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Data Fusion: An Energy Efficient Perspective for Device-To-Device (D2D) Communication.

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ABSTRACT

Device-to-Device (D2D) communication enhances user experience and resource utilization in any communication networks. D2D communication consumes high energy when operated on mobile phones, sensor nodes etc. As sensor nodes becomes the part of power constrained devices, energy efficiency becomes a challenge in D2D communication protocols. This paper focuses on increasing the energy efficiency and improving the throughput of D2D communication by using Data Fusion technique in sensor nodes. First, it works with tree based clustering technique to form minimum spanning tree which results in the nodes that communicate only with its neighbours in the network. Secondly, it adopts a methodology for selecting the cluster head (CH). The selection of CH is done on the basis of the unconsumed energy of each sensor nodes within each clusters after the completion of every round. So cluster head changes dynamically after every round which ensures that there will not be total nodal energy dissipation for the node that is acting as a cluster head. Data fusion algorithm focuses on merging two or more data packets into a packet of small size using Dempster-Shafer Theory (DST). The simulation results provided at the end of the paper concludes that the energy efficiency and throughput of devices using Data fusion is better than Low-Energy Adaptive Clustering Hierarchy (LEACH) and Power-Efficient Gathering in Sensor Information System (PEGASIS).

Keywords: D2D communication, wireless sensor network, energy efficiency, tree based clustering, data fusion

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INTRODUCTION

Wireless sensor network [1-3], a self-coordinating network, is a collection of sensor nodes distributed over the area of interest. These sensor nodes are portable, tiny and weightless. Fig.1 shows a schematic representation of wireless sensor network and how they are connected. A WSN contains numerous sensor nodes which may range from ten to several hundreds. These can be easily connected with existing control and wired measurement systems. The obtained data is then sent to the gateway where it can be analyzed, processed and can be presented using software. Usage of wireless sensor networks is flourishing rapidly pointing out the vital role for efficient energy utilization in the network and enhancing throughput which boosts the network lifetime. Applications of WSN include health monitoring, home automation, traffic control, healthcare applications, environmental monitoring, industrial process monitoring, object tracking and habitat monitoring. Thus having the applications in mind, lifetime and survivability are the important criterion for WSN's. And in addition to that, optimizing energy consumption has become an important criterion. These sensing nodes enable Device-to-Device (D2D) [4-6] communication when each are considered as devices which are used to sense, process and communicate with its peers. D2D establishes a direct communication link among neighbouring devices. This enhances energy efficiency, overall throughput and spectrum usage. In WSN, many routing protocols [7-9] like LEACH, PEGASIS, etc., had been implemented which to enhance the energy efficiency. LEACH is a protocol based on clustering, which has the drawback of selecting cluster head at random. PEGASIS is a protocol based on chaining and proves to be inconvenient if there are long chains. So we have proposed a model where, sending periodically correlated data to base station from sensor nodes using data fusion technique through tree based topology highly enhances the energy efficiency [10-12]. Dempster-Shafer [13, 14] combination rule is based on belief and plausibility used for data fusion in nodes.

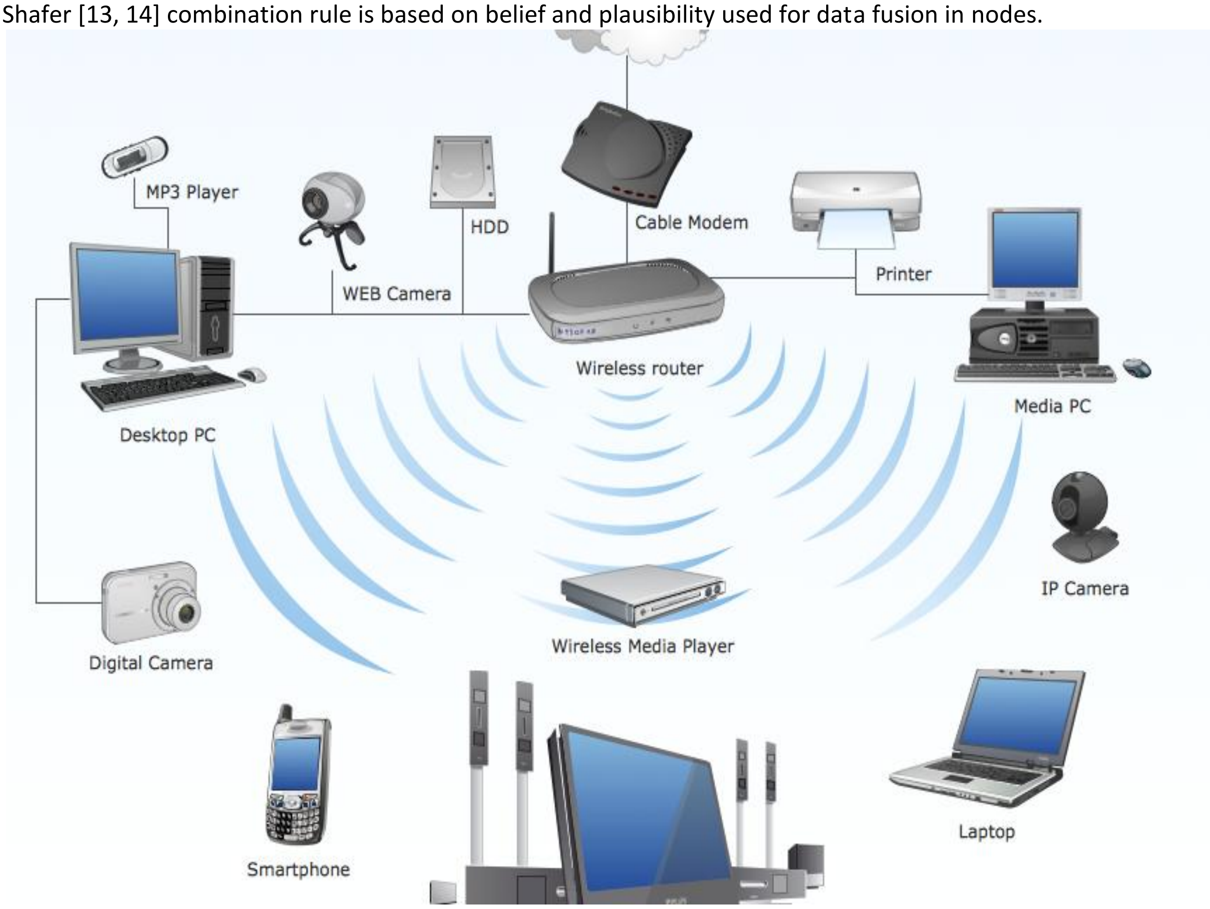

Figure 1: A schematic representation of wireless sensor network architecture

Implementation

Initially all the sensor nodes are created and initial configurations for the nodes are set. Then clustering is done based on the distance. Once after clustering is done, cluster head is selected for each cluster based on residual energy. Then the data packets are fused from two nodes to increase the efficiency and also to decrease the number of transmissions.

Energy Consumption Model

One of the concerning aspects in a WSN is its energy intake. The main goal in this paper is to propose an energy consumption model which improves the network lifetime. During data fusion the energy that is dissipated in the nodes is taken into account in this model. In this we consider a packet size of 'p' and 'd' is the range between two nodes under consideration. The energy is calculated as follows:

$$E(p,d) = p * E_{fixed} + p * E_{free} \ \ if \ d < d_{cd}$$
$$E(p,d) = p * E_{fixed} + p * E_{2ray} \ if \ d > d_{cd}$$

where E_{fixed} is the energy dissipated that is fixed for the working of receiver and transmitter electronics E_{free} and E_{2ray} are the units energies required to ensure acceptable SNR values at the receiver based on distance d_{cd} is the cross over distance $\sqrt{(E_{free}/E_{2ray})}$

Mathematical Model of Data Fusion Based on Dempster-Shafer Theory

Originally option of group cluster head is framed based on the highest energy among the nodes in the cluster. After the completion of each round of DFTBC the cluster head will be selected again on the basis of residual energy by the Base Station (BS). The node with higher residual energy than others will be selected as the cluster head.

$$E(avg) = \sum \frac{\text{Node's residual energy in cluster}}{\text{Total number of nodes in cluster}}$$

Tree based clustering is the first part of DFTBC routing algorithm. In this phase, minimum spanning tree will be formulated based on Prim's algorithm which uses the distance between the nodes in the cluster as the minimum sum of the weight for minimum spanning tree.

The second part of the DFTBC routing algorithm is data fusion, which combines one or more data packets into a single packet. In WSN, each sensor nodes will monitor and deliver the correlated packets periodically to the BS. However, sensor nodes transmitting the redundant data packets causes the energy loss to the network since the transmission is unnecessary. This issue can be solved by data fusion by applying Dempster-Shafer Theory. The CHs and parent nodes will fuse one or more data packets into a single packet, therefore amount of data to be relayed on the tree and to the base station is remarkably reduced. Data fusion will be advantageous in efficiently using the energy and which also results in prolonging the network's lifetime. Dempster-Shafer theory is used, since it has distinct features than other probabilistic approaches as it was useful on the creation of any new evidence for representing ignorance because of information lacking and aggregating beliefs. DS theory consists of new functions which can be used to check whether the data packets can be fused together or not. Dempster-Shafer used a variety of possibility rather than only one probabilistic variety to signify uncertainty. The belief function will be the lower bound of the probability and the plausibility will be its upper bound which can be defined as follows.

$$Bel(\mathrm{A}) = \sum_{\mathrm{B} \subseteq \mathrm{A}} \mathrm{m(B)}$$
$$Pls(\mathrm{A}) = \sum_{B \supseteq A} m(B)$$

Here Bel signifies the level of perception to which the proof A is supported and Pls represents the stage of understanding to which the evidence is not able to disprove A, that is, the degree of belief to which it remains plausible.

Comparative Study of Performance Metrics with Various Protocols

The simulation environment that we have adopted is NS-2, a discrete event simulator. It offers synergic domain for freely distributed open source and gives improved outputs. For obtaining run-time speed as well as easy usage, two languages are required namely C++ and OTcl respectively. C++ is the kernel part of NS-2 and used to employ the kernel of the design of the protocol models. There are many protocols that are supported by NS-2 such as ad hoc routing, unicast routing, hierarchical routing etc. Its components include NS-2 simulator, NAM –network animator, pre-processing and post-processing. Graphs are plotted using x-graph. Visualization of executed trace files is done in network animator. In post- processing, trace analysis is performed using Awk script.

RESULTS AND DISCUSSION

PACKET DELIVERY RATIO

This is identified as no of packets received by the sink to the no of packets started at the source. It can be shown mathematically as

$$PDR=p1\%p2$$

where p1 is the total packets collected at the destination and p2 is the total packets sent from the source. Results of simulation shows that ratio of total packets delivered to the destination increases relatively with simulation time. A comparative study is performed to validate the proposed algorithm which includes various routing protocols in wireless sensor networks. Fig.2 shows that DFTBC has relatively higher PDR ratio than other protocols.

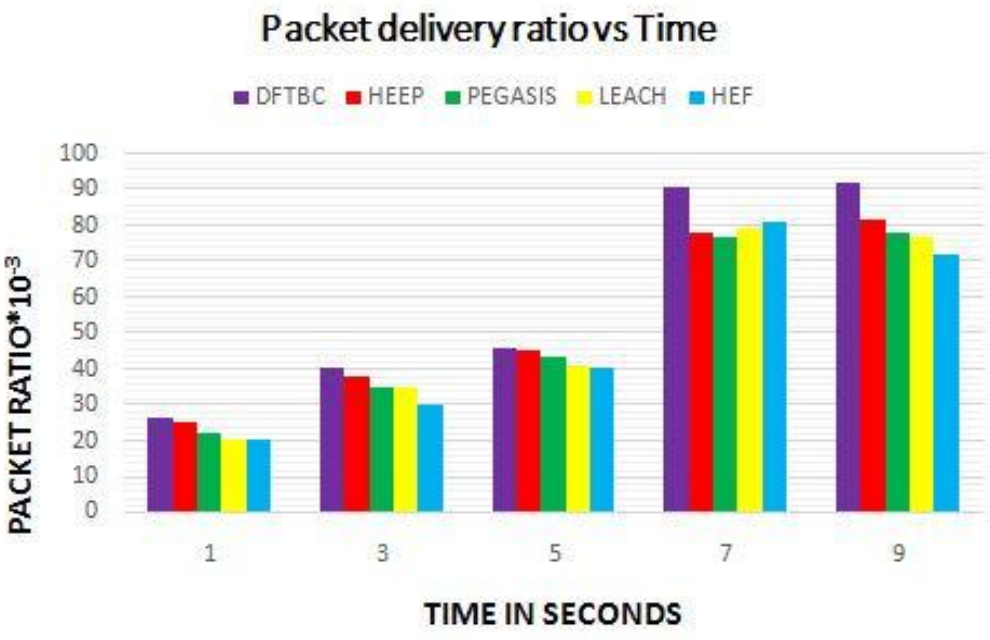

Figure 2: Analysis of Packet delivery ratio Vs time

Throughput Ratio

Throughput over a communication channel in a network is the rate of successful delivery of data packets. Throughput ratio is defined as total number of bits transmitted to the sink with in specific time interval. The outcome of the simulation in Fig.3 shows that the total number of packets reached to the sink node for every ms increased comparatively for DFTBC.

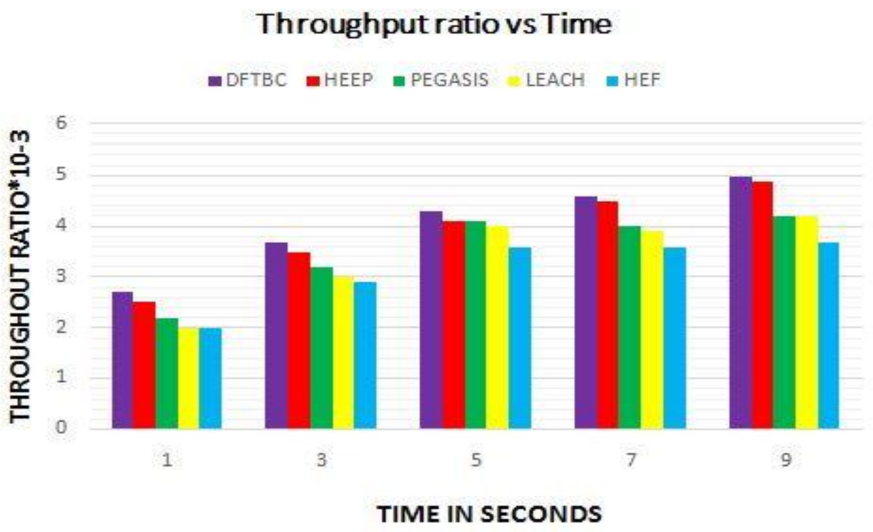

Figure 3: Analysis of Throughput ratio Vs time

Energy Consumption

Energy consumption for sensor nodes in wireless sensor networks mainly depends on the protocol used by sensor nodes for communication. It is calculated for specific number of rounds and plotted. The analysis of simulation in Fig.4 shows that energy consumption is low for DFTBC when compared to others.

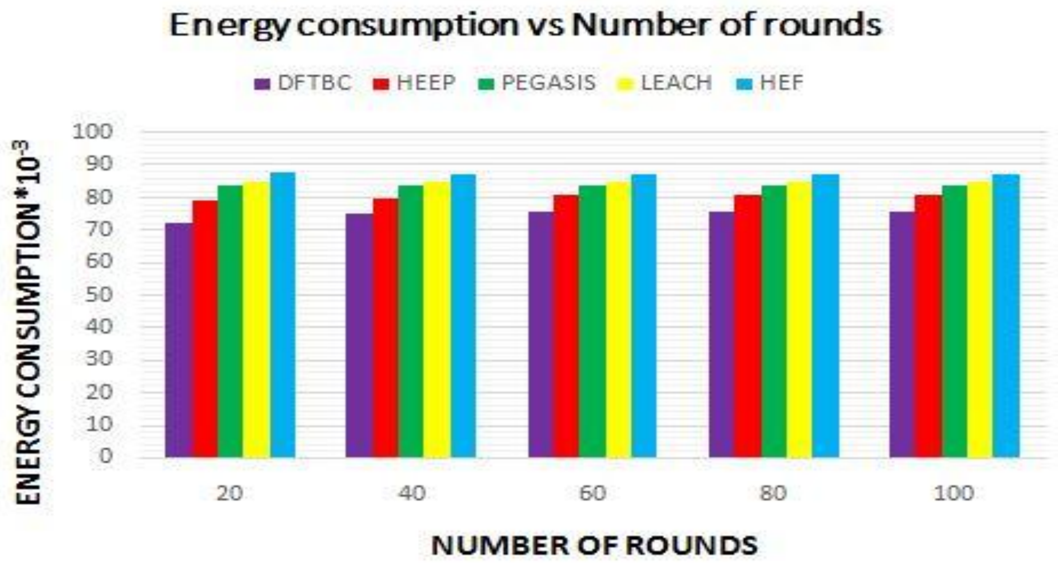

Figure 4: Analysis of Energy consumption Vs rounds

Average End-To-End Delay

It is computed based on the time gap between the data packets. It is the rate of time gap between the successive packets to the count of packets sent to the sink node. The graph is plotted between number of nodes and average delay. In Fig.5 simulation analysis shows that the delay is minimum when compared to other protocols.

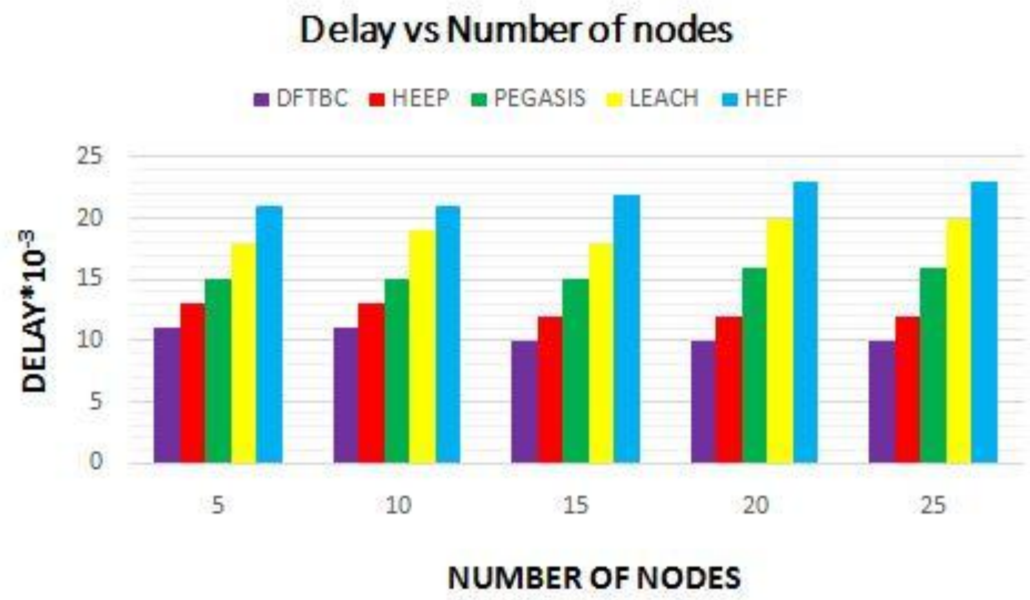

Figure 5: Analysis of Delay Vs number of nodes

CONCLUSIONS AND FUTURE WORK

Simulation results demonstrate that DFTBC algorithm is effective. It is compared with various other existing algorithms like LEACH, PEGASIS, HEEP and HEF and it is proved that energy consumption and average delay of packets are low; throughput and delivery of packets are significantly high for DFTBC than others. In this paper we have used TDMA schedule which ensures that there will be no congestion and no collision as it schedules each packet. Although Dempster-Shafer Theory is suitable for data fusion, one main drawback is its time complexity. To solve this, an event-based data aggregation algorithm based on matrix analysis can be proficient. In future along with this data compression can also be included to increase the throughput and energy efficiency further.

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