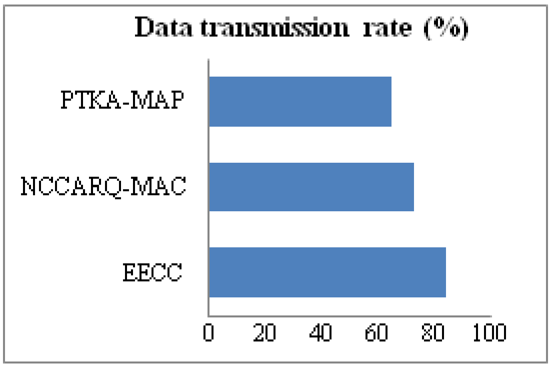


**Figure 7:** Measurement of data transmission rate (percentage)

From the figure 7, it is illustrative that the data transmission rate using the EECC method is higher than when compared to the existing methods NCCARQ-MAC [1] and PTKA-MAP [2] method respectively. This is because of the application of discrete-time stochastic dynamic programming in EECC method. The dynamic programming significantly performs the multi-hop transmission at the discrete time interval which in turn improves the data transmission rate by 13 % when compared to NCCARQ-MAC [1] method. In addition, discrete-time stochastic dynamic programming determines the minimum cost path for effective data transmission thereby EECC method improves the data transmission rate by 22 % when compared to PTKA-MAP [2].

## 5. Conclusion

In this paper, Energy Effective Cumulative Curvature (EECC) approach is developed for realistic physical layer data transmission. The main objective of EECC approach is to achieve the optimal data transmission with higher through put level and to minimize the energy utilization rate while performing data transmission. To do this, initially EECC method handles the arbitrary rate of data packet at the queue list by using the heuristic method. EECC method used queue list for storing the data packet and follows first in first out data structure for data storage. Then, Heuristic method forwards the data packets with respect to the changeable target constraints in queue list which results in optimal data transmission with minimal energy consumption. Finally, EECC method used the discrete-time stochastic dynamic programming in wireless network for performing the multi-hop transmission. The dynamic programming effectively finds the minimum cost path from the source node to destination node for transmitting the data packet which results in improved throughput ratio level. With the experiments conducted for EECC method, it is observed that of the throughput ratio level and energy consumption rate for different sensor nodes provided more accurate results as compared to the state of the art works. The results show that EECC method provides better performance with an improvement of throughput ratio level by 34 % and minimized the energy consumption rate by 26 % when compared to state of the art works.

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