A delay tolerant routing using cuckoo search for health care management using wireless sensor network

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Abstract
The most sought-after technology and one of prime research area in computer science and healthcare application is Wireless Sensor Network (WSN) and is all ready to improve the quality of life. The major issue under research in WSN is routing as irregular connectivity due to irregular mobility of nodes causes severe problem in the network. Delay Tolerant Networks (DTN) can be considered as a solution to this problem as it usually adopts routing based on carrier transfer. The proposed study presents Cuckoo Search (CS) based routing in DTN. Reproduction behavior is the basis for CS and can help in solving various optimization issues. It performs better than other meta-heuristic algorithms. Experimental results show that better performance can be achieved through the proposed technique.

Keywords: Wireless Sensor Network (WSN), Delay Tolerant Networks (DTN), Routing, Health Care Management and Cuckoo Search (CS).

Introduction

A wireless network system is a self-disciplined technology that is built by hundreds or even thousands of entities called sensors that are scattered randomly in the environment [1]. Sensor nodes have limited computing and communicating abilities, storage capacity and power supply. So, considering large scale WSN, design of network, topology, communication protocols and routing strategy pose a great challenge.

WSN is technology-driven and advances through networks which have a low-power sensor and medical sensors which are being watched closely recently with the advent of using WSNs in healthcare. Improving and expanding the quality of care on an extensive settings and differing population is carried on by WSNs.

For instance, the potentials of WSNs are demonstrated early system prototypes in order to make the detection of disease condition early, so as to avoid further deterioration, clinically through watching the patients closely in hospital, improving emergency care as a part of disaster management via electronic triage, to enhance the life's quality through smart environments, and to enable large-scale field investigation through human behavior and chronic diseases.

Hoard of technical challenges have to be met while meeting the potential of WSN in healthcare. These challenges go beyond the limitations of resource which are faced by WSNs with regards to restrictions in network capacity, processing and memory restrictions and also the energy reserves are scarce. To be more specific, irrespective of applications in other domains, stringent requirements are posed by healthcare applications on the reliability of the system, QoS and more specifically privacy and security.

The aim of medical application through WSN involves enhancement of the ongoing healthcare and monitoring services specifically for the aged, chronically ill and children. The advantages are numerous and to begin with, with regards to pervasive healthcare systems, remote monitoring capability is the major advantage. With the help of remote monitoring, the caring for critically ill patients will become easier and patients with physical disabilities can be more independent and can have an easy life. Infants and children can be cared for in a better manner at the absence of their parents and overall the dependence on special caregivers will be reduced [2].

While considering healthcare applications, the system is a soft real-time system where latency is allowed. Identification of critical conditions including heart attacks and sudden-falls where the golden hour is the most crucial one, these can prove to be very useful. So, provision of real-time identification and action taking in pervasive healthcare system can be included as the most important advantage.

DTN can be termed as a network of multiple smaller grids. Internet is one of the updated model of special-purpose networks. Long disruptions are accommodated as DTNs support interoperability of other networks and within those networks and translation is done within various communication protocols of those networks. To provide these functions, the movement and restricted power of evolving wireless communication services are accommodated through DTNs.

Basically, DTNs are developed for interplanetary use, where there can be slowing of speed of light and the greatest need is delay tolerance. But, there might be far more varying applications for DTNs on universe where there is more necessity for disruption-tolerance. A broad range of commercial, scientific, military and public service applications are being done through DTNs and they can accommodate various types of wireless technologies which include Radio Frequency (RF), Ultra-Wide Band (UWB), free-space optical, and acoustic (sonar or ultrasonic) technologies [3].

The characteristics of DTN are discussed below:

- Intermittent connectivity: This is otherwise called network partitioning i.e., this feature can take place where no end-to-end connectivity is present.
- Long or variable delay: There can be long propagation delays and variable queuing delays between nodes during intermittent connectivity i.e. end-to-end path delays.
- Asymmetric Data Rates: Asymmetric or bidirectional data rate is used by the user in the network.
- High Error Rates: Some correction or retransmission is required in a link when bit errors are generated for the entire packet where there is generation of link error rate [4].

The network architecture is referred to in the concept of DTN in which communication delay is exhibited and frequent network partitioning because of intermittent connectivity. Because of the lack of continuous path, designing routing protocols for such networks are always a challenge from source to destination and so traditional routing protocol generally fail. So, the models that are being assembled concentrate on effective routing solutions which ensure network performance at a low network cost [5].

With the help of static routing, simple structures similar to DTN are built which can effectively approach smaller networks; but if the network is advantageous to cater wider areas then the benefit will increase. In order to reach this goal, the configuration should be automated towards routing protocols and manage with changes and failures. A routing protocol should be designed which should be deployable and three design goals should be met.

First and foremost feature is that routing should be self-configuring. This is crucial for equipment which are deployed away from the access of the network experts and if any of the components fail, it should be able to maintain its communication capability.

Most of the domains were DTNs provide significant benefits have these problems. Secondly, it should be able to perform with wide range of connectivity patterns; for most DTN schemes, this protocol might be very helpful. So, the choice of protocol is not a problem. Finally, buffer and network resources should be made use of effectively by the protocol, where a large number of users can use them. So, it should be able to scale with demand.

Classification of DTN routing protocols can take place with effect to the type of information collected by nodes in order to make routing decisions. Two different properties are required in finding the destination: Replication and knowledge: Multiple copies are used for each message in order to enhance the probability of delivery and mitigate delivery latency. Based on information about the network forwarding decisions are made. DTN routing protocols are categorized into flooding routing protocols and forwarding routing protocols.

Other nodes receive a variety of copies without information about the structure of network, in case of flooding protocols. The copies of messages are kept and stored in their buffer until the next code is encountered or destination. There is increase in the chance of message delivery in message replication as more nodes are involved in delivering messages to the BS. The flooding routing protocols include epidemic routing, two-hop relaying, tree-based flooding and prioritized epidemic routing [6].

Forwarding routing – this is a technique which is knowledge based without replication. Here, knowledge about routing is required and the details about other nodes is collected in order to select the best paths in forwarding the message to destination. Location-based routing, source routing, per-hop routing and per-contact routing belong to the forwarding family.

The impact of CS-based routing in DTN for healthcare management is studied in this work. The rest of the study is organized as follows: Section 2 – Review of literature; Section 3 – Methodology used in the study; Section 4 – Discussion of results; Section 5 – Conclusion..

Related Works

A novel routing algorithm was proposed by Yu et al., [7] on the basis of hybrid of message delivery probability and redundancy in message in order to decrease the communication overhead on keeping the message delivery ratio high. Calculation of message deliver probability is done by combined impact frequency and length of contact duration. Furthermore, in the source code, the maximum number of copies of messages is designated and the task message is forwarded and assigned to relay nodes on the basis of pattern of a binary tree, so that implementation of multi-path transmission on message forwarding can take place.

An efficient authentication protocol for health-care applications using Wireless Medical Sensor Network (WMSN) was put forth by He et al., [8] and claim was made that various attacks would be withstood. However, it can be found out that the technique is prone to off-line password guessing attack and privileged insider attack. The author pointed out that user anonymity cannot be provided by the protocol. A robust anonymous authentication protocol will be proposed by the author for health-care applications with the help of WMSNs. Moreover, in comparison, the proposed protocol has robust security and computational efficiency. Therefore, it is more suitable for health-care applications using WMSNs.

An energy efficient reliable multi-path data transmission protocol for reliable data transport over WSN was proposed by Mohanty & Kabat [9] for healthcare application. At the time of congestion, the emergency and sensitive data packets are transmitted via an alternate path which has minimum correlation and transmission interference.

Attempts are made to avoid congestion by the proposed protocol which computes the probability of congestion and rate of transmission at the intermediate nodes. Fair and efficient data delivery is supported by the buffer. The reliability of the proposed protocol is achieved through hop-by-hop loss recovery and acknowledgement.

Deployment relay nodes into conventional WSNs with constraint was studied by Yu et al., [10], which aimed to optimize both average energy consumption and average network reliability. Three metaheuristics were considered by the author to handle this multi-objective optimization technique aiming a detailed analysis of the varied performances of these metaheuristics to the problems. For this, they employed a statistical procedure in order to study the outcome of confidence in order to consider two multi-objective quality metrics,, hyper-volume and coverage of two sets. Comprehensive evaluation of the results showed that Non-dominated Sorting Genetic Algorithm II (NSGA-II) provides the best performance.

An energy-efficient clustering mechanism was proposed by Kumar & Kumar [11] on the basis of Artificial Bee Colony [ABC] algorithm and factional calculus in order to improve the network energy and nodes' lifetime by selecting a CH optimally. Multi-objective Fractional ABC (FABC) is the hybrid optimization algorithm which is developed in order to control the rate of convergence of ABC with fitness function that is newly designed where three objectives like energy consumption, distance travelled and delays to minimize the overall objective where considered. The results proved that the proposed FABC maximizes the energy as well as life time of nodes as compared with existing protocols.

One of the major challenges faced by WSN is multipath routing. The lifetime of the nework can be increased, frequently easing the need to update the route table, balancing traffic load and improving overall network performance.

The above criteria could be met by the proposed Cost-Based Multipath Routing (CBMR) approach based on the cost of sensor nodes; whereas, selection of multipath is a Non-deterministic Polynomial (NP)-complete problem. PSO was used to optimize the paths of CBMR and was studied by Vairam & Kalaiarasan [12]. Simulation results show that CBMR-PSO routing approach has better performance as compared with CBMR and Energy Efficient Clustering Algorithm (EECA).

An adaptive CS based Optimal Rate Adjustment (ACSRO) was proposed by Narawade & Kolekar [13] for avoidance of congestion and control. So as to reduce the congestion, the rate adjustment regulates the share rate of the node. Evaluation metrics such as throughput, delay, normalized packet loss, normalized queue size, and congestion level are evaluated and the performance of the proposed rate optimization technique was studied. The results of the proposed rate optimization show that the congestion is compacted and the performance of the WSN is improved.

Mohsenifard and Ghaffari[14] proposed the Cuckoo Optimization Algorithm (COA) whichis a data aggregation tree that can optimize the consumption of energy in the network. GA, Power Efficient Data Gathering and Aggregation Protocol- Power Aware (PEDAPPA) and Energy Efficient Spanning Tree (EESR) where compared in this work. The results of simulations which were conducted in Matlab indicated that the proposed method had better performance than GA, PEDAPPA and EESR algorithm in terms of energy consumption. Consequently, the proposed method was able to enhance network lifetime

Materials and Methods

In sensor network, where energy is needed by every node for transmission over the network, energy efficiency seems to the primary requisite. Network life can be improved by energy efficiency, which in turn will improve the network lifetime. The aim of the present study is to perform energy effective routing to improve the life and throughput of the network. Opportunistic routing will be performed where the optimization of the network is done based on CS. A generation of better routes will be done through this routing optimization. Compared to the previous routing schemes, this new routing will perform better [15].

Xin-she Yang and Suash Deb [16] proposed CS optimization algorithm. The breeding behavior of a particular species of cuckoos is the inspiration for this algorithm. The cuckoo species evaluate a bird's nest which is built recently and has eggs similar to their own and lay their eggs there. They chose the host species in such a way that the chance of their egg being abandoned is less. Compared to the host eggs, the cuckoo eggs hatch slightly earlier and when the first cuckoo chick is hatched, their first instinct will be to throw the host eggs out of the next. Through this, the cuckoo egg has more food provided by its host bird. The CS algorithm models can be applied to various optimization problems.

Three ideal rules are described by CS:

- Only one egg is laid by the cuckoo at a time and is dumped in a nest that is chosen randomly;
- The nests which have high-quality eggs will be carried over to the next generations;
- There is a fixed number of host nests, and the cuckoo's egg is discovered by the host bird with a probability Pa [0, 1]. In such a case, either the egg can be gotten rid of

- by the host bird or the nest can be abandoned and a completely new nest be built.

As a further approximation, this last assumption can be approximated by a fraction Pa of the n host nests are replaced by new nests (new random solutions).

For easy implementation, new solutions can be generated by two methods. Levy flight and a fraction Pa of the n host nests are replaced by new random solutions.

For the search algorithm, the method of Levy flight was used because it chooses a random walk from probability density function consisting of power law tail. New solutions, $x^{(t+1)}$ is generated in which i is the cuckoo and a Levy flight is executed as shown in equation (1):

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \oplus Levy(\lambda) \qquad (1)$$

Where α >0 be the step size and it is associated to the scales of the problem of interests. Mostly α = (L/10) in which L is the characteristic scale of the problem of interest. Equation (1) is basically the stochastic equation for a random walk. A random walk is a Markov chain whose next status/location is based on the current location and the transition probability. The product $\oplus$ be the entry-wise multiplications which is comparable to those used in PSO. The random walk through Levy flight is well-organized in discovering the search space as like its step length is much longer in the long run [17].

Levy distribution follows the step length of random walk designed by Levy flight. It includes an infinite variance with an infinite mean as in equation (2):

$$Levy \sim u = t^{-\lambda},\ (1 < \lambda \le 3) \qquad (2)$$

Where λ be the constant, and the equation (3) helps to evaluate the step length:

$$Levy(\lambda) = \frac{u}{|v|^{1/\lambda}} \qquad (3)$$

Where u and v are drawn from normal distributions as following equations (4 &5):

$$u \sim N(0,\sigma_u^2),\ v \sim N(0,\sigma_v^2) \qquad (4)$$

Where

$$\sigma_u = \left\{ \frac{\Gamma(1+\lambda)\sin(\pi\lambda/2)}{\Gamma[(1+\lambda)/2]\lambda 2^{(\lambda-1)/2})} \right\}^{1/\lambda},\ \sigma_v = 1 \qquad (5)$$

To be brief, a random-walk process is formed with a step-length distribution with power-law with a heavy tail. Levy walk generates new solution with the best solution that is reached so far speeding up the local search. Additionally, the new random solution will be alternated with fraction Pa of the solutions which will be far off from the current best solution, thus making sure that that the system is not trapped in local optimum.

Results and Discussion

In this section, the prediction based delivery rate and proposed CS approach are used. The delivery rate for expiration Time to Live (TTL), delivery rate for buffer size and delivery rate for packet size as shown in table 1 to 3 and figure 2 to 4.

Table 1
Delivery Rate for Expiration TTL

Expiration TTL	Prediction based Delivery Rate	Proposed CS Approach
30	0.5524	0.5715
60	0.6337	0.6534
90	0.7303	0.7574
120	0.7612	0.7836
150	0.8252	0.8562
180	0.8547	0.8892

From the figure 2, it can be observed that the proposed CS approach has higher delivery rate by 3.39% for 30 expiration TTL, by 3.06% for 60 expiration TTL, by 3.64% for 90 expiration TTL, by 2.9% for 120 expiration TTL, by 3.68% for 150 expiration TTL and by 3.95% for 180 expiration TTL when compared with prediction based delivery rate.

Table 2
Delivery Rate for Buffer Size

Buffer size (each node)	Prediction based Delivery Rate	Proposed CS Approach
50	0.4622	0.4546
100	0.5043	0.5345
150	0.5801	0.6346
200	0.6008	0.6339
250	0.6708	0.7165
300	0.7156	0.7061

From the figure 3, it can be observed that the proposed CS approach has higher delivery rate by 1.65% for 50 buffer size, by 5.81% for 100 buffer size, by 8.97% for 150 buffer size, by 5.36% for 200 buffer size, by 6.58% for 250 buffer size and by 1.33% for 300 buffer size when compared with prediction based delivery rate.

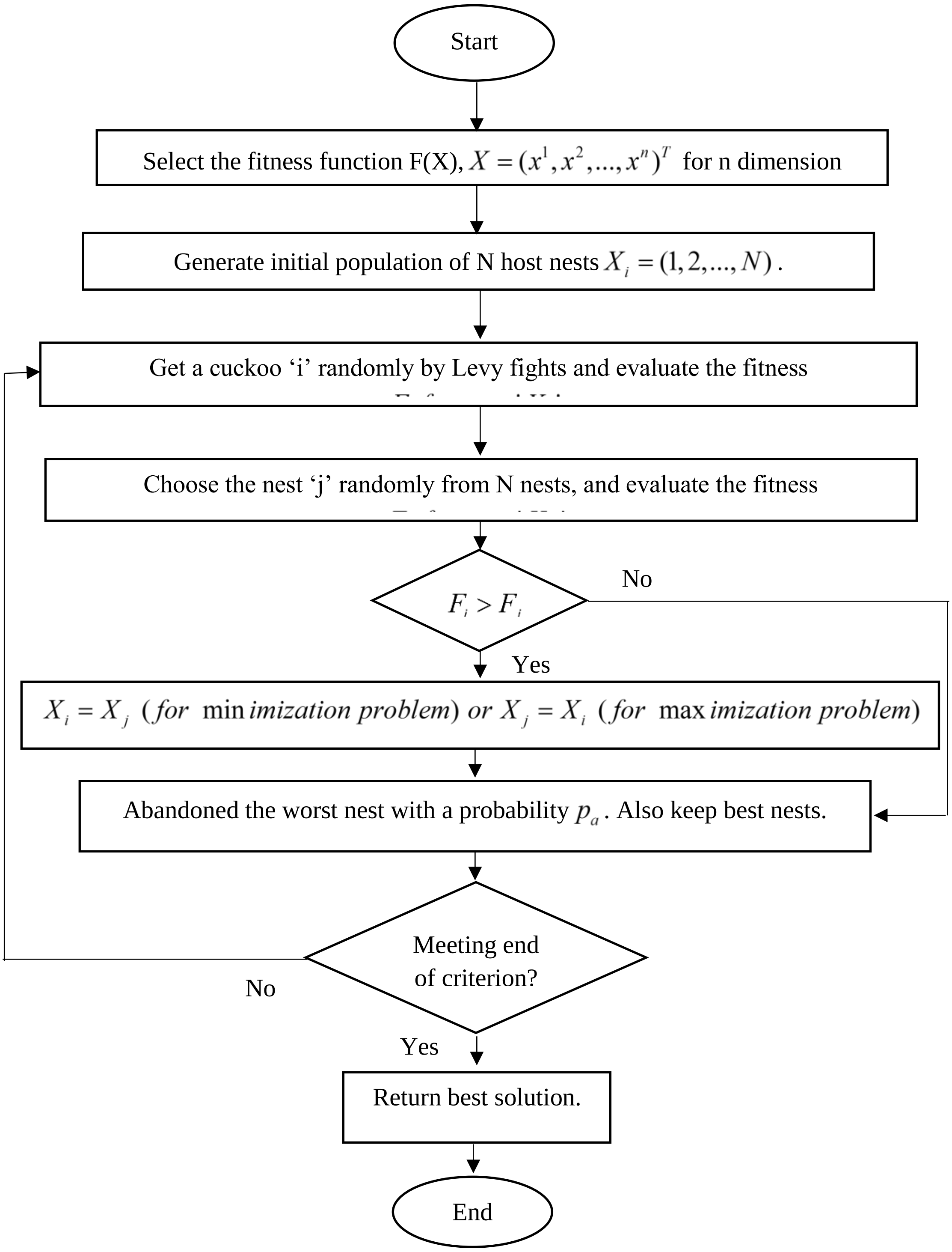

Figure 1: **Flowchart for Cuckoo Search (CS) Algorithm**

From the figure 4, it can be observed that the proposed CS approach has higher delivery rate by 3.23% for 30 packet size, by 2.46% for 60 packet size, by 2.05% for 90 packet size, by 6.31% for 120 packet size and by 1.87% for 150 packet size when compared with prediction based delivery rate.

Conclusion

Based on the demand from the end of user and the increased advances in hardware and software, the practice of medications has become more user-friendly by the use of first generation WSN healthcare. Delay Tolerant Sensor Network (DTSN) resource is quite limited and makes DTSN difficult. It is of importance that the transmission delay can be reduced and communication overhead based on ensuring the message delivery rate and also in case of network nodes. A routing delay tolerant algorithm based on CS nodes is proposed. This research work deals with the bio-inspired computing model by name CS algorithm to find energy efficient path through which routing can be performed. Results show that the proposed CS approach has higher delivery rate by 3.39% for 30 expiration TTL, by 3.06% for 60 expiration TTL, by 3.64% for 90 expiration TTL, by 2.9% for 120 expiration TTL, by 3.68% for 150 expiration TTL and by 3.95% for 180 expiration TTL when compared with prediction based delivery rate.

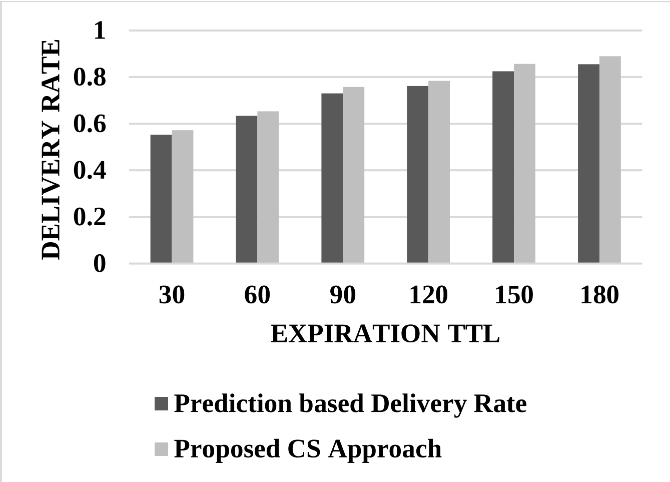

Figure 2: **Delivery Rate for Expiration TTL**

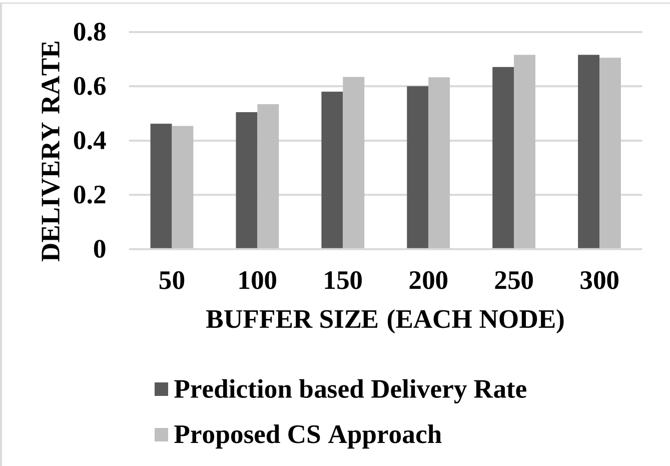

Figure 3 Delivery Rate for Buffer Size

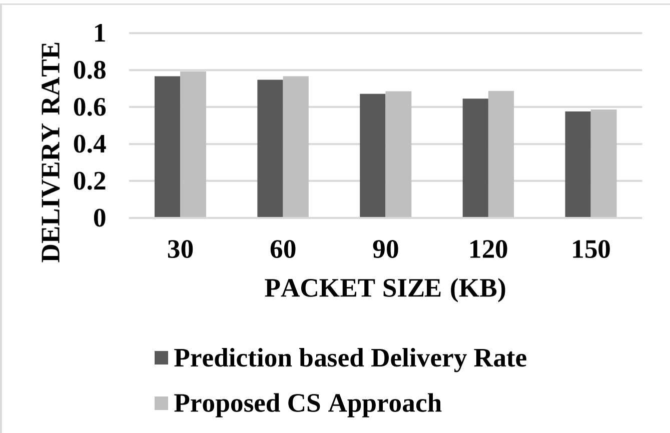

Figure 4: **Delivery Rate for Packet Size**

Table 3
Delivery Rate for Packet Size

Packet size (Kb)	Prediction based Delivery Rate	Proposed CS Approach
30	0.7673	0.7925
60	0.7482	0.7669
90	0.6711	0.685
120	0.6457	0.6878
150	0.5763	0.5872

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