REVIEW OF CROSS LAYER TECHNIQUES TO OPTIMIZE QUALITY OF SERVICE METRICS IN WIRELESS SENSOR NETWORKS

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Abstract- Research on the many aspects of the Wireless Sensor Network like reliability, time etc. has been vital from very long time. That is why we have reviewed the optimization techniques of quality of service techniques in wireless sensor networks. From the various research issues cross layer is the recent in which there are chances of optimization in the working of the wireless network. Cross layer is the need of the time to improve quality of metrics such as delay, time, and energy efficiency. Main problem of the wireless sensor network is that they are battery operated which gives rise to the problem of energy constraint. Congestion and collision in the network can lead to the delay or the packet loss which again consumes a lot of energy and needs to be deal with carefully. In this paper we have illustrated the prominent issues related to QoS and provided open issues for the researchers.

Index Terms— MAC layer, Routing layer, Protocols, Cross layer

I. INTRODUCTION

Wireless sensor network is the network in which tiny sensor nodes are deployed to sense the temperature, transportation, physical presence, moisture etc. These sensors are battery operated that is why the life of the nodes can be predicted only by the area in which these are used and by the application for which they will be used. The layout of these nodes can be homogenous or the heterogonous. In the homogenous all the nodes have the same level of energy and in the heterogonous some nodes are more powerful than the others. The designing of the nodes can be in the flat and the hierarchical modes. In the flat architecture all the nodes play the same role in the sensing task so they act as peers. On the other side in the hierarchical structure some nodes act as the relays for the other nodes. They transmit data on the behalf of the other nodes. Many protocols and algorithms have used this strategy with the homogenous or heterogeneous approach. They have achieved better results also in terms of energy efficiency. But some common problems in the wireless sensor networks are about the time, reliability, energy still exists there. The need of the time is to develop an approach by which all these problems could be solved. As OSI model has been designed for the networking to pass information from one site to another. In this model lower layers provide services to the upper layers. It has not defined the interaction between the different layers of the network. According to this model application layer can't interact with network layer directly. In the same way there is no direct communication between the non adjacent layers. It has been proved from the ongoing research that many problems of sensor networks can be solved by breaking the traditional stack of the layers.

This technique where non adjacent layers communicate directly is known as the cross layer. This paper is organized into various sections like need of the cross layer, related work, categories of protocols, various possible interactions among different layers and open issues.

II. CROSS LAYER IN WSN

There is direct coupling between the lower layer and the upper layers in the traditional protocol stack which is not sufficient for wireless networks. Cross-layer design methodology is an active research area to improve wireless network performance, where the information is exchanged between different protocol layers dynamically. In a WSN physical layer, MAC layer and routing layer together compete for the network resources. MAC and routing, transport layers are affected by transmission power and rate of the physical layer. Scheduling and allocating the wireless channel is responsibility of the MAC layer which finally determines the available bandwidth of the transmitter. Bandwidth also affects the

decision at the routing layer to select the link. The links are selected by the routing layers to transfer the packets to the destination. Contention level at the MAC layer, and the physical layer parameters are affected by the routing decision at the routing layer. Congestion at the transport layer is controlled by the proper information of the percentage of redundancy at the routing layer which is possible when the aggregation is performed at the routing layer. Channel errors are avoided by the proper modulation and demodulation of the data. Signal to noise ratio can decrease total transmit over the links. Cross-layer design can therefore play an important role for the upcoming wireless systems designed for the various applications, featured by all IP-based protocol stack, heterogeneous access networks, and multimedia data traffic. One obvious shortcoming of the two classical network reference models, OSI and TCP/IP, is the lack of information sharing between the protocol layers. This does not allow optimal performance of the networks, because sharing of information between different layers can lead to the optimization of the WSN. Cross layer allows us to design new kinds of applications. A major difference lies between the working of wired architecture and the wireless. The protocols defined for the wired are not suitable for the proper working of the wireless network which causes the problems like packet loss, delay etc.

III. RELATED WORK

Cross layer is like the revolution in the area of Wireless sensor networks. A lot of work has already been done on it but some aspects still need to be covered. MMSPEED [1] works on the network and the MAC layer. It promised to provide the reliable and timeliness delivery. In routing layer it performs the task of selecting the next node in the route based on the speed of the next neighbor node. It has adopted the idea of virtual separation of the speed layers so that the higher speed data do not experience the delay because of the low speed data. This work is carried on the routing layer. And to provide the reliability to access the shared channel based on the priority and to measure the average delay MAC support has been taken. But this paper does not consider the power consumption by the nodes which is the greatest threat for the wireless sensor networks. In [2] the single hop TDMA scheme is converted to the multi hop strategy with high powered access point. In this protocol the topology information is gathered by the nodes and then scheduling algorithm is used to schedule the delivery of the data. Although this protocol works on the Mac layer but when the message is broadcasted by the AP about the minimum number of hopes to reach to it the nodes and the nodes after receiving the packets determines whether it is sent by the neighbor or the interferer. Interference is determined by the received signal strength (RSS) which is the attribute of the physical layer. Mac layer in this protocol needs the help of physical layer to get the value of RSS. That is again the concept of cross layer. PCCP[3] protocol employs the benefits of the MAC and network layer. This protocol maintains the scheduler between these two layers to control the congestion by priority index and the inter arrival time over the service time of packet. But this protocol does not say anything about the reliability of the nodes. QoS metrics have been improved by QBCDCP[4] to for the video and image processing. Role of the cluster head is rotated in it for the long network lifetime. Low hop count increases the network life time been indicated in this work. But this is not true. As we can consider a case of route involving two nodes and a route having three nodes i.e. with two hop count and three hop count as in the Fig. 1 If data will go through the B,C,D then it will take less time and will consume less energy. But if It will go through the A,D then it will take more time and consume more energy. Instead of hop count ETX(Expected transmission time)can be the best criteria to measure delay and the energy consumption. Routing is made through the actor nodes in the QBRP[5] rather than by the sensor nodes or the sink to minimize delay, to improve efficiency and the reliability. All the work is carried out on the routing layer which can be further enhanced by the inclusion of MAC layer capabilities. Packets are served on the basis of the priority in [6].Two queues are maintained as low and high priority queues (PQ), Packets in the highest PQ are served first and then the lowest PQ.

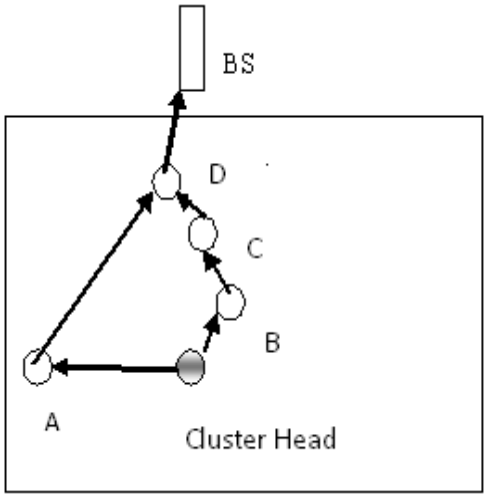

Figure 1 Hop Based Count

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be further enhanced by the inclusion of MAC layer capabilities. Packets are served on the basis of the priority in [6].Two queues are maintained as low and high priority queues (PQ), Packets in the highest PQ are served first and then the lowest PQ. By doing so ,packets in the lowest PQ can lose their importance which will never be serviced if the Highest PQ will never be empty so some idea is needed to save them from starvation. Collision problem is solved by the QOSMR[7] by the multipath routing protocol. This protocol takes time when it considers the path of the nodes in the data transmission phase. After having knowledge of the collision paths it makes the changes in the data transmission routes which take more time and it also affects the energy of the sensors which is limited due to battery operated devices. Priority is settled for the unusual events in the context of routing that data to the best path and the routine data to the secondary path in [8]. But how the QoS will maintain for the routine data is not discussed. An approach has to be used by which all the data is well maintained whether it is routine or the unusual event data .Life of the network is increased by queue management and the battery power adjustment at the Mac layer and Physical layer in the [9]. Routing layer functions can also be exploited to increase the reliability.

In HCR[11] the cluster head set is used to route the data. Rotation of cluster heads is done to send the data of other nodes. This protocol improves the energy efficiency but nothing has been said about the reliability, about route maintenance etc. All the work is done on the routing layer which can be further extended by inclusion of MAC and the Physical layer. QUATTRO[11] works on the routing and the MAC layer. This protocol has been divided into seven phases. If for any reason the selected route fails then all the phases have to be repeated depending upon the type of failure. But this can be avoided if Physical layer is also included in its working. The path between the nodes can be switched to the new path if the problem of the path is distinguished beforehand.

IV. PROTOCOLS CLASSIFICATION IN WSN

All the work in the network is carried out by following the protocols developed for the different layers of the stack. Several protocols are defined for the seven layers of the OSI models also. Many researchers have developed the new protocols to achieve the QoS metrics in the WSN. Objectives of the MAC layer are to achieve the better utilization of the channel, controlling latency, energy efficiency etc. To achieve these goals protocols for the MAC layer are divided into the two phases contention based and the contention free. In the contention based protocols nodes are allowed to contend for the channel. Nodes that are contending for the channel may collide with each other. Some protocols use like CSMA, ALOHA etc. uses techniques like by allowing the node to send and if the packet is collided that packet is discarded and the it is sent again after some time interval. Some protocols employ the technique of backing off if the channel is busy and those nodes wait for the channel to be free. Acknowledgement is also sent in some (MACAW) to inform about the successful transmission of the packet. In contention free nodes need not to contend t\for the shared channel but that channel is divided among the nodes based on the time (TDMA), frequency(FDMA) and the code (CDMA).Some protocols use both strategies of contention based and the contention free as in Z-MAC , Funneling MAC etc. They exploit benefits of both type of protocols. Routing protocols are divided into various categorized based on Location, In network processing, Multiple paths, Heterogeneity, Data, static and dynamic path of the sinks etc.. Various protocols are developed for the Transport layer on the basis of congestion, reliability, security etc. The protocols developed for the individual layer can be merged with each other to gain better efficiency of the wireless networks that is what we call the cross layer.

No doubt a lot of research work is already carried out in all these protocols but this is not the end, it is ongoing process. Because of the limited capacity of the battery of the sensors, environment features, application requirements protocols are still developing for the better security, reliability, delay tolerance etc.

With the help of cross layer all the QoS metrics discussed above which are essential requirements of the WSN can be gained.

V. VARIOUS INTERACTIONS AMONG THE NON ADJACENT THE LAYERS

- Phy and Transport: Transport layer performs the functions of the congestion control and reliability management. The transmit power of the sensor nodes affects the reliability. But the transmit power can improve end-to-end reliability. However, increasing the transmit power will increase the interference range of a node and may cause increased contention. To control the congestion at the transport layer the transmit power at the physical layer can be adjusted which will improve the reliability.

- MAC and Routing: Recently, exploiting cross-layer interaction has gained much interest among MAC and routing layers. To gain the maximum energy efficiency the sleep and the wake schedule of the MAC layer can be merged with the route management of the routing layer.

- Phy and Routing: Transmission power can play a great role in improving the reliability of the route elected to transfer the data between two nodes. If the power of the nodes is not taken into consideration for path then it can create the problem by introducing interference among the nodes.

- MAC and Phy: A wireless channel model is required for the proper evaluation of the protocols of both layers. Objective of the MAC layer is to provide the collision free access to the channel. There is tradeoff between the energy consumption due to the transmission and the communication. On this basis single hop or the multi hop approach is used but in the single hop problem of interference can be increased. So to solve and clear the aspect of both layers proper interaction between these layers is must.

Many other interactions are also possible to exploit the advantage of the every layer and to increase the network performance.

VI OPEN ISSUES OF MAC AND ROUTING LAYER

A] Open issues of MAC Layer:

Data link layer provides the most important function of medium access control (MAC). The primary objective of MAC is to fairly and efficiently share the shared communication resources or medium among multiple sensor nodes in order to achieve good network performance in terms of energy consumption, network throughput, and delivery latency. Network protocols have to be modified before applying them to the sensor because they do not take into account the unique characteristics of sensor networks, in particular, the energy constraint. For example, the primary concern in a cellular system is to provide quality of service (QoS) to users. Energy efficiency is only of secondary importance for the mobile users because there is no power limit with the base stations and the users can replenish the batteries in their handsets. In MANETs, mobile nodes are equipped with portable devices powered by battery, which is also replaceable. In contrast, the primary concern in sensor networks is energy conservation for prolonging network lifetime, which makes traditional MAC protocols unsuitable for sensor networks [12]. Therefore, a large amount of research work has been conducted on MAC and a variety of MAC protocols have been proposed to address different application scenarios. The primary task of a MAC protocol is to arbitrate access to a shared medium or channel in order to avoid collision and at the same time to fairly and efficiently share the bandwidth resources among multiple nodes. According to the underlying control mechanism for collision avoidance, MAC protocols can be typically classified into two broad categories: contention - based and contention free. Both ALOHA (Additive Link On - Line Hawaii System) and CSMA are the most typical examples of contention - based MAC protocols. In slotted ALOHA, time is divided into discrete timeslots. Each node is allocated a timeslot. A node is not allowed to transmit until the beginning of the next timeslot. Pure ALOHA is easy to implement. However, its problem is that the channel efficiency is only ~ 10%.Compared with pure ALOHA, slotted ALOHA can double the channel efficiency. However, it requires global time synchronization, which complicates the system implementation. CSMA differs from ALOHA in that it uses carrier sense; that is, it allows a node to listen to the shared medium before transmission, rather than simply transmits immediately or at the beginning of the next timeslot. However, CSMA cannot handle the hidden - terminal problem in multi hop wireless networks. To address this problem, CSMA/CA was developed and is adopted in the IEEE 802.11 wireless LAN standard, where as CA stands for collision avoidance. In CSMA/CA, a handshake mechanism is introduced between a sender and a receiver. To improve the performance of CSMA/CA, a MAC protocol called multiple accesses with collision avoidance (MACA) was developed for wireless local area networks (LANs). This introduces an additional field in both RTS and CTS packets to indicate the amount of data to be transmitted so that other nodes can know how long they should back off. To further improve the performance of MACA, another protocol called MACAW was developed, which makes several enhancements to MACA. The IEEE 802.11 distributed coordination function (DCF) was mainly based on MACAW and adopted all the features of CSMA/CA, MACA, and MACAW. Many protocols are developed to overcome the problems of MAC layer like AS-MAC, BAS-MAC, Crankshaft and SPC-MAC. These protocols are evaluated and compared by many researchers and found that no one protocol is optimal under all circumstances. The measurements provide insight into general strategies for reducing energy consumption in future WSN MAC protocols. Moreover, new techniques such as cooperation among nodes and network coding have been introduced to improve the network performance and provide the communication with diversity, robustness, and higher data rates. These new technologies create the need of designing new MAC protocols that exploit the benefits of the aforementioned techniques in order to efficiently use the system resources. It is required that bidirectional communication must be there between the relay nodes to achieve the benefits. In order to optimize the energy management in the network, MAC schemes have to be combined with energy-aware routing solutions, while sleep modes techniques for inactive nodes should be considered as an extra option. To further improve the network performance, there is a trend to take into account the effects across multiple protocol

layers in the design of MAC protocols, which provides various research opportunities in the future.

B] Open Issues of Routing Layer:

Important issues of wireless sensor networks are routing and data dissemination. The essential function of a WSN is to monitor a activities in a physical environment and report sensed data to a central node called a sink, so that processing and aggregation of the data is done there. The topology of the network is dynamic in nature and keeps on changing by addition and deletion of the sensors. When a new sensor decides to join the network, the neighbor nodes have to update their information about the route. In many cases, it is necessary to add more sensors to maintain certain coverage properties of a sensor field and network connectivity. Similarly, when sensors deplete all their energy, they may cause the problem of disconnecting the path used for the transmission of data in the network. In this case, the neighbor nodes of these sensors have to be updated as well. Also, in a mobile network, the network topology gets updated as sensors move in the sensor field. Consequently, any topology change in the network will have an effect on the communication paths (or routes) between the sensors. Therefore, routing and data dissemination paths should consider network topology dynamics due to limited energy and sensor mobility as well as increasing the size of the network to maintain specific application requirements in terms of coverage and connectivity. If there is no path between the source node and the sink or it is failed due to some reasons then maintaining only network coverage for the application will not work. Therefore, connectivity between all source sensors and the sink, either directly or indirectly, should be guaranteed for the proper operation of the network. Another challenge is network scalability. In other words, routing and data dissemination protocols should be able to scale with the network size. Also, sensors may not necessarily have the same capabilities in terms of energy, processing, sensing, and particularly communication. In most sensing applications, the sensed data should be as accurate as possible to assure better decision making by the sink. Moreover, the sensed data should reach the sink in a timely manner. Also, data redundancy is sometimes desirable in that it increases data accuracy but this data redundancy also increases the network load and important data may get delay because it will increase the congestion. So research work could be carried out to balance this management of data. A network should tolerate the failure of path and remain functional in spite of total depletion of energy by the nodes. The degree of fault tolerance of the network depends on the underlying sensing application. Therefore, the routing and data dissemination protocols should also be fault tolerant. Traditional routing protocols have several shortcomings when applied to WSNs, which are mainly due to the energy - constrained nature of such networks.

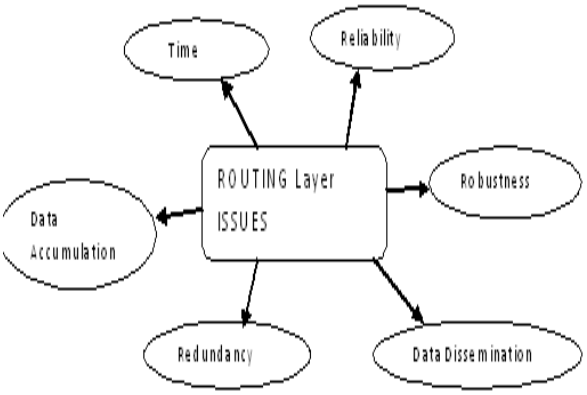

Figure 2. Issues of Routing Layer

Many protocols have been developed to combat with the above challenges like HCR, LEACH, PEGASIS, TEEN, APTEEN, SPIN, Directed Diffusion, Rumor Routing, Cougar ACQUIRE, EAD, Dynamic Proxy Tree-Based Data Dissemination as discussed in [12]. But no one protocol is optimal for the existing problems. Routing protocol HCR[11] have done work by assigning the duty of head node randomly to each node so that at the end every node played the role of cluster head and in this way uniform consumption of energy achieved in each node. In this way it has increased the life of the network. But nothing has been discussed about the maintenance of the path from where the data is transferred. MAC and Physical layer functions can be combined in this protocol to improve QoS features.

VII. RESULTS AND DISCUSSION

We have developed a new protocol [4] EEICCP in which layered architecture design has been implemented for the formation of clusters and the cluster heads. Data is transferred through the cluster coordinators of the different layers. With this new technique energy up to the large extent has been reduced i.e. 43% than HCR [11] and 50% than LEACH [14]. This protocol is developed for the densely deployed network which is required for the environmental monitoring and real time data. After routing layer issues, new features has to be added in it are cross layer communications of routing layer with MAC and Physical layers to make it more robust. Work is being carried out in MATLAB.

VIII. CONCLUSION AND RECOMMENDATIONS

This paper is an attempt to review the cross layer protocols and their need in today's era. WSNs have added

many improvements to many fields, still this area is facing many challenges to operate properly. The main concerns of applications for WSNs are regarding limited energy capacity of sensors, reliability, time. So, communication between nodes must introduce the minimal possible overhead to focus energy on data transfer, and thus the medium access method and the routing protocol (if needed) must be chosen carefully. Adaptive modulation, opportunistic transmission and coding should be done in this way so that it could avoid the loss of data due to channel, which will save energy also. Many energy harvesting techniques have been studied in order to give importance to the sensors energy, even though they are not very efficient. Despite these solutions for the energy problem, violating the layered communication stack has proven to result in better gains for WSNs. This technique is called cross-layer design and it has been used to overcome not only energy limitations, but also to increase network throughput and to improve quality of service. Protocols can be developed which can deal both delay and the reliability together which are contradict to each other. These types of researches can open the ways for the new platform in which there is no need to develop the protocols in isolation for the different layers but the concern about their interdependencies can help a lot to solve the existing problems of WSN. No doubt the work is in progress form lastly many years but still a lot has to be done because no simulator has been proved best for the experiments of cross layer solution so research could be carried out on new simulators. Above all review of this cross layer paper gives us an idea and motivation to consider all above mentioned QoS features in our newly developed [11] energy efficient protocol and also presents cross layer as a promising solution for the various researches.

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