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Power Consumption And Lifetime Improvement Of Hybrid Topology Control In WSN

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Abstract

A Wireless Sensor Networks (WSN) consists of spatially distributed sensor to monitor physical conditions and pass their data through network to the sink node. Topology control is an important technique used in WSN to achieve energy conservation and extend network lifetime without affecting important network performance such as connectivity and throughput. Topology control can be implemented in following ways: power adjustment technique, power mode technique, clustering technique. In each of these techniques, there are some limitations. To overcome the limitations of the existing schemes, new hybrid scheme is proposed by integrating the above mentioned schemes. It is proved that the proposed hybrid approach excels in the performance compared to the existing schemes in terms of energy savings.

Index Terms— Cluster, cluster head, idle mode, sleep mode.

[1] INTRODUCTION

A Wireless Sensor Network (WSN) consists of a large number of tiny wireless sensor nodes that are densely deployed to monitor the environmental parameters. Nodes measure the ambient conditions in the environment surrounding them. These measurements are, then, transformed into signals that can be processed to reveal some characteristics about the phenomenon. The data collected is routed to special nodes, called sink node, in a multi-hop basis [1]. Then, typically, the sink node sends data to the user via internet or satellite, through a gateway. Though, depending on the distance between the user and the network, a gateway might not be needed.

Combining the advantages of wireless communication with some computational capabilities, WSN allow for a wider variety of applications than traditional networks. The Wireless Sensor Networks are mainly used in environmental monitoring, managing inventory, health, surveillance, catastrophe monitoring, structural monitoring, military, surveillance, industry, agriculture, home, traffic monitoring, etc. For instance, each sensor node could only monitor its region and send the collected data to the sink node as shown in fig.1 and also in some applications sink send query message asking for the data from the nodes in the network.

However, the great potential of WSN lies in its ability to correlate collected data in time and in space.

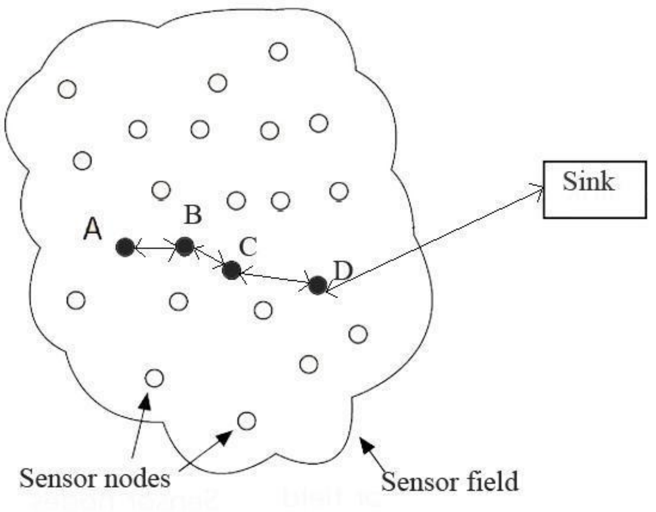

Fig.1 Wireless Sensor Network

A. Related Work

Low Energy Adaptive Clustering Hierarchy (LEACH) scheme [2] is one of the clustering technique in which each node sends their data to the respective cluster head and further the data is transmitted to the sink node directly. It has two phases via set-up phase and steady state phase. In set-up phase, clusters are formed and cluster head is elected. In steady state phase, data is transmitted to the sink node. The disadvantage is that energy is wasted, as the cluster head is transmitting data to the sink in single hop. In Hybrid Energy Efficient Distributive protocol (HEED) scheme [3] the cluster heads collects data and send to the sink node via other cluster heads using multi-hop concept. Though the energy used by the cluster head is distributed to other cluster heads in the path, the latency increases.

Power adjustment technique [4] ensures that network lifetime and energy can be improved by varying the transmission power of the nodes. If it is transmitting at the same power level nodes battery will drain quickly. Hence, if the power is varied between minimum and maximum range lifetime can be increased. But the disadvantage is that transmitting power cannot be increased more than a certain level.

In this approach, nodes work in a collaborative manner to adjust the transmission power of the nodes [5], three algorithms namely, Minimum Energy Communication Network (MECN), Small Minimum Energy Communication Network (SMECN) and Common Power Level (COMPOW) are explained.

Sparse Topology and Energy Management (STEM) [6] describes energy can be saved when the nodes are put to sleep mode while it is idle. Nodes will be waiting in the monitoring state once it receives the wake up signal it goes to the transfer state for data transmission. In Power mode technique [7], network has both listening nodes and forwarding nodes. When beacon frame with sleep command arrives it is send to listening nodes via forwarding nodes. Thus, synchronous sleep and wake mechanism can be viewed clearly and also transmission power is controlled according to the distance between the neighboring nodes. Energy savings and feasibility are considered as advantages.

B. Motivation

Wireless Sensor Networks(WSN) is a network that consists of tiny nodes with sensing, computation and communication capabilities.WSNs are rapidly growing area due to its wide applications, lower cost and smaller in size. Such a potential network have to last for long time. But it is operated with battery of limited energy. At the same time, it is difficult to replace or recharge the battery used in the sensor node. This factor motivates to propose a hybrid scheme.

The remainder of the paper is organized as follows. Section II describes the proposed hybrid scheme. Section III provides simulation based results are discussed. Section IV concludes the paper.

[2] PROPOSED HYBRID SCHEME

In the proposed scheme, three different techniques namely clustering approach, power adjustment approach and power mode approach are integrated. The transmission power of the nodes is varied to reduce energy incurred in transmission. Rather than transmitting at maximum transmission power, nodes work in a collaborative manner to adjust and find the appropriate transmission power to form a connected network [8]. The most important performance metric of the distributed Wireless Sensor Networks is the average energy consumption due to data transmission with different power levels. In the sensor node, the transceiver consumes maximum energy compared with other components such as sensing and computation. But the transceiver is not transmitting the data always. Most of the time, the node is in monitoring state waiting for the event to happen which is called as the idle state. The energy in this idle state is almost equivalent to energy required for reception. So the energy can be saved by sending the node to sleep mode which consumes the least energy. Different nodes use a fixed transmission power level irrespective of its location from the sink node [9]. To overcome these issues clusters are formed and cluster heads are elected based on its energy level. The cluster head computes its distance to the sink node and compare it with neighbor cluster heads. The neighbor cluster node, which is nearer to the sink, will become the next node on the path to the sink. This proposed approach is shown in fig.2

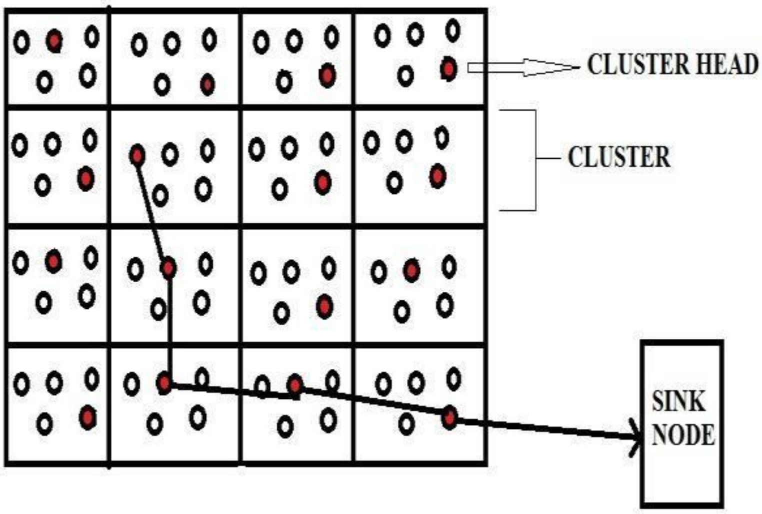

Fig.2 Cluster formation

The sensor nodes are deployed in uniform or random fashion based on the application, in the area under consideration. After deployment, network is formed in the field. In this scenario, clusters are formed. The number of clusters is based on their area of deployment and their range of communication [10]. In each cluster, cluster head is selected based on its energy level and its distance to the sink node. The cluster head role is rotated evenly to all the nodes in the clusters.

A. Cluster head and its selection

A cluster head can simply act as a relay for traffic generated by the sensors in its cluster or perform aggregation of data collected by the sensors. Sometimes cluster head act as a sink or a base station that takes actions based on the detected phenomena or targets [11]. Cluster head is selected based on their residual energy. When the energy of the cluster head reduces below the threshold level then its role is given to other node in the cluster and informs to all other cluster members. Initially, cluster head is selected based on the following manner:

$$CH_{prob} = C_{prob} * E_{residual} \div E_{\max} \;\&\&\; (\text{Dis} < \text{Djs}) \qquad (1)$$

Where $E_{residual}$= Estimated current residual energy

E_{max}= Reference maximum energy

CH_{prob} = Cluster head probability

If more than one node in the cluster having same energy level then the node which is closer to the sink becomes the cluster head.

B. Energy calculation

In order to calculate the total energy, transmission energy and receiving energy are computed. In the power management scheme, both the sleep energy and start-up energy are taken into account, whereas idle energy is considered, when there is no power management scheme. Energy spent during idle mode is almost equal to the receiving energy [12], hence to save energy; nodes are put in sleep mode. Here start-up energy is also considered so that extra energy saved can be found accurately as mentioned below:

$$E_{tx} = (E_{elect} * S) + (E_{amp} * S * d^{\lambda}) \quad (2)$$

$$E_{rx} = (E_{elect} * S) \quad (3)$$

$$E_t = E_{tx} + E_{rx} \quad (4)$$

$$P_{pm} = (E_t * T_p * n) + [E_{sleep} * (10 - T_p) * n] + [E_{start} * S_p \quad (5)$$

$$P_{wpm} = (E_t * T_p * n) + [E_{idle} * (10 - T_p) * n] \quad (6)$$

Where
S =Packet size,
n = no of nodes,
T_p= Packet sending time,
S_p = no of sent packets,
E_{tx} = transmission energy,
E_{rx} = receiving energy,
E_t= total energy,
E_{elect} =Electronics energy,
E_{amp} = amplifier energy.

E_{elec} is taken as 50nJ/bit to run the transmitter and receiver circuitry. E_{amp} is taken as 100pJ/bit/m^2, the energy dissipation of the transmission amplifier.

[3] SIMULATION RESULTS

Network Simulator (NS2) is used for simulation in which C++ is used at back end and TCL is used at front end.

A. Cluster formation

Fifty nodes are deployed randomly in the area of field then clusters are formed with neighboring nodes as shown in fig.3

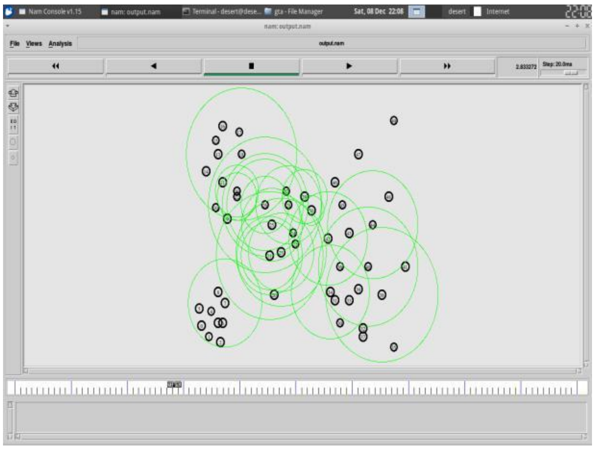

Fig .3 Cluster formations

In this scenario, nodes radio range is considered as 20m and the entire field is divided into five clusters. The snap shot of random deployment of nodes is shown in fig.3. In each cluster, a cluster head is elected and thus there are five cluster heads. Simulation parameters used are listed in the table.1.

TABLE I SIMULATION PARAMETERS

Network size	100 sq.m
Number of sensors	50
Transmission power	25db-250db
Packet size	64bytes-1024bytes
Data rates	10kbps-100kbps
Simulation time	10sec

In the fig 4, power consumption of existing and proposed approach is compared. Simulation is performed by varying the packet size in bits keeping the data rate constant at 10kbps. Actually, power management technique is applied on the topology approaches where the nodes remain idle when the event doesn't occurs, thus energy is saved by putting the nodes into idle mode. From the graph it is seen that when the packet size is increased power consumption decreased because occurrence of retransmission is less.The maximum power consumption at 64bits in clustering is 0.57mw then for power adjustment it is 0.99mw where as for proposed hybrid scheme it is just 0.46mw thus it is inferred from the graph proposed scheme is efficient comparitively.

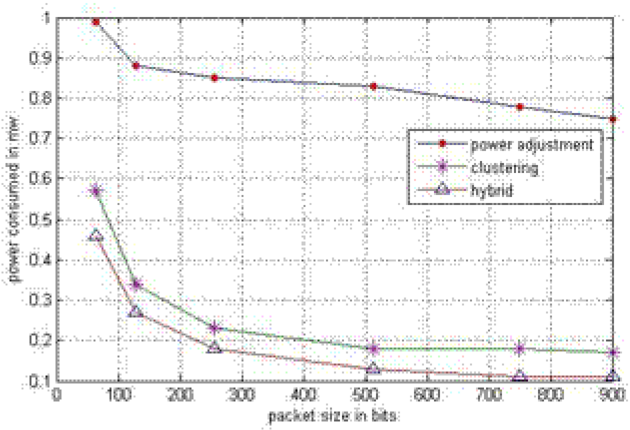

Fig.4 Power consumption at constant data rate(10 kbps)

In the fig 5 power consumption of existing and proposed approach is compared. Simulation is performed by varying the data rate and keeping the packet size constant at 128 bits. From the graph it is clearly seen that as data rate is increased power consumption also increased linearly.The maximum power consumed at 100 kbps in clustering approach is 3.25mw and in power adjustment approach is 2.8mw where as in hybrid approach it is 2.28mw thus proposed hybrid scheme is found to be efficient.

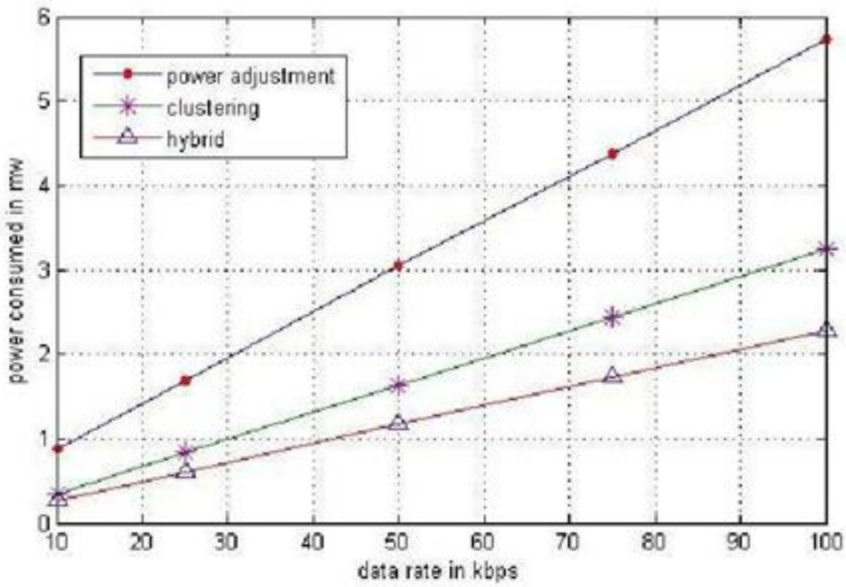

Fig 5 Power consumption at constant packet size(128 bits)

In the fig 5, residual energy of existing and proposed approach is compared.Residual energy in the network at every instants of time has been calculated and plotted. Clearly it is seen that proposed hybrid energy has more residual energy compared to other existing schemes. For example at 10sec hybrid scheme has 99.9973joules then power adjustment approach has 99.9912joules and clustering approach has 99.9966joules.

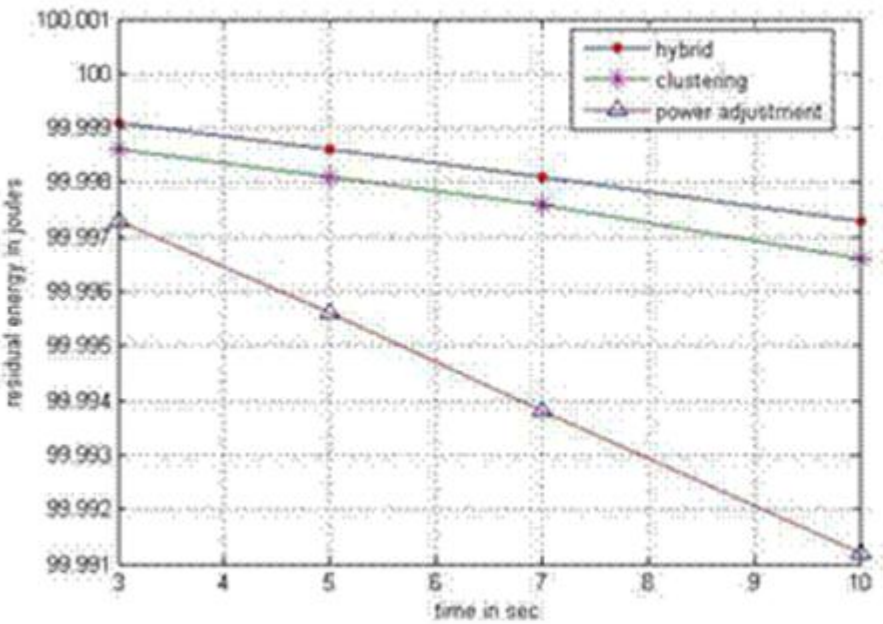

Fig.6 Residual energy of existing and proposed approach

TABLE I RESIDUAL ENERGY FOR VARIOUS DATA RATE

Data rate	**25kbps**	**50kbps**	**75kbps**	**100kbps**
clustering	99.9917	99.9837	99.9756	99.9675
Power adjustment	99.9881	99.9696	99.9562	99.9427
hybrid	99.9939	99.9883	99.9828	99.9772

In the fig 7, lifetime of existing and proposed approaches are compared. Simulation is performed by varying the packet size in bits at constant data rate at 10 kbps then lifetime is calculated and plotted. As the packet size increases lifetime increases i.e just inverse of the power consumption graph. When the power consumption is high network dies soon thus lifetime is less and when power consumption is high network sustain for long time thus lifetime is more.

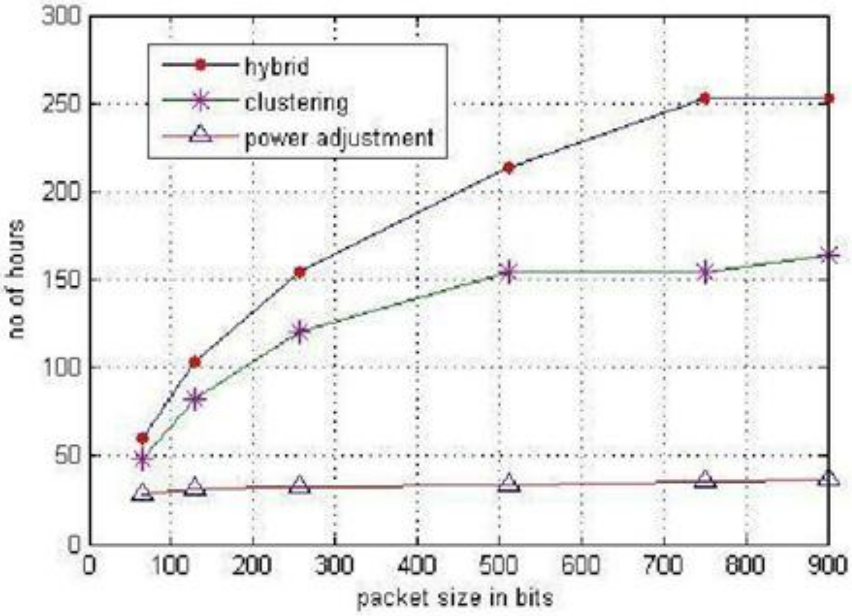

Fig .7 lifetime of existing and proposed approach at constant datarate (10 kbps)

In the fig 8 lifetime of existing and proposed approaches are compared. Simulation is performed by varying data rates and keeping the packet size constant at 128 bits. When data rate increases power consumption increases thus lifetime gets reduced. At 10kbps, clustering has lifetime of 81.69hrs then in power adjustment it is 34.72hrs and in hybrid it is 102.8hrs.

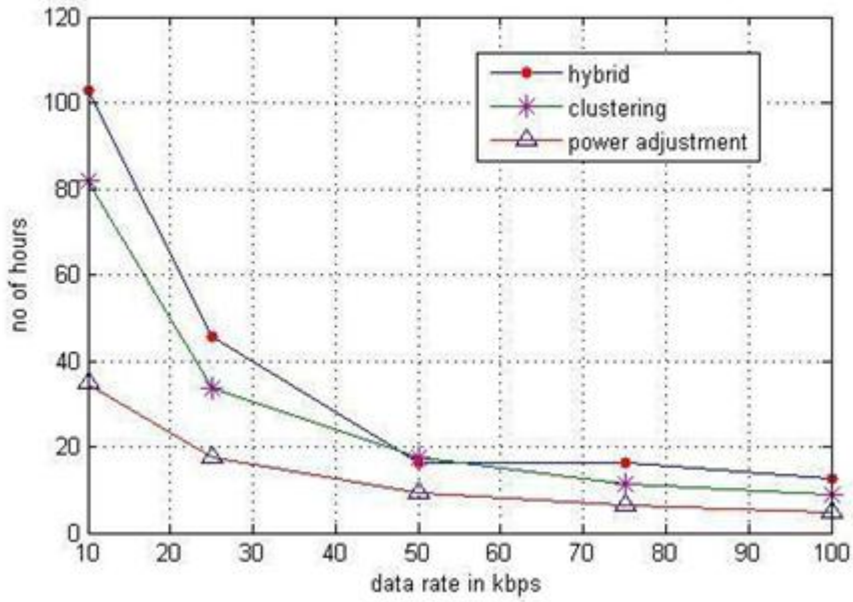

Fig .8 lifetime of existing and proposed approach at constant packet size (128bits)

In fig 9 comparison of lifetime of existing and proposed scheme is shown in improvement factor. Simulation is performed by varying the data rate and lifetime improvement factor is calculated and plotted. When data rate is high, clustering provides higher lifetime improvement factor with hybrid where as power adjustment provides lower lifetime improvement factor. For example at the data rate 10kbps hybrid scheme is 26% greater than clustering and 62% greater than power adjustment in lifetime.

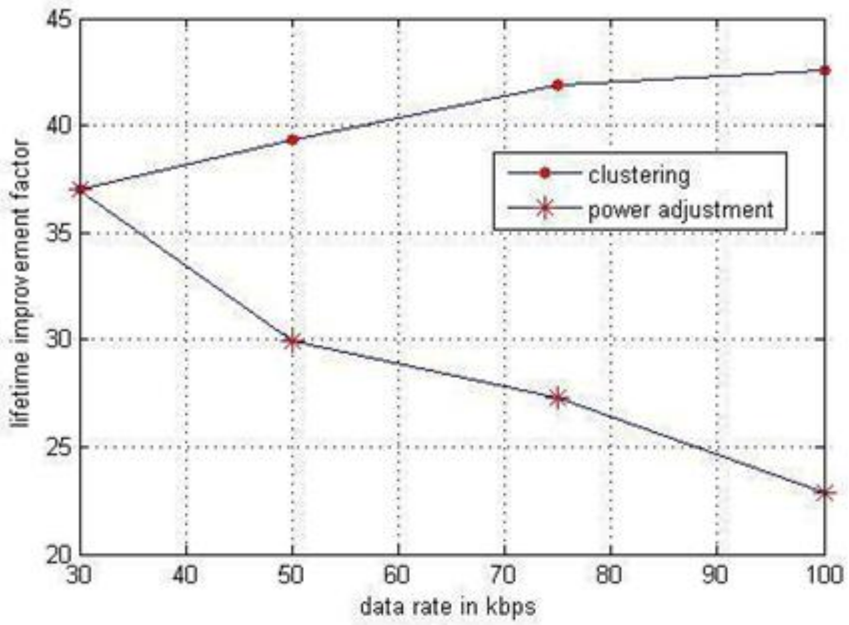

Fig .9 Comparison of lifetime improvement

[4] CONCLUSION AND FUTURE WORK

In this paper, three schemes namely Clustering approach, power adjustment approach and power mode approach are combined together and proposed a new hybrid scheme. The proposed hybrid scheme is compared with all the three techniques and proved to be efficient comparatively in terms of Power ,lifetime and Energy. Throughout this work, nodes are considered as static whereas in future, mobile nodes can be considered. In this work, only one of the scarce resources (energy) is considered and proposed the solution for efficient operation. In future, energy efficient transmission of multimedia applications over the bandwidth scarce resource may be considered.

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